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Large Vineyard Discovered in Ancient Pompeii

Root and stake cavities reveal vineyard of A.D. 79.

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Recent excavations have uncovered a large vineyard within the city walls of ancient Pompeii (*1–4*). For over 200 years, the large city block [region II, *insula* 5 (*5*)] to the north of the amphitheater, in which this vineyard was found, has been known as the *Foro Boario*, or cattle market, a name that still appears on the plan of the city distributed to tourists. This large and valuable property, located at the eastern edge of the city, faces, on the north, the largest thoroughfare in the city, the busy Via dell'Abbondanza, which leads from the Sarno Gate, in the eastern wall of Pompeii, to the Forum, at the opposite end of town.

The first limited excavations in this insula took place in 1755, and the site was then identified as the cattle market (*6*). In 1814, the south wall of the insula was uncovered. An entrance, formed by two columns giving access to a triclinium (three masonry dining-couches), was found in the center of the wall, directly across from the entrance to the amphitheater. The 1814 excavations lasted for less than a week and are reported in one sentence, which concludes with the statement that this was the place where gladiators who had been killed in the amphitheater were buried (*7*). This explanation no doubt suggested itself to the excavators because a short time before they had found at Pompeii a triclinium that had been built as a tomb monument on the Street of the Tombs outside the Herculaneum Gate. Other scholars believed that the Gladiators were given a banquet at public expense at the triclinium before going to possible death in the amphitheater. Some believed the animals used in the amphitheater were penned in this insula, for the amphitheater, the oldest known, has no underground chambers for animals, as do later ones.

There were no further excavations in this area until the 1950's, when much of the insula was uncovered—with the exception of the northeast part, which is occupied by a modern house, and a portion of the northwest part, where there appeared to be an ancient structure (*8*). The two rooms that were excavated had been equipped for making wine, which suggested that the insula might have been planted with grape vines, but the belief that the area was the cattle market persisted.

Only subsoil excavation could determine whether this valuable property had been planted. This I began in June 1966. If modern vegetation has not been too destructive, it is possible to find evidence of the roots of trees and plants that were growing at the time Vesuvius erupted in A.D. 79. When these roots decayed, they left cavities that the lapilli (volcanic debris) which covered Pompeii gradually filled. Volcanic ash makes the soil so fertile that an excavated area is soon covered with vegetation; the roots of saplings and brambles often destroy all evidence of the ancient root cavities. Because, fortunately, this insula was less overgrown than most, I hoped that we, my workmen and I, might be able to determine whether it had been planted in A.D. 79.

A trench was begun along the east wall, where there was a substantial covering of the original volcanic debris. Digging down through more than 122 centimeters of lapilli, we came to the ground level of A.D. 79 and almost immediately found a cavity filled with lapilli. After the lapilli had been removed, we found that the cavity was a perfect mold of an ancient tree (30 cm in diameter at ground level). Encouraged by our initial success, we continued the trench along the east wall, but the undisturbed covering of lapilli soon ended; the excavators in 1955 had removed the volcanic debris down to the original ground level and later covered the area with backfill. Days of hard work yielded only a few scattered root cavities, which were 4 to 9 cm in diameter. Trenches dug in the western half of the insula also yielded disappointingly little. The few roots found were not sufficient to disprove the theory that the site was the cattle market. But as we continued a trench from the west wall to the center of the insula, a scattering of root cavities (4 to 10 cm in diameter) and a large tree cavity (38 cm in diameter at ground level) were found. It began to look as though there had been considerable planting in the cattle market.

Soon eight evenly spaced root cavities were found—then row after row of cavities, until the east wall was reached. The cavities were carefully emptied, measured, and filled with cement. After 3 days, the soil was pulled away from the casts, and the shape of the root that had been growing at the time of the eruption was revealed. The small cavities appeared to be those of vine roots. By the end of the summer 5 large tree-root cavities and over 200 vine-root cavities had been found (*9*), almost twice that number of vines if the second cavity found in most locations was that of a root and not a stake (local growers believed

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the second cavity had been formed by a stake). It became obvious that this important area was a vineyard and not the cattle market, as had been believed for so many years.

Roman Viticulture: Literary Sources

Until the discovery of this vineyard, knowledge of ancient Roman viticulture was limited primarily to the information preserved in the extant literary sources (*10*). The most detailed discussions are found in three agricultural manuals (*11*) and Pliny the Elder's encyclopedia. The oldest manual, the *De agri cultura*, written by the farmer-statesman Cato (234–149 B.C.), is a loosely organized series of shrewd and pithy comments, based on practical experience, giving directions for the administration of a farm. A pioneer work often quoted by later authors, it gives a valuable picture of the large farms, operated as investments by wealthy individuals, that were then coming into vogue. In describing the ideal farm, on which the culture of vines and olives was emphasized, Cato lists the vineyard first, as the most important part.

