some 18 hours of computer time (with a CDC 1604 computer) to evaluate 23 hypotheses for a 16-atom transition state (*23*). Although every transition state must include an impressive list of structural parameters, very few of these have any important influence on kinetic isotope effects. It must then be equally true that an experimental kinetic isotope effect should be used to judge only those parameters that have such an influence. As expected, these are found to be very largely the force constants in the immediate vicinity of the isotopically substituted atom.

We have been principally stimulated by a problem that is almost classical in its simplicity (see Fig. 4): To what degree will a choice among the paths a, b, and c be altered as we vary the structure of the polyatomic fragments *X* and *Y*? Each such path includes an untold number of quantitative variations. And so it often occurs that a single experimental value will accommodate several transition states, often appropriate to more than one of these paths. For this reason we have always had to measure both carbon and oxygen kinetic isotope effects. Two nuclear probes are obviously better than one. We have quite recently encountered at least one example which required us to use still a third probe (at *X*, fortunately a carbon atom) in order to distinguish one variant of b from one of c. Although more such difficulties are to be expected, so too are the techniques for their solution.

We now have the means with which to formulate the structures of transition states and to exclude a great number of possibilities through the measurement of kinetic isotope effects. It is still much too early to judge, in general, how many more possibilities might then remain. We can only hope that, in the end, these will differ so trivially that their differences then reflect only the uncertainties in experimental data. Surely we cannot ask for more than this.

References and Notes

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The Search for Good Wine

Two of the oldest industries in the world are in the midst of biochemical and technological change.

Maynard A. Amerine

Among the glories of the Neolithic Revolution were the domestication of grapes, the discovery of fermentation as a food process, and the subsequent development of the wine industry. At a very early stage the industry acquired regional and varietal wine types, presses, crude filters, at least one by-product (vinegar), a host of legends, heroes (Noah), and widespread acceptance by consumers. Although Greek and Roman wines were probably better than those of Egypt or the Fertile Crescent countries, they were undoubtedly crude by modern standards (*1*). The pitch-lined clay amphora, at best, was a poor container for wine, although more aesthetic than animal skins as storage vessels. Toward the end of the Roman period, introduction of the wooden barrel improved storage and facilitated transportation. Some time during the Middle Ages sulfur dioxide, as an antiseptic agent, was introduced into wine-making; international trade in wines continued throughout this period for the consumption of the nobility and the wealthy, and particularly for ecclesiastic use. The monastic system also helped to maintain a certain degree of sophistication in grape-growing and wine-making; in fact, it was responsible for the development of several of the best wine regions of Europe.

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But in most essentials there was little difference in production techniques or quality, so far as we can determine, between the wines of 2500 B.C. and those of A.D. 1800. After about A.D. 1800, distillation of alcohol from wines became common. Fortification of fermenting musts (crushed grapes, or grape juice) with this alcohol enabled regular production of dessert wines, especially in some of the Mediterranean countries. However, most of the production continued, and still continues, to be of unfortified, low-alcohol, natural table wines that were highly subject to spoilage; most were, therefore, consumed within 1 year of the vintage. Some great wines and even some aged wines were surely produced in ancient and in modern times before Louis Pasteur, but the process was highly empirical and the process of fermentation was so inadequately understood that success was limited and sporadic.

The prevalence of wine spoilage, particularly of the wines of Burgundy, was one of the reasons why Pasteur started his investigations on wines. It was the subsequent pasteurian revolution (*2*) that changed the wine industry from a speculative venture, producing so much bad wine and so little good wine, to the modern stable industry, which need never produce a bad wine and only occasionally a poor one.

Looking back on the period 1857–77 one is amazed by the number of scientific discoveries that Pasteur made and applied to the wine industry. He was responsible for much more than pasteurization—a process that has never been of critical importance to the wine industry. Pasteur's first contribution was to define and elucidate the importance of yeasts and bacteria in winemaking and storage. His biochemical studies of the by-products of alcoholic fermentation were not only pioneering but remarkably accurate. His major contribution was his demonstration that the problems of the wine industry could be solved by application of the scientific method. The development of pure yeast cultures soon followed. Methods of controlling bacterial spoilage were then introduced, particularly in preventing growth of aerobic bacteria.

