4 Saving the vine from *Phylloxera*: a never-ending battle

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Introduction

During 1866, a 5 hectare (*c.* 13 acre) patch of lower Rhône grapevines sickened and died from unknown causes. Over the next year the patch extended considerably, with the area of sick and dying vines moving out in all directions from the original center of infection. By July 1868 the situation had become so grave that growers in the region appealed for help to Montpellier's highly respected Société Centrale d'Agriculture de l'Hérault (SCAH). SCAH appointed a three-member commission to inspect stricken vineyards on the west bank of the Rhône. Members of the commission were Georges Bazille, President of the SCAH, Jules-Émile Planchon, a physician and professor of pharmacy and botany at Montpellier, and Felix Sahut, a well-regarded winegrower. The commission began its work on 15 July, spent three days at the task, and immediately reported their results in all available media. At first the commission had focused upon examination of the dead vines; nothing exceptional was found. But when, by happy accident, an apparently healthy vine was uprooted and inspected, something extremely exceptional was found. As Planchon relates:

> Loupes were trained with care upon the roots of uprooted vines: but there was no rot, no trace of cryptogams; but suddenly under the magnifying lens of the instrument appeared an insect, a plant louse of yellowish color, tight on the wood, sucking the sap. One looked more attentively; it is not one, it is not ten, but hundreds, thousands of the lice that one perceived, all in various stages of development. They are everywhere . . .
>
> (Cazalis 1869a, p. 237)

In this fashion was discovered that worst of all scourges of the vine: *Phylloxera*. From this small patch of an unimportant Rhône vineyard came the destroyer of the world's traditional winegrowing: within several years Phylloxera had spread to all the major European winegrowing areas. Within a decade it had begun devastating California. Winegrowers in Australia, South America, Algeria and South Aftrica prepared their defences in anticipation of the bug's arrival on their shores. In the end, the entire winegrowing world was not only affected but transformed – agriculturally, economically and socially – by the plague. Effects of the disaster rippled out from the vineyards into their embedding cultures at large, invoking such large-scale consequences as rural depopulation and massive emigration. Even recent troubles in places like Algeria and the former Yugoslavia have their roots in the *Phylloxera* disaster.

What is worse is that the disaster is not really over. The vicious and terribly expensive *Phylloxera* outbreak in California during the 1980s and 1990s revealed again the truth of the French conclusion that *Phylloxera* will never go away, it is a fact of life that must be lived with.

Battling the *Phylloxera* to a standstill took 30 years of all-out warfare, from 1870–1900. French scientists, joined at crucial junctures by their American colleagues, tried anything and everything they knew, gradually coming to an understanding of their enemy, finally learning enough to take back their devastated vineyards. Understanding how the battle was fought reveals much about the way in which science and scientists interact with each other, with nature, and with their cultural environments. And, perhaps just as importantly, understanding how the battle was fought will serve permanently to alert us to the dangers of complacency in the face of this devastator of vines.

Identifying the cause

It took nearly seven years after the initial discovery of the bug for scientific consensus to be reached about the actual cause of the vine sickness. Although Planchon and his two colleagues were immediately convinced that the sickness was caused by the bug (Cazalis 1869a, p. 238), they initially formed a small, little-regarded minority. Arrayed against them was most of the French scientific and professional establishment, which waged a loud and widespread campaign to discredit the views of the Montpellierians. A number of factors, sociopolitical as well as scientific, weighed against Planchon and his colleagues. In the first place, even though Montpellier housed an ancient and highly regarded university, plus one of the three national medical schools, as well as the École de Gaillard, France's major agricultural school, it was far from Paris, it was southern, and, most importantly, it was of an ethnically, culturally and politically different tradition from that of the capital. Second, Montpellier was capital of the Midi wine-growing region or *vignoble*,[1] known for its only ordinary (and lower) quality bulk wines. Midi wines were generally disrespected; transferrence of this attitude to Midi wine scientists and producers could only be expected. Third, although the three men had hypothesized an entomological aetiology for the new malady, none of them were entomologists. For whatever reason, the national entomological establishment immediately took the offensive against the Montpellierian theory that the insects themselves caused the disease. As always, the ever-outspoken large estate owner Duchesse Fitz-James gets it exactly right: Planchon, Bazille and Sahut are mockingly derided as 'the Hérault entomologists' because: 'not one of them is an entomologist by profession, and the number of ignoramuses who think they know more defies arithmetic' (Fitz-James 1881, p. 689). Chief among the professional entomological opponents was Signoret, president of the Entomological Society of France, who published a strongly polemical monograph against Planchon and his theory about 'the alleged cause of the current malady of the vine' (Signoret 1870). Although professional jealousy is clearly involved in this attack upon the Hérault (non)entomologists, it also must be noted that the professional insect scientists had never before seen an insect do such severe damage; hence, the *Phylloxera* as cause was beyond their experience.