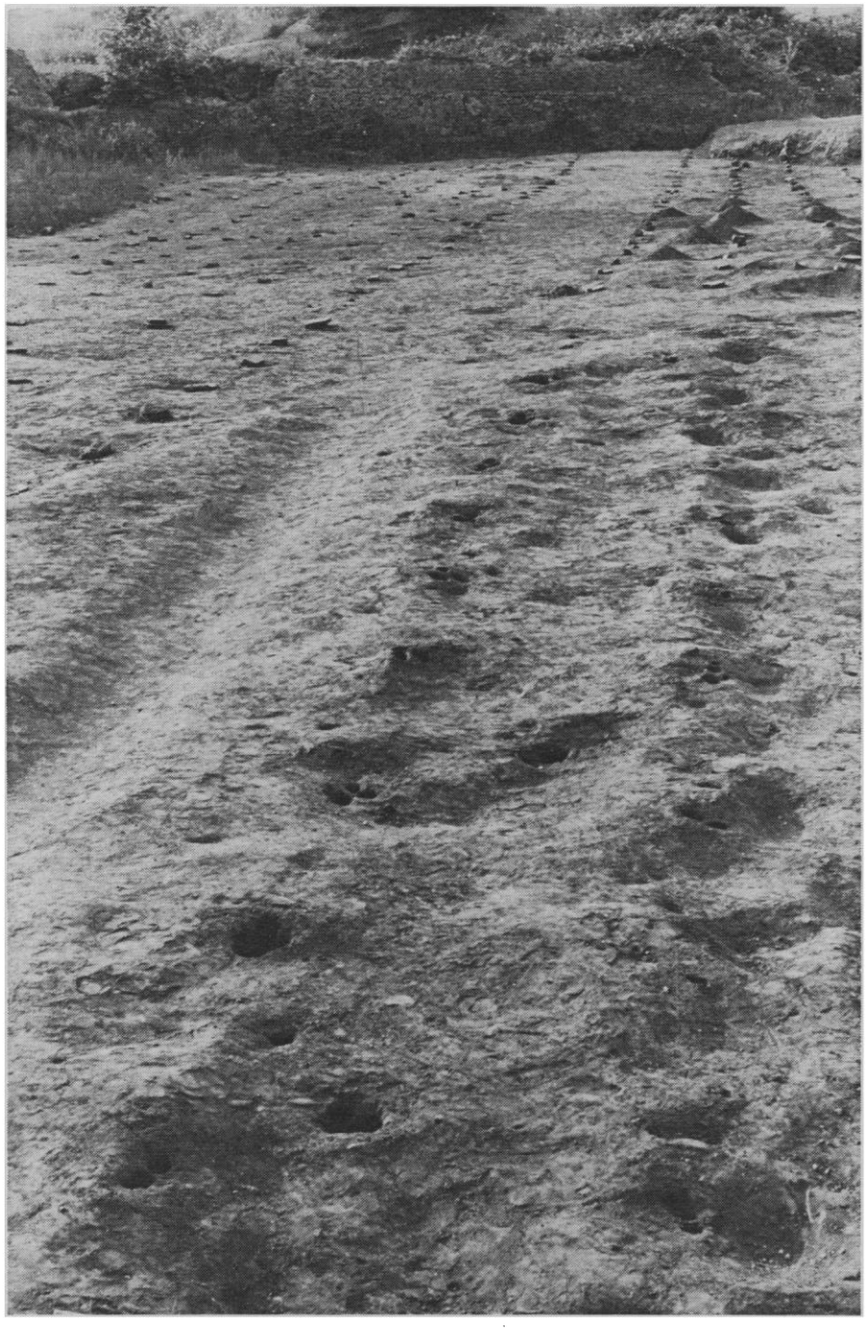


Fig. 1. Contour of surface of vineyard in A.D. 79.

Varro (116–27 B.C.), known as Rome's greatest scholar, began the *De re rustica* when he was 80 years old as a practical manual for his wife, who had just bought a farm. Longer and more polished than Cato's manual, Varro's is an immensely practical one. Viticulture is discussed in book 1, which is concerned with agriculture; book 2 takes up domestic cattle; the last book deals with smaller stock.

The longest and most comprehensive of the manuals was written by Columella, a native of a Roman municipium in southern Spain who lived in the early part of the 1st century A.D. His knowledge of agriculture in the province of Spain was learned at least in part from his uncle, a distinguished farmer whom he quotes often. Later Columella moved to Italy, where he owned a number of farms in the vicinity of Rome. About one-quarter of the material in the 12 books of his *De re rustica* pertains to viticulture and reflects the author's practical experience. Book 4 discusses Italian viticulture; book 5, viticulture in the provinces. Columella also wrote a shorter book on trees, *De arboribus*, which covers the material treated more fully in his longer manual.

The encyclopedist Pliny the Elder was a contemporary of Columella. His *Naturalis historia*, which deals with much more than the natural sciences, is essentially a compilation, as the author admits in crediting his many sources. But he adds many observations of his own, and his work contains much important information not found elsewhere. Pliny spent the last years of his life in command of the Roman fleet stationed at Misenum, across the Bay of Naples from Pompeii, and was killed at Stabiae by poisonous fumes during the eruption of Vesuvius. An eyewitness report of the eruption is preserved in two letters written long after the event by Pliny's nephew, known as Pliny the Younger, who as a 17-year-old boy had watched the eruption from Misenum.

Because of the importance of viticulture in Roman life, it is not surprising to find frequent references to it in poetry. Most are casual, but Vergil's *Georgics* is a poem devoted entirely to agriculture. Book 2 has much to say of vines, but even though the author had practical knowledge of farming, the material has more charm of expression than practical value for the farmer.

Having discovered an actual vine-

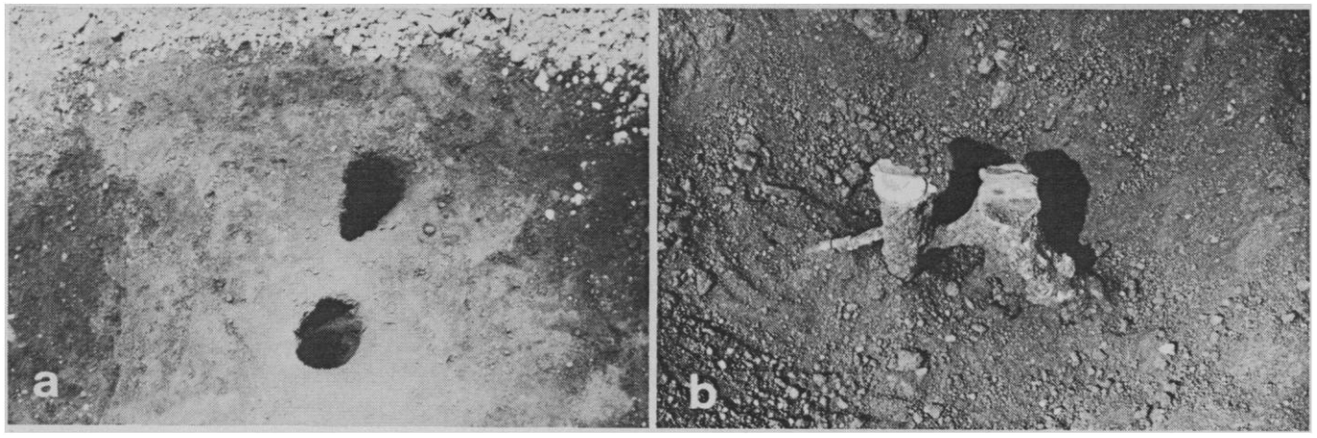


Fig. 2. Cavities left by stake (top) and vine root (a) and casts of stake (left) and vine root, with its side root reaching behind stake (b).

yard, it was of great interest to see the extent to which the ancient proprietor had followed the practices described in the agricultural manuals and to what extent this advice was applicable to the Pompeii area.

Recovery of the Planting Pattern

The vines in this vineyard were planted almost exactly 4 Roman feet (1 Roman foot = 29.59 centimeters) apart, which would seem to indicate that they were cultivated by hand. Columella (*12*) says that rows should be at least 5 feet apart if cultivated by hand, at least 7 feet apart if cultivated by oxen and plow. Pliny the Elder (*13*) may have been drawing on his own observations of the Pompeii area when he said that, in a rich soil, vines should be planted 4 feet apart. The planting pattern in the vineyard is strikingly similar to that still used in the vicinity of Pompeii. Even the three or four depressions found around the root cavities were recognized by the workmen as similar to the depressions that they put around their vines to hold water.

Systematic excavation of the vineyard was continued during the summer of 1968 (*14*). Much of the insula was excavated and the ancient planting pattern recovered. In parts of the insula the work was extremely tedious and difficult, especially in the western half, where the original fill had been removed and the cavities had been badly damaged by the passage of trucks in 1955. Modern roots had destroyed the evidence of the ancient roots in many places, but by the end of the summer over 1200 vine root cavities had been found (still counting only one vine root to a location), making a total of 1423.

Work was resumed during the summer of 1970 (*15*). Because a portion of the hill of original volcanic debris and accumulated soil (about 6 meters in height) had been removed down to 1 m of lapilli, it was possible to begin excavating an area that had not been damaged by previous excavations. It was possible for the first time to study the contour of the surface of the vineyard as it had been at the time of the eruption (Fig. 1). Around the root cavities were found the three or four depressions for water that had been found before, but these depressions were much deeper and more pronounced than those found previously. It was also possible to see how much of the original contour had been sliced off during the former excavations or destroyed by the weight of passing trucks.

Identification of Vine-Root and Stake Cavities

For the first time, cavities in an undamaged area could be examined. The areas excavated in the two previous seasons had been too disturbed for me to be certain if the second cavity found in many places was that of a stake or of another root. Local growers unanimously insisted that the vines had been staked in antiquity, just as they are staked today. They were sure that the Pompeians had always done it that way. However, fruit experts at the University of Naples believed that the second cavity found in many locations was that of another root and that the vines had been pruned low and left unstaked.