Research in viticulture and enology became worldwide during the 19th century. Experiment stations specializing in research on grapes and wines were started in many countries: for example, at Yalta in the Crimea in

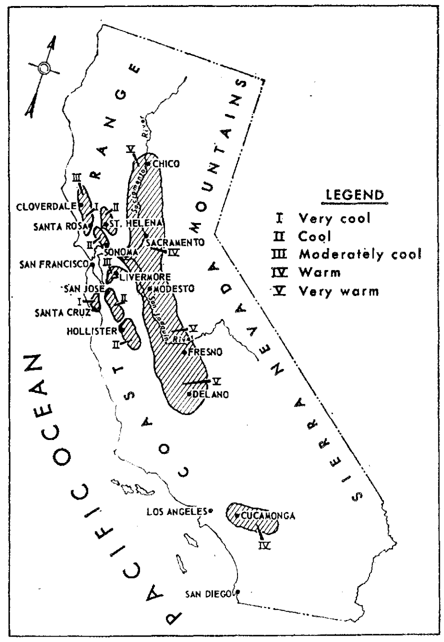

Fig. 1. Grape-growing regions of California.

1828, at Klosterneuburg (near Vienna) in 1860, at Geisenheim-am-Rhein in 1872, at the University of California, Berkeley, in 1880, and at Bordeaux in 1880. Thereafter many such stations developed in the wine-producing countries. The contributions of these stations that resulted from the application of scientific methods to viticulture and enology were very great. A recent report of the Office International de la Vigne et du Vin (*3*) listed 231 experiment stations engaged in research on grapes and wines.

At the University of California, research on viticulture and enology was expanded in 1880 by its second professor of agriculture, Eugene Waldemar Hilgard, and has continued until today; during prohibition the enological aspects were not studied. Viticultural research is also carried on by many other experiment stations in this country and by the United States Department of Agriculture, but until recently nearly all of the publicly supported research on wine in this country was conducted at the University of California.

As a result, in almost every viticultural region grape-growing developed rapidly as a separate and stable industry, though often excessively dependent on hand labor. The small family-owned vineyard-winery continued to exist, but now with technical advice. The larger wineries and wine merchants had their own technical staffs. The result was that the spoilage and unsanitary conditions of the 19th century gave way to the sound wines made under sanitary conditions in the 20th. The improvement in quality, especially of the everyday wines, has been remarkable and continues. World production of grapes and wine is now at an all-time high: nearly 25 million acres (10 million hectares) producing more than 7 billion gallons (26.5 billion liters) (*4*). Much of the credit for this increase is due to the mechanization and technological control applied to the industry.

The main scientific problems of the grape and wine industry are similar to those of other agricultural processing industries. From the viticultural point of view, these include better understanding of the principles of plant physiology as they apply to the problems of vine growth and fruit production. One would expect, with increasing labor costs, to find increasing mechanization of vineyard operations from planting to pruning to harvesting. From the enological point of view, the problems are microbiological and biochemical, with mechanization of operations also an urgent necessity—again because of increasing labor costs within the winery. For both grapes and wines, maintenance and improvement of the quality of the product is necessary. Even their greatest admirers would not claim that grapes or wine are necessities of life; their place in the diet then obviously depends on how they satisfy the consumers' desires.

Viticultural Studies

Grapes are the raw material for wine, and their composition intimately influences the type and quality of wine that can be produced; thus viticultural studies have traditionally accompanied enological investigations. This has been particularly true during the last century, while ampelography (classification of grape varieties) became more nearly standardized. Viala and Vermorel's classic 7-volume text (*5*) from early in the century has not been surpassed, although a Soviet ampelography (*6*) is now in its 8th volume and there have been recent books from Yugoslavia (*7*), Rumania (*8*), and France (*9*).

The grapevine is especially responsive to relatively minor variations in climatic conditions. The fruit of a variety grown in a warm region will be quite different in chemical composition from that of the same variety grown in a cool region; such differences markedly affect the qualities of the grapes and the wines. Elucidation of this climate-composition-quality relation has been a major research project in California since Hilgard's time. California has a wide variety of climatic zones suitable for the growth of grapes. Hilgard's early investigations in the 1880's were the first systematic studies in this field; they emphasized the importance of the variety per se and of the effects of California's climatic conditions.