But the major reason behind the opposition to the theory of Planchon *et al*. was deeper, more pervasive, and fundamentally scientific: their hypothesis that the insect was the cause of the malady contradicted the disease paradigm then prevailing in French medicine and plant pathology. From shortly after the French Revolution, French medicine had increasingly renounced the *ontological* model of disease in favor of the *physiological* model. Finally, in 1827, the French Academy of Medicine officially adopted the physiological approach to disease (Ackerknecht 1948, p. 573). According to the physiological approach, disease is due to some sort of disequilibrium in the animal or plant body's internal function, due, perhaps, to predisposition, diathesis or degeneration. Galenic medical practice exemplifies this tradition. Opposed to this model is the ontological approach, which looks for the cause of disease in some external agent, such as a contagion or a germ. As Cohen notes: 'the two notions varying a little in content and occasionally overlapping have persisted' since antiquity; 'the dominance of the one or the other at different epochs reflecting either the philosophy of the time or the influence and teaching of outstanding personalities' (Cohen 1961, p. 160). During the epoch in question, French medicine, and thereby plant pathology – most of whose pratitioners were physicians (Whetzel 1918, p. 33) – was dominated by physiological thinking.

According to these plant pathologists, attacks by parasites, including funguses and insects, occurred only *after* the physiological imbalances had rendered the diseased plant defenceless against them (Whetzel 1918, p. 28; Ainsworth 1981, p. 34). In the case of the *Phylloxera*, the original cause of the malady was attributed variously to meteorological conditions (Cazalis 1869a, p. 234), the state of the soil and or the vines (Barral 1868), the processes or structures of the plant itself (Falières 1874, p. 16) or, finally, 'general circumstances' (Cazalis 1869b, p. 29). Included in the plant science establishment espousing this disease paradigm were Guérin-Méneville, an entomologist and academician who had solved the silkworm pebrine problem; Naudin, a botanist, academician, director at Paris's Jardin-des-Plantes, the national botanical gardens; Trimoulet, a leading entomologist in Bordeaux; and, of course, Signoret. They were a formidible opposition.

Planchon most often characterized the opposition's view as *Phylloxera*-effect, since they believed that the insects' arrival was only an effect following the plant's original illness. His own view was, naturally, called *Phylloxera*-cause, since the *Phylloxera* itself was taken to be the 'original and unique cause' of the vine malady (Planchon 1874, p. 554).

Battle between the two viewpoints was fierce. Very early in the fray a rivalry grew up between Montpellier and the high-quality wine region of Bordeaux, where a separate and distinct disease focus was discovered shortly after that in the Rhône. Confrontation between the two regions began in summer 1869, when the Viticulture Section of the Société de Agriculteurs de France set up a national commission to survey the extent of the damage and report on its findings. A large committee of scientists and viticulturalists, most taken from the membership of the SCAH, was formed and sent on its way throughout the Midi, and, at sudden notice and unbenownst to local officials, the Gironde region, most especially Bordeaux. The commission's subsequent report, which unanimously took a strong and explicit *Phylloxera*-cause position, was published in the autumn and given wide circulation (Vialla 1869). Shortly after its publication, a series of increasingly polemical written attacks against the views of Planchon *et al*. were launched by the Linnean Society of Bordeaux; the series ended six years later with Trimoulet's vituperative Fifth Report (Société Linnéenne de Bordeaux 1869a, 1869b; Trimoulet 1875). The battle was well and truly joined.