When we began to empty the cavities, we found them perfectly preserved, and, with few exceptions, one was always clearly that of a vine root, easily identified by its shape and small lateral roots. The second was always that of a stake (Fig. 2a). After the cavities were cleaned, measured, and studied, they were filled with cement to form casts. After 3 days, the surrounding soil was pulled away; in almost every location the casts were of a stake and of a root (Fig. 2b).

Frequency distribution charts were made of the measurements of the depths and diameters of the stake and root cavities, as well as of the cavities of the large posts along the paths in the undisturbed areas examined. The results showed that:

1) Almost all of the stake cavities were between 8 and 23 cm deep, with a median depth of 15 cm.

2) 90 percent of the root cavities were between 7 and 28 cm deep, with a median depth of 16 cm; the range was from 7 to 55 cm.

3) Almost all of the stake cavities had a diameter of 2.5 to 5.5 cm, with a median diameter of 4 cm; the range was from 2 by 3 cm to 7.5 by 8 cm.

4) 90 percent of the root cavities had a diameter of 2 to 5.5 cm, with a median diameter of almost 4 cm; the range was from 1 by 1 cm to 8.5 by 8.5 cm.

This survey shows that the well-preserved stake and root cavities did not differ significantly from each other in depth or in diameter, but that there was a greater range in the diameters of the root cavities. The root cavities with very small diameters were probably those of cuttings that had been set out the previous year to replace vines

that had died. Cuttings were always set out after the vintage; therefore, the eruption on 24 August came too early for them to have been planted in A.D. 79. In the few locations with a perfectly preserved stake cavity and no root cavity, the vine had probably died and no new cutting had been planted. In a few places there was no stake cavity, but a definite depression marked the spot where a temporary prop had been placed, pending replacement by a permanent stake. It is interesting to note that the few very large root cavities found were along the paths where the vines were trained to grow higher and thus got more sun.

By the end of the summer it seemed certain that the entire area had been a vineyard. Time was running short, and the backfill (up to 2 m in height) had not yet been removed from certain areas to the east of the path in the southeast quadrant. To make certain that the entire area had been planted, we excavated three rows to the east of the path and the first row of root cavities to the north of the triclinium, thus showing that the entire area was enclosed with rows of root cavities. During the summer, 578 vine-root cavities were found, bringing the total to 2001 (Fig. 3).

Evidences of Layering

In antiquity, new vines were often propagated by layering, just as they are today. The ancient writers give detailed instructions for various methods. Two well-preserved examples of layering were found in this vineyard, where the technique used was simple: the shoot was bent over and shallowly covered with soil until it rooted. Of the two examples found, one had formed two roots and the other, a long one (over 100 cm), had grown three large roots.

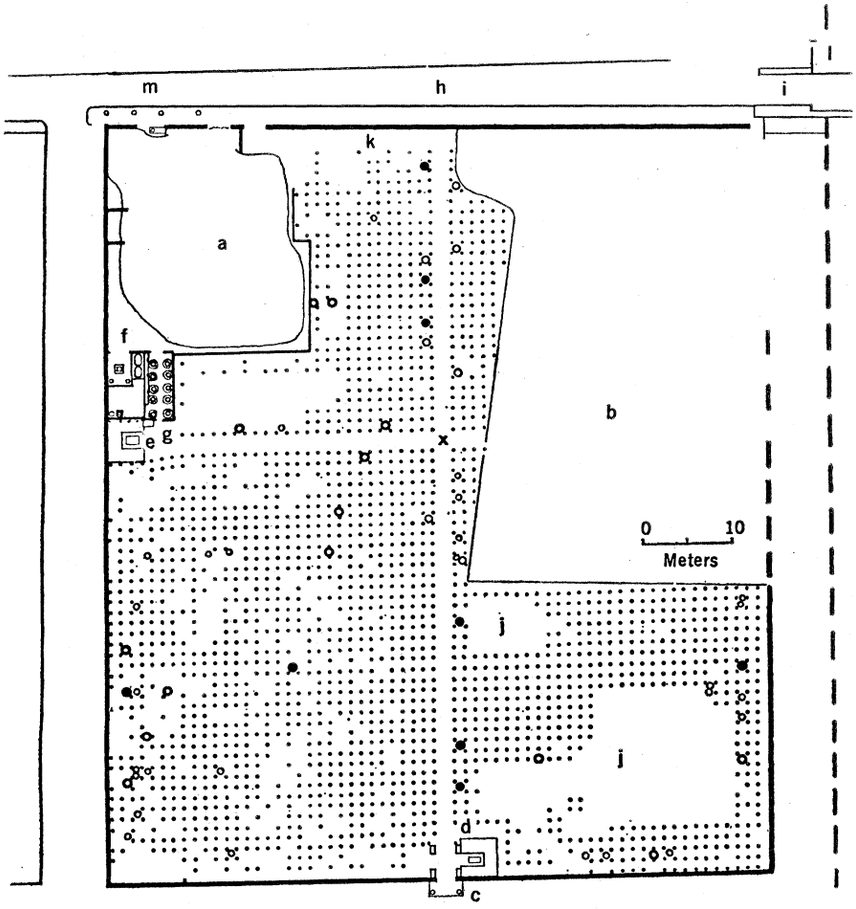


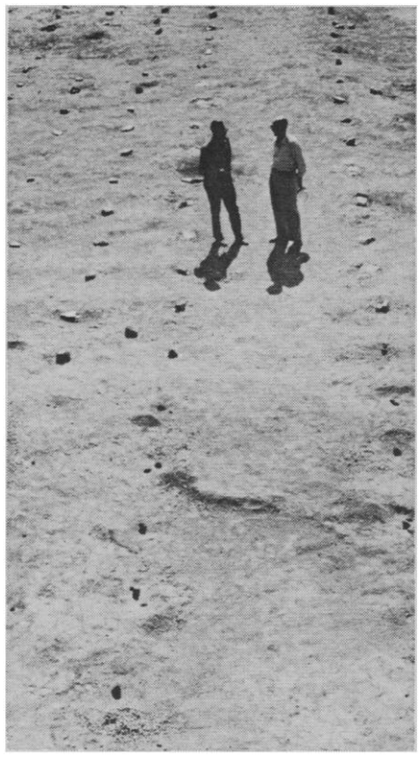
Fig. 3. Plan of vineyard at end of 1970 season: (a, b) unexcavated areas; (c) south entrance; (d, e) masonry triclinia; (f) room with wine press; (g) shed with ten dolia embedded in the ground; (h) Via dell'Abbondanza; (i) Sarno Gate; (j) unexcavated back fill 1955 excavations; (k) path along the north wall; (m) wineshop and portico; (x) the crossing of the north-south and east-west paths. Dots indicate vine roots; small circles indicate tree roots 10 cm or less in diameter; large circles indicate tree roots 11 to 29 cm in diameter; solid circles indicate tree roots 30 cm or more in diameter.