The relation has also been studied in France (*10*), Germany (*11*), Hungary (*12*), Australia (*13*), Switzerland (*14*), Czechoslovakia (*15*), and the Soviet Union (*16*) and elsewhere. In California particularly it has influenced viticultural studies because of the wide range of favorable climatic conditions in this state under which regular and high yields of grapes are possible. The purpose of these climate-quality studies is to find the best region for planting a grape variety to produce a certain type and quality of wine. Much of this research in Europe was done in an empirical way over many centuries, but even today there is great interest in many countries in testing new varieties or in finding better mixtures of varieties for the production of distinctive types of wines.

When Prohibition was repealed in 1933 the climate-quality relation became the subject of extensive studies in California, and interest therein was renewed in Europe at about the same time. On the basis of the amount of heat received during the growing season California was divided into five major grape-growing regions (Fig. 1). Correlations of acid and sugar contents and of *p*H with climatic conditions (Table 1) became the basis of recommendations for planting the various varieties of wine grapes (*17*). Detailed studies of grape maturation (*18*) and statistical studies of field sampling (*19*) provided the logical foundation for more rational harvesting of grapes. The chief difference between grape-growing in California and in France or Germany is in the climate: California's long rainless summer, with early ripening in the warm valleys in the interior, versus the shorter, cooler, rainy growing season in northern Europe. There is marked variation in the amount of heat received from one growing season to another in any one climatic region in California, but none approaching the extremes experienced in Europe.

Table 1. Soluble solids, acidity, and *p*H for four varieties of grapes grown in three climatic regions in California (from Amerine and Joslyn, *119*). Day-degrees of temperature above 50°F during the growing season were: Fresno, 4680; Davis, 3618; and Bonny Doon, 2400.

Variety	Balling (deg)			Total acid (%)			*p*H		
	Fresno	Davis	Bonny Doon	Fresno	Davis	Bonny Doon	Fresno	Davis	Bonny Doon
Cabernet Sauvignon	22.9	22.4	20.7	0.65	0.67	1.10	3.48	3.63	3.41
Sauvignon vert	24.2	24.3	22.4	0.44	0.57	0.57	3.67	3.81	3.28
Sémillon	21.0	18.1	24.1*	0.41	0.55	0.69	3.42	3.36	3.07
Zinfandel	21.0	22.8	24.7*	0.55	0.55	1.16	3.51	3.58	3.14

* Figure is high because of late harvesting and a light crop.

Intelligent hybridization of grapes probably began in France around the turn of the century. The original object was to develop varieties resistant to phylloxera (*Dactylasphaera vitifoliae* Shimer), a root louse native to the eastern United States, to which indigenous species of grapes are more or less resistant. When introduced into Europe about 1860, the louse spread rapidly through the vineyards of nonresistant *Vitis vinifera*. The use of native-American species (such as *V. rupestris*) as rootstocks, with the original *V. vinifera* varieties grafted as scions, at once suggested itself to French botanists and was carried out on an immense scale. By crossing European and resistant American varieties, hybridizers hoped to obtain progeny having the American resistance to phylloxera; they also hoped for grapes lacking the distinctive odor of the American varieties. This odor, mainly due to methyl anthranilate, is considered objectionable by many wine connoisseurs (especially European) because it is so different from the odor of European varieties and wines. These hybrids, so-called direct producers, are still being developed and have gained considerable acceptance in France and the eastern United States (*20*). Nowadays much of the interest in hybrids is in the development of varieties having greater resistance to various cryptogamic diseases. Germany (*21*), Italy (*22*), Austria (*23*), the Soviet Union (*24*), and other countries have made progress in the development of new varieties for specific climatic conditions and types of wines; Lysenko seems to have had a less baneful influence on Soviet vine geneticists than on other breeders. Clonal selection also has been widely employed in France (*25*) and Germany (*26*) and elsewhere (*27*).

In California an extensive program of hybridization, started in 1934, has resulted in the release of several new varieties of table and wine grapes (*28*). The new wine-grape varieties are specially adapted for the production of specific types of wine when grown under warm climatic conditions; they have also been selected for productivity and resistance to disease. The United States Department of Agriculture and several state experiment stations also are conducting studies in this field.

The physiology of the vine has been a subject of intense investigation in California since the 1920's; studies have related to such things as vine training and pruning; the relation of vine vigor to productivity; the use of various growth regulators to influence set, size, and time of maturation of the fruit; the influence of various essential elements on vine growth and on the composition of the fruit; and the development of special rootstocks for resistance to the root louse (phylloxera), nematodes, and suchlike. Similar studies are going on in many other countries. The emphasis of many of the European studies is on means of mechanizing cultural operations; mechanization has, of course, long been standard practice in California (*29*).