Some progress is made

The years 1869–71 marked both the worst conflict in the controversy over the cause of the malady, and some first inklings of how progress in fighting the insect might begin. Unfortunately, these years also marked *Phylloxera* salients into departements to both the north and the east of the Midi, and north-east out of Bordeaux. Worried officials in the newly threatened regions commissioned investigations into the disease's progress, typically instructing the investigators to examine both sides of the aetiological controversy (Barral 1869a).

At the École, Planchon found a strong ally in Camille Saintpierre, who had entered the Montpellier faculty in 1860 after completing a medical dissertation called *On Fermentation and Putrefaction* (Saintpierre 1860). The dissertation was not only strictly Pasteurian, it was in fact dedicated to Pasteur 'as a modest tribute in recognition to the savant whose work and ingenious discoveries have offered a signposted path to our researches' (Saintpierre 1860). Ten years later, in 1870, Saintpierre was to ascend to the directorship of the École, there to carry out his earlier promise regarding Pasteur: 'This École will totally follow the path he has so surely traced'. It is clear that Saintpierre's Pasteurian thinking, and resolve to realign Montpellier along the lines of the ontological disease paradigm is the major philosophical-cum-theoretical reason why Planchon *et al*. were so immediately ready to hypothesize that the insect was the cause of the malady.

In a more practical vein, Planchon succeeded in finding answers to several specific questions that he had posed, in particular: ‘Where did it come from? Had it been described? What were its closest relatives?’ (Planchon 1874), p. 547). His investigations soon revealed that the bug was a close relative of the *Phylloxera quercus*, which lived on oaks. It had indeed been described, both in the USA (described by New York state entomologist Asa Fitch in 1854 as the so-called *Pemphigus* aphid) and most recently in England. The question of its origin, however, was difficult to work out. In this Planchon had some help from the USA.

British-born C. V. Riley became the state entomologist of Missouri in 1868. His seven successive *Annual Reports on the Noxious, Beneficial and Other Insects of the State of Missouri* became almost instantly famous for their unique blend of humor, quotes from classical literature, technical advice and, above all, enormous practical wisdom. Each of the seven sold out immediately it was published. Riley got involved in the French crisis in mid-1870. As soon as he saw Planchon’s published description of the French vine devastator, Riley wrote both to him and to Signoret, announcing his suspicions that Planchon’s *Phylloxera* and Fitch’s *Pemphigus* were the same beast. Unfortunately, Riley’s hypothesis failed in one important regard: the US bug lived solely in galls on the leaves of the various American vine species, while the French bug had been observed only on the roots of the European species. Tipped off by Riley, Planchon looked for the bug on the leaves of American vines in Europe and found them (Planchon 1874, p. 548). Several days later, Leo Laliman, Bordeaux’s brilliant but irascible vine collector and grower, replicated Planchon’s observation. Planchon, with assistance from his brother-in-law Jules Lichtenstein, soon demonstrated *in vitro* that leaf-gall bugs would rapidly infest clean European vine roots (Lichtenstein and Planchon 1870). It was clear that the investigators were seeing two phases of the same insect’s life-cycle. The origin of the bug was now clear: it had come from the USA. How and why it got to France was not difficult to discover.

During the 1850s there had been a viticultural crisis caused by powdery mildew, an import from the USA. It was widely noted during the crisis that the US vine specimens on exhibition in botanical gardens and private collections were immune to the mildew’s depredations. A small but significant number of French vineyardists decided to investigate the wide-range of American species to see if any of them were both disease-resistant and of interest for winemaking. Hundreds of US vines were imported, transported on the new, fast steamships. So fast, in fact, that the *Phylloxera* on the US vines didn’t die during the trip, and lived to flourish in their new country. Two of the largest collections of US vine varieties were near the sites of the original *Phylloxera* outbreaks in Bordeaux and the Rhône. Once Planchon’s experiment solidified the connection between the US bug and the French bug, evidently settling the question of the pest’s origin, anger against the US vines and those who had imported them grew markedly. This attitude would harm the practical campaign against the disease for years, as is noted below.