The Footpaths

In 1966, as the original east-west trench was widened southward, in the direction of the gate, it became evident why one north-south row of roots had been impossible to find. This row had been left unplanted in order to form a path leading directly to the south entrance of the vineyard. Columella recommends that vineyards be divided by footpaths for laborers carrying stakes, repairs for the frames, or fruit. Since he recommends that vineyards be divided into areas of 0.5 *jugerum* each (approximately 0.25 hectare), which is approximately the size of each quarter of this vineyard, we were anxious to see if this vineyard was divided by paths in the same way. As the western part of the insula was cleared, in 1968, a path running east and west was discovered. The east-west path, however, did not divide the insula into four equal parts, since it was designed to give access to a triclinium just outside the door leading to the rooms where the wine was made. Trenches dug to the north and to the east showed that the north-south and east-west paths intersected and then continued. It appeared that the vineyard was divided into four parts, but, because of the location of the triclinium, the east-west path was a little off center.

The major part of the north-south path was excavated during the 1970 season. This path, which lead directly from the entrance in the south wall and continued to the north wall, divided the insula into two equal parts (Fig. 4). The perfectly preserved cavities on each side of the paths could be easily identified. The large cavities that outlined the path were those of posts, the smaller cavities to the side of the posts were those of vine roots. The posts along the paths were considerably larger than the stakes in the vineyard, and they were set much deeper in the ground (Fig. 5). The depth of the post cavities in the undisturbed area excavated ranged from 32 to 55 cm, with a median depth of 42 cm. It was not unusual to find two root cavities at each location along the path, a rare occurrence elsewhere in the vineyard. The largest posts (14 to 32 cm in diameter) had been cleanly cut to form quarter round posts, smaller ones (9 to 17 cm in diameter) to form half rounds, and the smallest (7 to 10 cm in diameter) were used whole. The nails which were found near several of

Fig. 4 (left). View of vineyard looking south toward the amphitheater. Stones protect casts made by pouring cement into emptied cavities. Fig. 5 (right). Path in vineyard excavated at Pompeii; large cavities were left by posts, small ones by vine roots. The lapilli that gradually filled the cavities when the posts and roots decayed have been removed. Stones in the background protect casts made by pouring cement into emptied cavities.



the postholes had probably been used to fasten the frames of an arbored passageway.

The carefully cut posts were probably chestnut (*Castanea sativa* Mill.). Pliny (*16*) speaks of the growers' preference for the chestnut tree for props because of the ease with which it could be worked, its "obstinate durability," and its resistance to decay. Columella (*17*) also recommends chestnut stakes. Vineyard owners in the Pompeii area today continue to prefer chestnut. They tell me that poplar stakes last only 1 or 2 years, chestnut stakes at least 10 years. Chestnut is more expensive, but there is a plentiful supply nearby on the slopes of the Lattari Mountains. It is known that chestnut stakes were available in antiquity because Pliny specifically mentions the chestnut trees of Campania. The willow (*Salix*) (*18*) and the poplar (*Populus*) (*19*) were planted in antiquity to furnish withes for tying vines. Today in the Pompeii area vineyard owners still grow the willow and the poplar to provide ties.

During the 1970 season a third path, which runs parallel to the north wall, was found. It is possible that there was an entrance to the path from the building belonging to the vintner, but the wall of this building is too damaged today to furnish any evidence.

Coins

The discovery of a path along the north wall makes more easily understandable the presence of two groups of coins (11 in one group, 4 in the other) found there in 1968. They were probably lost by someone walking along the path. The coin found at the edge of one of the postholes on the pathway to the triclinium may have rolled there, after being accidentally dropped. There were, in all, 14 asses and two dupondii. All had been coined between A.D. 22 and 74 and had been in circulation during the last days of the city. There were four from the reign of Tiberius, three from Claudius, six from Vespasian, two from Titus, and one from Domitian (*20*). A bronze ass too badly corroded to identify was found near a posthole on the north-south path in 1970.

Tree-Root Cavities

A total of 58 tree-root cavities was found in this vineyard. The cavities were all carefully cleaned and measured, and cement casts were made of them, the large cavities first being reinforced with heavy wire (Fig. 6). The cavities varied greatly in size, the diameter at ground level ranging from 3.5 to 40 cm. Trees were usually found in the center of the space between four vines, but occasionally in the row between two vines. The small cavities found near large ones were undoubtedly volunteer seedlings, such as are frequently found in modern vineyards. The plan of the vineyard (Fig. 4) shows rows of widely spaced trees around the edges, usually between the second and third rows from the wall, with a few trees placed at random throughout the interior of the vineyard. Widely spaced trees were also planted between the first and second rows of vines on each side of the paths.

There are more trees in this vineyard than Columella recommends. He says that the fig, pear, or apple tree

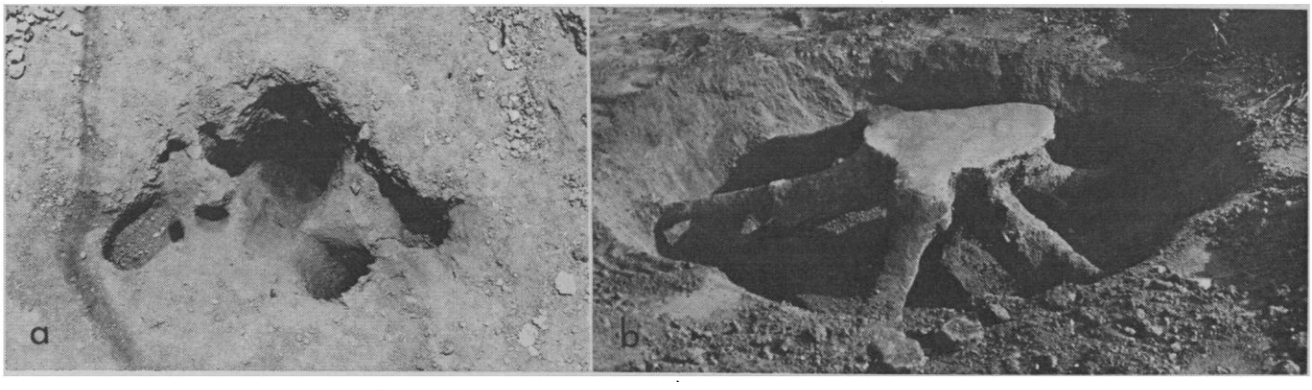


Fig. 6. Tree root cavity (a) and cast of tree root (b).

may be planted, but only at the end of rows on the north, where they would not shade the vineyard. But in the Pompeii area, both in antiquity, as this vineyard shows (*21*), and today, trees are generously planted throughout the vineyard. In one modern vineyard that is much like this one, even to the arbored pathway, there are 13 different species of trees growing at the edges and among the vines. In addition to the willow (*Salix alba* L.) and the poplar (*Populus nigra* L.), which were used for tying vines, there were the Persian walnut (*Juglans regia* L.) and the filbert, or hazelnut (*Corylus avellana* L.). The fruit trees included the pear (*Pyrus communis* L.), the fig (*Ficus carica* L.), and the apple (*Malus pumila* Mill.) recommended by Columella, as well as the plum (*Prunus domestica* L.), the peach (*Prunus persica* [L.] Batsch), the sour cherry (*Prunus cerasus* L.), the apricot (*Prunus armeniaca* L.), the sorb (*Sorbus domestica* L.), and the loquat (*Eriobotrya japonica* Lindl.). All of these trees except the loquat, which is a modern introduction from Japan, were known to the 1st century Romans and could have been raised by the ancient Pompeians. Carbonized walnuts, filberts, figs, cherries, peach pits, and possibly plums and pears have been found in the excavations at Pompeii and Herculaneum (*22*); all of these nuts and fruits, plus apples, are depicted in the wall paintings (*23*). It would not be surprising if they were all represented in the tree-root cavities found, with the possible exception of the walnut. Pliny warns that it causes injury to anything planted nearby, but, as I have said, it grows in Pompeian vineyards today.