California is also a center for the investigation of vine diseases, particularly of virus diseases (*30*). Successful cold storage of table grapes also is partially a problem of controlling disease; both the University of California and the United States Department of Agriculture have been active in research on storage problems; excellent work has been done in South Africa but in few other countries. American viticultural research has been summarized (*29*); few similar books have been published abroad (Italy, *22*, *31*; Rumania, *32*; Spain, *33*; Yugoslavia, *34*; Bulgaria, *35*; Israel, *36*).

Microbiology and Enology

The pasteurian revolution reached California too late to have much influence on Hilgard's research, but in 1887 and 1890 Hilgard wrote bulletins on the

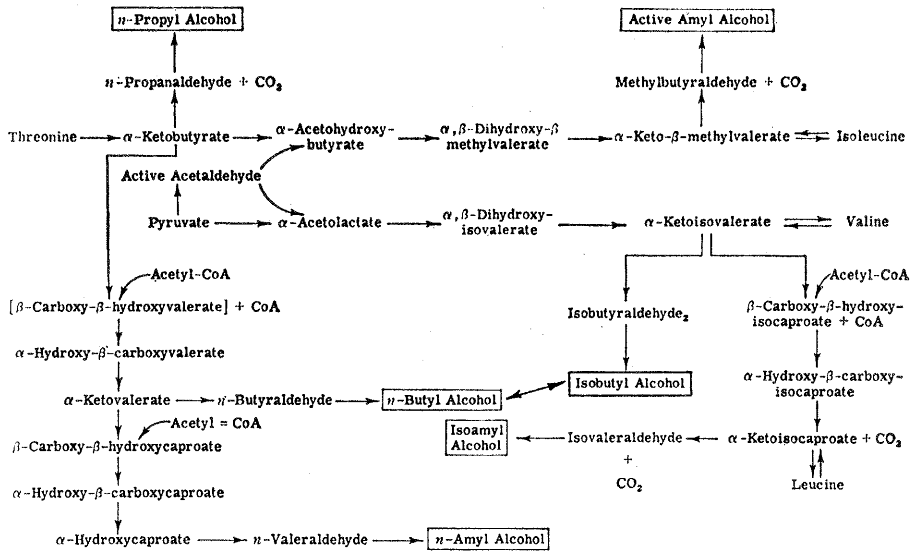

Fig. 2. Pathways of formation of major fusel-oil components and *n*-butyl and *n*-amyl alcohols (from *72*).

values and rational use of pasteurization (*37*). During this period, before the days of pure yeast cultures and the general use of sulfur dioxide, pasteurization was the only method of controlling spoilage. In Germany pure yeast cultures were introduced in the 1890's, whereas in California Hilgard delayed even the commencement of yeast studies until 1893; not until the French-trained Edmund Twight was added to the staff in 1903 was a strong impetus given to such studies. The Yalta experiment station had started them in 1887 (*38*).

There was consequent influence on the staff of the University of California, as Holm published in 1908 a bulletin on the yeast and mold flora of California grapes (*39*). When Cruess became a member of the staff in 1911 he immediately instituted extensive studies of yeasts. The native flora of grapes and their influence on quality were emphasized in these early studies (*40*).

With the repeal of Prohibition, Cruess reactivated his studies and expanded them to include bacterial problems; such investigations emphasized the effect of sulfur dioxide, pure yeast cultures, association of yeast and bacterial growth, and the activity of lactic acid bacteria. Cruess had been active in yeast investigations as early as 1912 (*41*), and many others participated in these later studies (*4*). The possible contribution of pure yeast cultures in producing flavor precursors (*42*) is still under investigation.

As a result of these studies sulfur dioxide became the universal antiseptic in California wine-making, sometimes perhaps too ubiquitously and often too generously. However, yeast and bacterial spoilage have practically disappeared from the California wine industry, probably to a greater extent than in any other country.

Intensive studies of the native yeasts have been carried out in Italy (*43, 44*), Czechoslovakia (*45*), Hungary (*46*), South Africa (*47*), Spain (*48*), France (*49*), and the Soviet Union (*50*). The biochemistry of yeast activity as applied to wines has been particularly well studied by the Bordeaux school of enologists (*51*) and in the Soviet Union (*52, 53*). California's warm fall climate also poses special problems for the control of fermentation temperature; probably nowhere has the precise control of fermentation temperature been more closely studied than in California. The use of relatively low temperatures for white-wine production is common, with results similar to those obtained abroad (*54*).

Many microbiological problems remain. Investigations of the amino acid composition of grapes were started before World War II (*55*); such investigations are now worldwide, not only as they affect the growth of microorganisms but also because of their potential effect on production of flavor compounds—and hence on wine quality (*56*). Use of paper and gas chromatography (*57*) has greatly facilitated study of the amino acids in grapes and wines.

The so-called malo-lactic bacteria were studied in Europe early in the century, particularly in Switzerland (*58*). Bacterial decarboxylation of malic acid to lactic acid reduces the excess acidity of many wines, moderates the acid taste, and may be desirable for other reasons. Use of simple paper chromatography makes it possible for even the smallest winery to follow the process and to stop it at the proper stage. More recently these bacteria and their metabolism have been extensively studied in California (*59, 60*), New York (*61*), Australia (*62*), France (*63*), Germany (*64*), and Japan (*65*) and elsewhere (*66*). The possibility of using the enzymes of lactic acid bacteria for this decarboxylation had been known at least since 1912. Studies in Portugal (*67*), at Bordeaux (*63*), in this country (*60, 68*), and elsewhere established that living bacteria also serve the same purpose during alcoholic fermentation; commercial application of this research is currently under study.

The higher-alcohol content of wines was formerly believed to depend on the classic Ehrlich mechanism for the deamination of amino acids, but the mechanism is responsible for only a minor part of the higher alcohols present. Studies in California (*68, 69*), France (*70*), and the Soviet Union (*53, 71*) have shown that higher alcohols are synthesized by a route common to many reactions by which corresponding homologous amino acids, those with one more carbon atom, are synthesized—that is, from carbohydrate (Fig. 2; *72*). Because of the possible contribution of higher alcohols to desirable and undesirable odors, control of this fermentation is important. Current investigations are directed toward development of methods of more precise control of the production of higher alcohols and other by-products of alcoholic fermentation.

It is known that many yeasts produce atypical by-products, some of which may contribute to wine quality; the possibility of mixed cultures has, therefore, intrigued enologists for many years. In spite of many experiments and continuing experimentation (*44, 73*) no practical process has been developed.

Two notable papers in 1936, Spanish (*49*) and German (*74*), called the attention of enologists to the film-forming properties of the true wine yeasts; applications followed almost immediately in South Africa (*75*) and California (*76*). It was demonstrated that these film-forming yeasts had properties similar to those of the film (flor) yeasts of Spain that are used in the production of certain Spanish sherries. A series of practical studies (*77*) in California before and during World

War II demonstrated that high-quality film-yeast wines could be produced there. Fornachon and other Australians made notable contributions regarding the best conditions for the growth of these yeasts (*78*); Saenko (*50*), in the Soviet Union, studied their properties and practical uses.

Despite the high quality of the products it became evident after World War II that for California the use of relatively small casks for production of flor sherry was prohibitively expensive. In larger containers the lower surface-to-volume ratio was unfavorable for the accumulation of adequate flor character. It was known that aldehyde accumulation, one of the characteristic features of the flor yeasts, takes place very rapidly in shaken cultures of yeast (*79*). A process for the submerged culture of flor yeasts by stirring under maintained aerobic conditions was developed (*80, 81*); production of aldehyde is very rapid (Fig. 3). Similar processes were developed independently in Canada (*82*), and the process has been applied in Spain (*83*) and the Soviet Union (*84*); it is being used commercially in California. While the product does not yet have the complicated odor characteristic of wines made with surface yeasts, as in Spain, it does have a clean distinctive aldehyde character and offers many opportunities for further development of flavor.

Many European wines, including French sauternes and German *Auslese* types, owe their high sugar content and concentrated and special flavor to the growth of *Botrytis cinerea*. The development of the mold is capricious and the quality varies from year to year; Nelson and Amerine (*85*) studied the conditions for its growth and developed a laboratory procedure. The process has been used on a limited scale commercially in California.