Table 1. Animal remains found in vineyard (14 bones are indeterminable; 2 of these have tool marks).

Field number	Bone	Tool marks	Probable tool marks
	Bos taurus (domestic cow)		
1	Metacarpal		
3	Metatarsal, distal end	x	
9	Os coxae		
10	Metatarsal (Fig. 8a)	x	
11	Metatarsal (Fig. 8a)	x	
14	Metatarsal, proximal end		
15	Metatarsal, distal end		x
29	Molar		
30	Molar chip (from No. 29)		
31	Femur, distal end	x	
34	Calcaneum	x	
35	Second phalanx		
45	Metatarsal		
47	Metatarsal (fragment)	x	
2	Scapula*		
	Equus caballus (domestic horse)		
5	Ulna	x	
19†	Tibia, distal end		
20	Tibia, center section near proximal end (Fig. 8B)	x	
21	Radius		
23†	Tibia, proximal end		
32	Humerus, distal end (fragment)		
25	Rib*		
	Bos taurus or *Equus caballus*		
18	Vertebrae	x	
22	Calcaneum		
43	Metatarsal or metacarpal (fragment)		
46	Rib		x
	Sus scrofa (wild boar)		
12	Scapula		x
36	Scapula (fragment)		
37	Lower mandible (fragment)		
38	Scapula (fragment)		
44	Tarsus center (fragment)		
50	Piece of mandible		
	Canis familiaris (domestic dog)		
6	Os coxae		
7	Radius		
17	Radius		
	Ovis aries (domestic sheep)		
33	Femur, distal end		
	Ovis aries or *Capra hirca* (domestic goat)		
51	Metapodial		
	Felis catus (domestic cat)		
52	Lower left mandible		

* Identification of species not entirely certain. † Part of the same bone.

Plant Material

Small amounts of carbonized, or slightly burned, roots, as well as bits of dry roots, were found in some root cavities. Traces of carbonized material were found in 1970 as my workmen and I approached the level of the ancient vineyard in the undisturbed area where the upper part of the hill of debris had been removed. When the lapilli were removed, by hand, two oval objects were found almost at ground level. After being photographed in situ, they were removed for further study. One disintegrated almost immediately upon being exposed to the air. The other, when examined under the microscope, appeared to be an olive (*Olea europaea* L.), with part of the flesh of the fruit still visible on the seed, the striations quite marked, and the characteristic peduncle and collar still on the fruit. Not surprisingly, a tree-root cavity was found in the center of the area between the four vine roots where the fruit was found. I had predicted that the widely spaced row of trees between the second and third rows of vine roots from the east wall would continue, and I had hoped that by some fortuitous good fortune some carbonized fruit or nuts might be found there. It was in this row of trees that the olives were found. The discovery of an olive was somewhat unexpected, but olive trees are found in Italian vineyards today, as well as in antiquity, for Pliny says the olive is one of the trees on which the vine might be trained.

A carbonized bean that we found amid the lapilli at ground level may indicate that vegetables were raised between the vines. I have found no such recommendations in the ancient authors, only references to the planting of lupines or clover as fertilizer in worn-out vineyards; but fertilizer would not have been needed in the already fertile volcanic soil of Campania. Intercultivation is common in the Pompeii area today. I remember my surprise when I first saw vines growing beneath the shade of trees—and, under the vines, corn, tomatoes, beans, and other vegetables were thriving! So fertile is the soil, so strong is the sun of Campania.

Method of Vine Training Used

Now that it is certain that the vines were staked, the question of how the vines were trained remains to be answered. Various methods are described by the ancient writers. Vines can be

divided into two general categories according to the way in which they are trained: vines with support and vines without support. The most complete list is found in Pliny (*24*), who gives six methods of training vines. Unstaked vines might have their branches spread out on the ground or they might stand alone, like a small tree; staked vines could be propped up with or without a cross bar on the stake.

The fifth method involves vines growing on a trellis with a rectangular frame (*vitis compluviata*). Pliny says that this kind of vine training took its name from the similarity of the rectangular frame to the opening in the ceiling of the atrium in a Roman house. The exact meaning of the term *compluviata* has been much discussed (*25*), and modern scholars have explained this method of vine training in many quite different ways. But Varro's and Columella's descriptions leave no doubt as to the method. Varro says (*26*) that vines can be trellised in two ways: in a straight line, as in the district of Canusium, or yoked lengthways and sideways in the form of a compluvium (*compluviata in longitudinem et latitudinem iugata*), as is the practice generally in Italy (Fig. 7). Columella gives detailed directions for training and pruning vines in the latter manner in the part of *De re rustica* in which he discusses Italian vineyards (*27*). The advantages of this method of training are stressed by the ancient writers. They point out that vines spread out in four directions remain better anchored and more stable after storms and heavy rains. Such conditions are found in Pompeii.

The Pompeians were also familiar with the sixth method, vines wedded to trees (*arbustum*), for in Campania vines were often wedded to poplars, as they still are today. Cupids are shown gathering grapes from vines supported by trees in a wall painting in the House of the Vettii.

Knowing the characteristics and the relative advantages and disadvantages of the various methods used by the Romans to train vines, I have tried to determine the method used in this vineyard. Since it is certain that the vines are staked, the first two methods listed by Pliny can be eliminated. The ancient writers pay little attention to the vine with a single stake, and the yoked vine arranged in rows is recommended for cold, rainy areas, which is not descriptive of Pompeii. In this vineyard, the trees were too irregularly placed and the vines were too close together for them to have been trained on the trees. This leaves the vitis compluviata as the most probable method. The ancient authors say that this method is the one most commonly used in Italy and that it produces the most wine. They stress its suitability for areas with a hot, dry climate and rich soil, which describes conditions at Pompeii. In fact, this method is still being used in the Pompeii area today. It is not known what material was used for frames in this vineyard. Nails (3.5 to 10 cm long) found in the interior of the vineyard may have been used to fasten frames to the stakes, but, since these nails were all found in the backfill, it is possible that they were originally used only in the arbored passageway. In antiquity, frames were made of stakes, poles, or reeds bound together. Today in the Pompeii area the frames are most often made of poles or stakes.

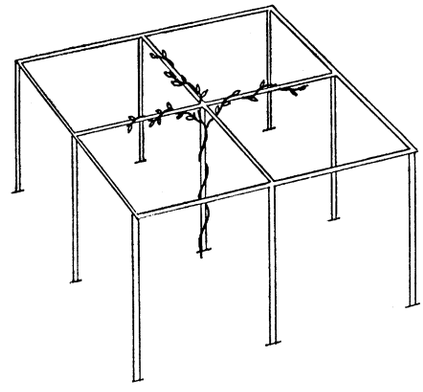


Fig. 7. Wines trellised with frame (*vitis compluviata*).

Since no stakes were found in the vineyard, I do not know their height. Columella recommends that frames be about 5 feet above the ground, never more than 7 or less than 4. Varro suggested that the height of a vineyard not exceed the height of a man. According to Pliny, the richer the soil and the more level the ground, the greater the height of the crossbars required. Both archeological and epigraphical evidence confirm the use of stakes in the Pompeii area. Unfortunately, the dimensions of the stakes found during the excavation of a villa in the Sarno Valley, 2 kilometers to the south of Pompeii, were not included in the report of that excavation (*28*). Stakes are mentioned in two graffiti found in another villa. One reads: "1023 stakes in a big pile"; the other, "840 sharp stakes, 460 which are not sharp, a total of 1300" (*29*). It is quite possible that the "not sharp" stakes were used for making frames.

Soil, Topography, and Drainage

The ancient Romans appreciated the importance of soil, topography, and drainage in a vineyard, and they believed these factors should determine the type of vine planted. They believed that hill slopes produced better wine, but they knew that a profitable vineyard was possible on level ground if the soil and drainage were favorable. Well-drained soil is very important. The soil in this vineyard is good. In fact, the volcanic plain of Campania was known in antiquity for the great fertility of its soil and also for its good texture: it is described by Pliny as "dusty on the surface, and also porous like pumice," so that "the earth allows the frequent rainfall to percolate and pass through it" (*30*).

A survey of the vineyard reveals a decided slope away from the triclinium and the complex of buildings in the northwest corner of the insula. The grade is most apparent in the east-west path, between the triclinium and the intersection with the north-south path, and in the north-south path, between the intersection with the east-west path and the entrance to the vineyard, where the grade averages from 4 to 5 percent.

The marked depression down the center of the slightly sloping north-south path suggests that it served as a drainage channel during periods of heavy rain (Fig. 1). The small portion of the east-west path uncovered on the east side of the intersection slopes downward toward the north-south path. Because the soil is porous, drainage was not a major problem. More important was the conservation of rainwater. The constant digging and hoeing recommended by ancient writers tended to conserve the moisture by dry-farming techniques (*31*). It was also possible to channel and conserve the rainwater in the three or four depressions that were made around each root.

The contour of the surface soil in the undamaged area that we excavated showed definitely that the vineyard had been dug by hand, thus confirming the impression I had formed when we discovered the close spacing of the vines. Judging from ancient estimates, one man could easily care for a vineyard this size.

Estimate of Yield

The room to the west, in the small building equipped for the production of wine (Fig. 3), has fittings for a beam

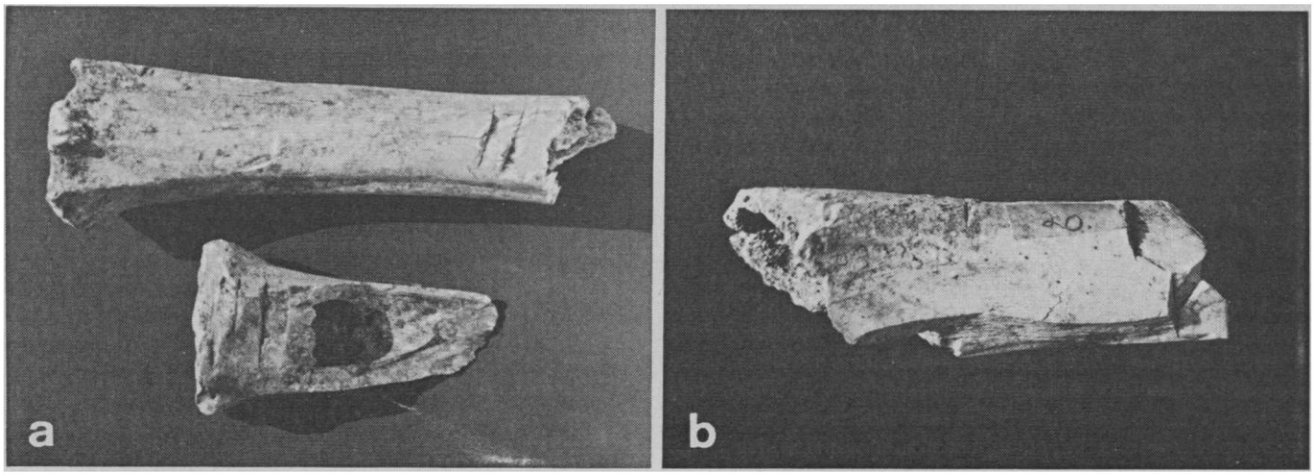


Fig. 8. Cow (*Bos taurus*) bones (a) and horse (*Equus caballus*) bone (b) split for marrow. Tool marks can be seen on these bones.

press similar to the one that has been restored in the Villa of the Mysteries at Pompeii (*32*). The juice extracted from the grapes was stored for fermentation in the ten dolia embedded in the dirt floor of the adjacent shed. If the entire insula was under cultivation, this vineyard was a little over 2 jugera in size. Columella recommended that any vineyard which did not produce at least 3 cullei (almost 2000 liters) of wine per jugerum should be uprooted. Assuming that this vineyard met Columella's minimum standards of yield, it should have produced 6 cullei. Because of the great fertility of the soil and the intensive cultivation possible in a small vineyard worked by hand, it is quite possible that this vineyard produced two or three times that much, perhaps even 9 or more cullei per jugerum.

The capacity of the terra-cotta dolia embedded in the floor of the wine shed may be significant. Since each dolium has a capacity of approximately 2 cullei, the ten dolia in this wine shed then had a capacity of 20 cullei (almost 10,390 liters), which may well approximate the annual yield of the vineyard.

Although any estimate of yield can be little more than informed speculation, it is interesting to compare this estimate based on dolia capacity with an independent estimate made by John McGrew, a Department of Agriculture viticulture expert. His estimate is based on the temperature zone (*33*) and the soil conditions at Pompeii. If the unexcavated part of the insula was also planted in vines, as seems probable, there would have been approximately 4000 vines. It seems reasonable that each vine, if pruned to have eight buds per vine as Columella recommends, would produce about 16 clusters, weighing about 0.25 kilogram each. Therefore, 4000 vines would produce 16 metric tons of grapes. Figuring 600 liters of wine per metric ton of grapes, 4000 vines would produce 9600 liters of wine. The two estimates are remarkably close.

The Triclinia

The two triclinia in the vineyard were excavated in 1968. The many triclinia found in the gardens of homes, inns, and restaurants at Pompeii testify to the popularity of eating al fresco. Although the ancient Romans preferred to recline at meals, slaves and the poor probably sat on stools at a table. The Roman poet Martial speaks disparagingly of "eating places with stools" and taunts the boor who does not recline to eat (*34*). Wall paintings found at Pompeii show the triclinia made comfortable with mattresses and pillows. Outdoor triclinia were usually shaded by vine-covered pergolas, perhaps sometimes by an awning.

The triclinia in this vineyard are important because each had features found in no other triclinium, but, as is the case in most Pompeian triclinia, the two parallel couches (*lectus summus* and *lectus imus*) were of equal length. The triclinium just inside the entrance across from the amphitheater had been uncovered during the excavations in 1814, shown on a map published in 1819, never described, and at some time covered again. Its dimensions are lectus medius, 4.27 meters; lectus summus, 4.15 m; lectus imus, 4.15 m. The table is 0.64 by 1.33 m. What makes this triclinium unique is the way in which it was planned to harmonize with, and be a part of, the architectural design of the entrance. An extension of the lectus imus has the same width (0.50 m) and length (0.92 m) as the entrance pier directly opposite it. In line with the other entrance pier is a low masonry pedestal that has the same dimensions as the extension of the lectus imus. The evidence found provides no basis for the statement of the original excavators that the entrance led to a little vestibule with three arches and that the right arch gave access to the triclinium. The extension of the lectus imus, which is about the same height as the couch, seems quite clearly to be a serving table, as does a similar extension adjacent to the other triclinium. The low pedestal opposite, added to give architectural balance, probably had some other function, perhaps to hold a statue or a lamp such as have been found in other Pompeian gardens. Visitors attending the games at the amphitheater were no doubt served at this triclinium and perhaps also at the other triclinium.