Wine Processing

Wine processing still includes procedures and equipment that were developed in Neolithic times: basket presses, fermentation with the grape skins present, filtration, fining (clarification) with organic and inorganic materials, and so on. As the cost of labor increased, agriculture and food processing all over the world introduced more and more labor-saving devices. Crushing graduated from the use of the feet to mechanical methods nearly 100 years ago, except in parts of Portugal and Spain. Pumps replaced gravity for transferring wines in the late 19th century. The efficiency of fining and filtration processes has increased dramatically during this century, so that clarification is no longer dependent on long aging in oak cooperage, and large stainless-steel tanks can be used for storage. Control of temperature has been a major method of controlling fermentation and aging (*17, 86*).

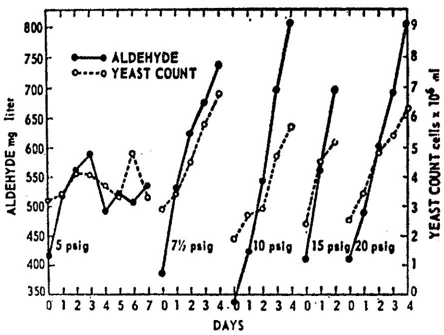

Fig. 3. Formation of acetaldehyde and yeast growth in submerged cultures of *Saccharomyces cerevisiae* var. *ellipsoideus* under 5 atmospheric pressures (from *81*); *psig*, pounds per square inch, gauge; 1 atm, 0 psi.

One of the modern recommended means of reducing hand labor is continuous fermentation. Continuous fermentation is admirable when the supply of raw material can be continuous. Since grapes ripen over only a short period, it is unlikely that fully automated continuous fermentations can be economically applied to the primary fermentation of fresh grapes, as they have been for beer.

Soviet scientists (*87*) have produced sparkling wines in a continuous fashion. There appears to be no theoretical reason why sparkling wines cannot be produced in a continuous system, equal in quality to and possibly cheaper than products of the batch process in tanks. Certain practical difficulties in securing adequate and continuous yeast growth under high pressure have been detected (*88*), and several laboratories now have the problem under study. Tests have shown that submerged yeast cultures of flor yeasts also can be operated continuously (*81, 89*). In both cases a supply of raw material is available throughout the year.

A major production concept being developed in California is that of the "winery without solids." The traditional process of making red wines involves crushing the grapes, pumping the juice and skins to a fermenting tank, punching-down the floating cap of skins during the fermentation in order to extract color and flavor from the skins, drawing-off the free-run juice during fermentation, pressing the skins (frequently with addition of water to the slightly sweet pressed pomace), and refermentation of the pomace to produce material for distillation. The initial fermentation on, or in contact with, the skins causes death of the surface cells of the berry and release of their color and flavoring components into the juice. The multiple handling of solids in wineries is not only inefficient but also laborious and difficult to standardize. Some of the variability in composition and quality of the product probably arises from this inefficient system.

Special belt presses for crushing and pressing and counter-current extractors for removing residual sugar are being developed (*90*). For red wines a brief treatment with steam under pressure to kill the cells of the skins and thus release the pigments and flavoring constituents without fermentation on the skins is under development. Use of heat to release color is an ancient concept, but only recently have the necessary engineering skills been applied to the problem.

Industrial developments have also been notable. Automated ion-exchange equipment, with the use of programmed photometric analysis, is employed by one winery to insure stability of the wine (*91*); the winery also uses a compact solid-state control, with digital-analog circuitry, to secure in-line high-volume blending of two wines, with accuracy within 0.5 percent. Automated analysis for alcohol and other components is also being employed. Many other technological applications of modern process control are under study both in this country and abroad.

Quality Control

One of the oldest problems in enology is the evaluation and maintenance of the quality of the product. During and after prohibition, when table grapes were a major subject of research in California, the problem of quality of the product arose again. It still remains, but since World War II many new techniques for sensory evaluation of foods have been developed and applied in this country. These are mainly pragmatic procedures, designed to determine difference between samples; pair, duo-trio, and triangle tests have been used. Once a difference is established, ranking, scoring, and hedonic rating are used to establish the degree of difference. Much of the California research in this field has emphasized the inherent differences in human preference, and thus the danger in reporting results as averages; the latest information is reported (*92*). European enologists, with exceptions in Austria and Germany, have been notably reluctant (*52*) to use these newer techniques for sensory examination—probably because of unfamiliarity with the technique.