The triclinium adjacent to the building in which the wine was made had been partially excavated in 1954 and 1955 and was covered again without any information about it having been published. Its dimensions are lectus medius, 4.70 m; lectus summus, 4.10 m; and lectus imus, 4.10 m. The table is 0.86 by 1.50 m. A small serving table (0.75 by 1.10 m) is inserted 0.10 m into the lectus summus. What makes this triclinium unusual is the row of five amphoras embedded along the outside edge of the lectus summus, close to the wall of the building. When the lapilli were emptied from the amphoras, I found that the amphoras were broken off below the neck and that the bottom parts were missing. I concluded that

the amphoras had been placed there to hold posts that supported the pergola which shaded the triclinium. I discarded the possibility that vines might have been planted in the amphoras, for there were no root cavities in the soil below, nor were the mouths of the amphoras in line with the rows of vines in the vineyard. Those planted close to the edge of the triclinium would have been more than ample to shade the triclinium. The location of the triclinium against a wall on two sides left no space for columns such as are found in some outdoor triclinia at Pompeii. A large cavity (15 by 16 cm) near the wall at the east end of the serving table appeared to be a post hole and also a part of the pergola.

Bones

Numerous bones were found in the course of our excavations (Table 1). It was probably the presence of bones in the limited area that they uncovered that led the first excavators to identify this insula as the cattle market. Since our excavations have shown that this identification is not valid, the presence of bones must be explained in some other way. This is made considerably more difficult by the fact that the bones were not found in their original location, but were mixed in the backfill with which the former excavators covered a good part of the insula. Nor is there any way of knowing how many bones were removed when most of the fill was trucked away.

Several explanations present themselves. It is quite possible that animals fleeing through the streets at the time of the eruption might have come into the vineyard. Animals were more common in the ancient city than is often realized today. The skeletons of two cows were found in a stall in the House of the Faun, one of the most elegant houses in Pompeii (*35*). Skeletons of horses have also been found. The presence of wild boar bones, including a mandible with teeth, and the proximity of this vineyard to the amphitheater suggest that the boar might have come from there. Wild boars were popular in the animal hunts held in the amphitheater. They are mentioned on the tombstone of A. Clodius Flaccus, whose epitaph records the spectacles that he put on at Pompeii during his magistracies. They are also included in the animal hunt pictured on the tombstone of A. Umbricius Flaccus (*36*).

But a close examination of the bones suggests another explanation. Eleven have definite cleaver marks and give evidence of having been split for marrow (Fig. 8). Of these 11, six are *Bos taurus*, two *Equus caballus*, one *Bos taurus* or *Equus caballus*, and two indeterminable. Three others have marks that were probably made by tools. Two of these are *Bos taurus*, one is *Sus scrofa*. Marrow was regarded as a delicacy in antiquity, as it still is in some parts of the world today. It appears that these bones are the remains of meals served at one or both of the triclinia in the vineyard. If so, this may incidentally give us some insights into Roman eating habits. Cow and sheep bones are to be expected, also those of the wild boar, which was considered a delicacy among the Romans. The discovery of a mandible with teeth is not surprising, for it was common practice to serve the boar whole (*37*). Human consumption of horse meat is not mentioned in the ancient sources (*38*), but it is eaten in Italy today, where it is commonly believed to be especially nutritious for children and the aged. Meals served in the vineyard may have been not only an important source of income for the vintner, but also the means of retailing much of the wine that he produced. The discovery that meat was served may indicate that it was a more important part of the Roman diet than is sometimes thought. The fact that guests were served at a triclinium would indicate that this was a higher class restaurant than some of those found in the vicinity of the amphitheater.

The discovery of bones, and the identification of them as debris from vineyard meals (and perhaps also as bones of animals that had fled into the vineyard during the eruption) finally explains why this insula was mistaken by the first excavators for the cattle market.

Wineshop

Wine produced in this vineyard was probably also sold in a shop that belonged to the owner and fronted on the Via dell'Abbondanza. During the summer of 1972, we excavated the front of this shop (Fig. 3m) and found that it had a single masonry counter (150 cm long, 60 cm wide, and 85 cm high) with three step-shelves (approximately 15 cm wide and 10 cm high) for glasses and cups. The four columns that stood at the edge of the walk in front of the shop undoubtedly supported a roof to protect passersby who stopped to buy wine.

Conclusion

The discovery of this large vineyard, the first such ever found, provides a detailed picture of Roman viticulture. Especially significant is the confirmation of practices recommended in the Roman agricultural manuals. Destroyed before the grapes were ready for harvest on a late August day almost 1900 years ago, this vineyard, with its facilities for making wine and its two triclinia, gives the first detailed picture of the production and sale of one of the most important staples of Roman life. Moreover, the discovery that a large and valuable piece of land within the city walls was planted in vines is of considerable importance in the study of ancient land use and city planning (*39*).

References and Notes

1. Funds for the excavations were provided by the General Research Board of the University of Maryland. For excavation reports, see W. F. Jashemski (*2–4*). This vineyard is one of the gardens and cultivated areas discussed by W. F. Jashemski, in a book in preparation, written in part during the tenure of a senior fellowship (1968 to 1969) and a research grant (1972 to 1973), both awarded by the National Endowment for the Humanities.
2. W. F. Jashemski, *Amer. J. Archaeol.* **72**, 69 (1968), plates 33–34.
3. ———, *ibid.* **74**, 63 (1970), plates 17–18.
4. ———, *ibid.* **77**, 27 (1973), plates 3–4.
5. When Giuseppe Fiorelli became director of the excavations at Pompeii in 1860, he divided the city into nine regions; each region was subdivided into numbered *insulae*, or blocks, and each entrance in each insula was numbered.
6. A. Maiuri, *Pompei* (Istituto Geografico de Agostini, Novara, 1928), p. 43.
7. G. Fiorelli, Ed., *Pompeianarum antiquitatum historia* (Naples, 1860), vol. 1, part 3, p. 150 (entry for 8 May 1814).
8. C. Giordano, unpublished manuscript.
9. See W. F. Jashemski (*2*) for a detailed report of the 1966 season.
10. Some information can be obtained from scattered archeological evidence such as details in wall paintings and mosaics, wine-making facilities in villas in the Pompeii area, and numerous vineyard tools. For the latter, see K. D. White, *Agricultural Implements of the Roman World* (Cambridge Univ. Press, Cambridge, England, 1967).
11. The manual written in calendar form by Palladius during the 4th century A.D. lies outside the limits of this study.
12. Columella, *De re rustica*, book 3, chap. 13, sect. 3. The specific references to the agricultural manuals and other ancient sources referred to in this article are cited in the excavation reports (*2–4*).
13. Pliny, *Naturalis historia*, book 17, sect. 171.
14. See W. F. Jashemski (*3*) for a detailed report of the 1968 season.
15. See W. F. Jashemski (*4*) for a detailed report of the 1970 season.
16. Pliny, *Naturalis historia*, book 16, sect. 212; *ibid.* book 17, sect. 147.
17. Columella, *De re rustica*, book 4, chap. 30, sect. 2.
18. Several willows were known to the ancient Romans, including the white willow (*Salix alba* L.) and the purple, or red, willow or osier (*Salix purpurea* L.). The specimens that I collected at Pompeii are *Salix alba* L.