Among the most effective quality-control procedures are those using chemical analyses. These appeared in national regulations in many countries about the turn of the century. After Repeal, the Bureau of Food and Drug Inspection of the California Board of Public Health drafted and secured wide acceptance of regulations for California wines that were as stringent (or more so) as those of the federal Internal Revenue Service; they regulated minimum and maximum alcohol contents, maximum sulfur dioxide and volatile acidity, ranges in or maximum sugar content, and so on. The volatile acidity, which is largely acetic acid, is primarily a measure of undesirable activity of aerobic bacteria. The limits on sugar and total acidity were partially designed to secure reasonable balance and uniformity in taste; careful enforcement of this requirement soon resulted in the disappearance of spoiled, or spoiling, and unbalanced wines from the market. Similar, but often less stringent and less rigidly enforced, regulations are in effect in other wine-producing countries. However, German regulations prohibiting the importation of wines made from direct producers (hybrids) appear to have been rigidly enforced (*93*), possibly as a hedge against the dumping of cheaper French and Italian wines in Germany under the European Common Market. Other chemical limits may be applied in the future; they may refer to acetaldehyde and acetal in sherry, total or specific higher alcohols in dessert wines, pigment pattern and amount of aroma constituents in various wines made from specified varieties of grapes, and more closely limited sugar, total acidity, and *p*H for certain standard types of wines.

Modern and accurate chemical procedures for measuring the contents of alcohol, volatile acidity, sugar, and sulfur dioxide were developed by university, regulatory-agency, and industry chemists (*94–96*). Control of quality has been brought to a very high level both in California and in most European countries. A European example is the development of a sensitive paper-chromatographic procedure to detect the anthocyan pigment malvadin diglucoside in wines (*97*); the purpose of the test is to distinguish wines made from American species of grapes (non-*vinifera* species and hybrids) from those made from pure European grapes (*V. vinifera*); only the former contain diglucosidic anthocyanin pigments. The European prejudice against wines made from *V. labrusca* varieties is based on their possible toxicity and probably also, as I have mentioned, on their special flavor (*98*).

Studies of composition have focused on the nature of the organic components of fusel oils (*99*) and brandies (*100*), the separation of the odor components of wines produced from certain varieties of grapes (*101, 102*), the nature of the flavor materials in flor sherries (*103*), and details of the polyphenolic components of grape seeds and skins (*104, 105*). The object of these investigations is a better understanding of the mechanism of the aging of wines (*106*) and of the taste effects of these constituents (*107*). Controlled aging of wines has been a major objective of enologists for many years; hundreds of processes (*108*) have been recommended for rapid maturation but few have succeeded—primarily because the mechanism of aging is so poorly understood. The need to relate basic scientific studies to technological processes has been most cogently argued by Ribéreau-Gayon (*109*).

Besides the studies of the polyphenolic compounds, there have been many of the oxidation-reduction potential as a possible means of controlling aging (*110*).

The advent of gas-liquid chromatography has greatly assisted research on the chemical components of wines (*102, 103*). While chromatography does identify very small amounts of materials, Bayer (*111*) and others have noted no direct relation between chromatographic peaks and human olfactory sensitivity to a compound. Correlation of quality with the size of chromatographic peaks is unlikely to be very fruitful. The influence of one odor on another must also be considered (*92*).

Medical Aspects

A significant amount of research on the medical aspects of wine has been conducted in France (*112*), Germany (*98*), and this country (*113*); it has been of great interest to the medical profession. Unfortunately, the California program has recently been curtailed. The most significant work has been on the sociologic aspects of wine consumption; it has resulted in books on wine in Italian culture (*114*), in French culture (*115*), and among Jews (*116*). There have also been significant papers on the use of wine by diabetics, in certain cases of diarrhea, and so on (*113*). American and European investigators have carefully studied the amino acid and vitamin contents of many wines (*117*), and particularly how these are affected by various winery practices (*118*). Some of the newer procedures for handling wines, such as ion exchange, and clarification with bentonite, are undesirable from the point of view of retention of amino acids and vitamins—though few consumers drink wine as a source of either, in which it is relatively poor.

Most of the California investigations on table and dessert wines are recounted in three books (*4, 119, 120*); the European literature is reviewed in many texts (*11, 12, 39, 48, 52, 95, 96, 104, 121*).

Thanks to the application of biochemistry and plant physiology, the influences of cultural practices and climate on the composition of grapes are well advanced in explanation. The detailed chemical composition of grapes is rapidly being established and the means of controlling it more closely are thus at hand; composition is particularly important in varieties that contribute distinctive aromas to the wines.

Application to wines of our increasing knowledge of the biochemistry of fermentation has led to explanations of the sources of many, but by no means all, of the by-products of alcoholic fermentation. The effects of the various biological and physical treatments on the number and amounts of the components of wines are becoming clearer. Multifactorial correlation of composition with quality can, therefore, be expected; it will certainly be complex, varying from type to type, between individuals, and in different parts of the world.

Far from detracting from potential

quality, the search for good wine now makes it possible for all wines to meet minimum standards of palatability and consumer acceptance. There is no doubt that new types and finer examples of standard types will result from this research. The golden age of wines is not in the past but now and in the future. As Ribéreau-Gayon (*122*) has so aptly written,

> Les industries de la bière, du pain, du vin sont de très vieilles industries, qui ont existé avant que n'existent la biochimie et la microbiologie; mais elles ont profité largement des données scientifiques depuis un siècle. Inversement il est bien certain, que des activités de recherche basées sur une technique apportent souvent d'important progrès en biochimie générale.

Thus enology may be said to have become a kind of specialized branch of biochemistry, with unique problems of technology and quality control.

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NEWS AND COMMENT

Share the Wealth: LBJ Directive Beginning To Show Some Effects

Ever since September 1965, when President Johnson issued a directive titled, "Strengthening the Academic Capability for Science Throughout the Nation," it has been government policy to promote the development of new centers of academic excellence.

Just what has happened as a consequence of this policy is difficult to determine, since, first of all, the money that is an instrument of this policy moves slowly, and, secondly, once delivered, its impact is likely to be felt slowly. Furthermore, in some instances there has been more talk than action. Last spring, for example, the Defense Department announced that it would parcel out $20 million among institutions that had received little or no Defense research support; but the money is yet to go out.

Nevertheless, the capillary system that carries federal funds outward from Washington is beginning to flow with money specifically earmarked for development. Last week the National Science Foundation announced three more grants in its development program, bringing the total to 20 institutions and $63.7 million. The latest are the University of Texas, Austin, $5 million—the largest single grant so far in the program; the University of Indiana, Bloomington, $3.7 million; and Duke University, $2.5 million. (NSF's program actually got under way in May 1965, when pressures had built up for a broader distribution of research funds but before the President had made such a goal a matter of national policy.)

Though little attention has been paid so far to the consequences of this federal policy, the available evidence suggests that it is beginning to introduce a considerable amount of turbulence into the academic marketplace. Whether the turbulence is beneficial depends on one's vantage point. But, just recently, a panel of deans (mostly from the wealthier enclaves of the academic world)* put together a cautiously worded statement which suggests that Johnson's academic welfare program may be pinching some of the haves in its efforts to promote the betterment of the have-nots. Sitting as the Committee on Policies of the Association of Graduate Schools of the Association of American Universities, they stated (in a draft of a document yet to be released):

". . . Federal programs are needed which *provide for additional centers of excellence* in graduate education and research, *and* at the same time *preserve the existing centers of excellence.* [original italics]

". . . new centers of excellence can be created only relatively slowly since the number of professors qualified to offer graduate education and research can be increased only relatively slowly. If new centers are created too rapidly, the result simply will be the raiding of established departments and the consequent game of musical chairs will unduly inflate salaries and debase standards of appointment in areas of scarcity. The tendency of some professors to be predominantly concerned with rising within their professional specialty rather than growing with their university will tend to be strengthened while their loyalty to the university and the students, an important part of sound graduate education, will become weakened."

Though it would be interesting to trace the career patterns of some of those who espouse the virtues of staying put, the fact is that the deans do have a point when they note that "the supply of available qualified professors appears to be the factor which, above all others, will govern the maximum possible rate of expansion of the centers of excellence in graduate education. . . ." They go on to suggest that "statis-

*The members are Robert A. Alberty, Wisconsin; J. P. Elder, Harvard; Ralph Halford, Columbia; Joseph L. McCarthy, University of Washington; M. N. McGeary, Pennsylvania State; John L. Snell, Tulane; and V. Whitaker, Stanford.