(field Nos. 88 and 104). They are part of the collection of Pompeian flora that I have deposited in the U.S. National Arboretum herbarium.

19. The Romans knew both the white poplar (*Populus alba* L.) and the black poplar (*Populus nigra* L.). I collected *Populus nigra* L. (field No. 87).
20. The individual coins are identified elsewhere (*3*, p. 69).
21. Trees were also found in the informally planted vineyard in the garden restaurant of Euxinus (region I, insula 11, entrance 10), which I excavated in 1964 [W. F. Jashemski, *Archaeology* **20**, 36 (1967)].
22. See L. Wittmack, *Beibl. Bot. Jahrb. No. 73* (1903), p. 38 for a study of the carbonized fruits and nuts that had been found in the excavations up to that time.
23. A study of all the plants known from the wall paintings, sculpture, mosaics, carbonized remains, and graffiti in the area destroyed by Vesuvius will be included in an appendix of a book on the gardens of the Pompeii area (W. F. Jashemski, in preparation; F. G. Meyer is collaborating on the appendix).
24. Pliny, *Naturalis historia*, book 17, sects. 164–166, 199–200.
25. See the report of the 1970 season (*4*) for a description and criticism of previous explanations of the vitis compluviata.
26. Varro, *De re rustica*, book 1, chap. 8, sect. 2.
27. Columella, *De re rustica*, book 4, chap. 17, sects. 3–6.
28. *Notizie degli scavi* (1923), p. 273.
29. *Corpus inscriptionum Latinarum*, vol. 4, inscriptions 6886–6887.
30. Pliny, *Naturalis historia*, book 18, sect. 110.
31. For a discussion of the "dry farming" techniques practiced in the Mediterranean area, see C. E. Stevens, in *The Cambridge Economic History of Europe*, M. M. Postan, Ed. (Cambridge Univ. Press, Cambridge, England, ed. 2, 1969), vol. 1, pp. 96–104.
32. For a description of this press, see A. Maiuri, *La Villa dei Misteri* (Istituto Poligrafico dello Stato, Rome, ed. 3, 1960), pp. 41–44.
33. For the marked effect of temperature on wine production, when expressed as heat summation ("sum of the mean daily temperature above 50° F" from April through October), see A. J. Winkler, *General Viticulture* (Univ. of California Press, Berkeley and Los Angeles, 1962), p. 58: "The base line is set at 50° [Fahrenheit] because there is almost no shoot growth below this temperature." The summation is expressed as degree-days. Naples has "4010 degree-days above 50° F" (p. 61, table 3), which would place it in climatic region 5 of Amerine's and Winkler's classification scheme of five climatic regions for wine production. Region 5 includes locations that have 4001 or more degree-days. Pompeii would be in the same region as Naples.
34. Martial, *Epigrams*, book 5, sect. 70, l. 3.
35. *Notizie degli scavi* (1900), p. 31.
36. *Corpus inscriptionem Latinarum*, vol. 10, inscription 1074; F. Mazois, *Les ruines de Pompéi* (Firmin-Didot, Paris, 1812), vol. 1; pp. 47, 51; pl. 30, fig. 1; pl. 31, fig. 3; pl. 32, fig. 3.
37. Pliny, *Naturalis historia*, book 8, sect. 210; Juvenal, *Satires*, book 1, ll. 140–141.
38. Pliny (*Naturalis historia*, book 28, sect. 265) gives horse flesh thoroughly boiled and taken in drink as a specific for the diseases of pigs.
39. The discovery that this large insula was planted makes me believe that other large open areas in the city may also have been planted and not used for commercial or other purposes. Several important areas were excavated in 1972, and in each I was able to recover the planting pattern and determine land use.
40. The excavations were conducted with the permission and generous cooperation of Professor Alfonso de Franciscis, superintendent of antiquities in Campania. Nicola Sicignano was foreman. I am also grateful to John R. McGrew, research plant pathologist, U.S. Department of Agriculture, Plant Science Research Division, Beltsville, Md., for invaluable counsel regarding the technical aspects of viticulture; to Frederick G. Meyer, research botanist in charge of the U.S. National Arboretum, for his generous help in identifying carbonized specimens and comparing them with contemporary specimens; and to Henry Setzer, mammalogist in charge of the African section at the Smithsonian Institution, through whose kindness the bones found in our excavations were examined and identified. All photographs, drawings, and statistical studies were made by Stanley A. Jashemski.

Antibody Structure and Molecular Immunology

Gerald M. Edelman

Some sciences are exciting because of their generality and some because of their predictive power. Immunology is particularly exciting, however, because it provokes unusual ideas, some of which are not easily come upon through other fields of study. Indeed, many immunologists believe that for this reason, immunology will have a great impact on other branches of biology and medicine. On an occasion such as this in which a very great honor is being bestowed, I feel all the more privileged to be able to talk about some of the fundamental ideas in immunology and particularly about their relationship to the structure of antibodies.

Work on the structure of antibodies has allied immunology to molecular biology in much the same way as previous work on hapten antigens allied immunology to chemistry. This structural work can be considered the first of the projects of molecular immunology, the task of which is to interpret the properties of the immune system in terms of molecular structures. In this lecture, I should like to discuss some of the implications of the structural analysis of antibodies. Rather than review the subject, which has been amply done (*1–3*), I shall emphasize several ideas that have emerged from the structural approach. Within the context of these ideas, I shall then consider the related but less well explored subject of antibodies on the surfaces of lymphoid cells, and describe some recently developed experimental efforts of my colleagues and myself to understand the molecular mechanisms by which the binding of antigens induces clonal proliferation of these cells.

Antibodies occupy a central place in the science of immunology for an obvious reason: they are the protein molecules responsible for the recognition of foreign molecules or antigens. It is, therefore, perhaps not a very penetrating insight to suppose that a study of their structure would be valuable to an understanding of immunity. But what has emerged from that study has resulted in both surprises and conceptual reformulations.

These reformulations provided a molecular basis for the selective theories of immunity first expounded by Niels Jerne (*4*) and MacFarlane Burnet (*5*) and therefore helped to bring about a virtual revolution of immunological thought. The fundamental idea of these theories is now the central dogma of modern immunology: molecular recognition of antigens occurs by selection among clones of cells already committed to producing the appropriate antibodies, each of different specificity (Fig. 1).

The results of many studies by cellular immunologists (*1*) strongly suggest that each cell makes antibodies of only one kind, that stimulation of cell division and antibody synthesis occurs after interaction of an antigen with receptor antibodies at the cell surface, and that the specificity of these antibodies is the same as that of the antibodies produced by daughter cells.

 The author is professor of biochemistry at Rockefeller University, New York 10021. This article is the lecture he delivered in Stockholm, Sweden, on 11 December 1972 when he received the Nobel Prize in Physiology or Medicine, a prize he shared with Professor Rodney R. Porter. It is published here with the permission of the Nobel Foundation and will also be included in the complete volume of *Les Prix Nobel en 1972* as well as in the series Nobel Lectures (in English) published by the Elsevier Publishing Company, Amsterdam and New York. Professor Porter's lecture appeared in the 18 May 1973 issue, page 713.