Planchon's work had another important result as well. Within the next few months, as word of his experiment circulated around France, converts were made for the phylloxera-cause side. Of course, not all were convinced – it was during this period that Trimoulet's first attack was published in Bordeaux, followed at the end of the year by Signoret's notorious polemic. But in the USA, Riley was convinced that Planchon and Lichtenstein had it right. In his *Third Annual Report* he attacked Signoret, and came out solidly in favor of the identity of the US and French insect (Riley 1871). Late the next year, in one of the first of several instances of direct international cooperation in the war against *Phylloxera*, Riley himself visited Planchon in Montpellier, observed the bug, and took specimens back to the USA with him (Legros and Argeles 1994, p. 214). In his next report, Riley concluded: 'That the two are identical there can no longer be any shadow of a doubt' (Riley 1872a, p. 2).

Identification of the origin of the bug led some workers to suspect that, if the devastation came from the USA, then salvation would ultimately come from there as well. As many have noted, beginning with Planchon, this is the great paradox of the phylloxera, that the source of the problem might also be the solution to the problem (Pouget 1990, p. 51). Somehow, through grafting or growing them as wine grapes, or special breeding, US vines held the secret to solving the phylloxera problem.

Riley's Darwinian views supported the paradox. According to Riley's understanding of Darwinian theory, prey and predators evolve together, each becoming 'adjusted' to the other over long eons of adaptation (Riley 1872b, p. 623). Accordingly, in the case of the US vine + phylloxera combination, the vine would have evolved defences to sustain it under attack from the insect. European vine species, which had evolved without exposure to *Phylloxera*, had no such defences and consequently perished. Europeans, including Planchon and Laliman, although they were not staunch Darwinians, took Riley's word for it (Planchon 1877; Laliman 1872). For his part, Laliman had earlier observed that the US vines in his collection did not suffer from the insects' attacks and had suggested that perhaps US vines could be used to produce wine directly (Barral 1869b, pp. 666–7). His suggestion had been taken by many, and experimentation began immediately. By the Winter of 1872–3, enough success had been demonstrated that over 400 000 dormant US vine cuttings had been sent to winegrowers around Montpellier by the St Louis firm Bush and Sons and Meissner (Morrow 1972, Chapter 4).

Two other trials also spoke to the efficacy of the *Phylloxera*-cause position. In late spring 1869, Louis Faucon, a commited *anti-Phylloxeriste* – as *phylloxera*-effect proponents were frequently called – with a small vineyard on the east bank of a tributary of the Rhône, had the apparent misfortune of losing his vineyard to a severe flood. It must have seemed like overkill to Faucon: his vineyard was already doomed by a bad case of the malady, and the insects had flocked to the roots. But lo and behold, when the flood receded a month later, the *phylloxera* was gone, drowned by the flood. Faucon's vines immediately perked up, and he harvested a decent crop at the end of the year instead of having a dead vineyard. Needless to say, Faucon dropped his former beliefs and became a thorough-going *Phylloxeriste*, joining Planchon *et al*. (Vialla 1869, p. 358). At the Beaune agricultural congress in November, Faucon distributed information about his observations, and provided some directions about methods for flooding. Within the next year, his method was proven; from that time forward, flooding was accomplished wherever conditions – and finances, since it was an expensive scheme – allowed (Faucon 1870; Borde de Tempest 1873). A small number of estates continue to use the method today.

Water was not the only protective medium. It had been early noticed that sandy soils seemed to protect vines from the disease. Phylloxera-cause explanations of the result hypothesized some lethal effect of the sand upon the insect. Some test vineyards were planted in the sand dunes around the medieval walled city of Aigues-Mortes, near the eastern bank of the Rhône's mouth. Although no right-thinking winegrower would ever before have planted vines in these dunes, these were desparate times. Nicely enough, the vines succeeded. Moreover, although the vines in the nearest soil-based vineyard were completely *Phylloxerated*, the vines in the sand around Aigues-Mortes flourished, remaining clean and clear from the infestation.

The success of these two methods provided practical support for the efficacy of the *Phylloxera*-cause theory, evidence that was sorely missing from the purely theoretical research side of the position. Theoreticians from both camps were still at it, vigorously bombarding each other with journal articles and pamphlets throughout the time from 1869 until late in 1872. But the tide began to turn during early 1873. Most importantly, the government had finally awakened from the torpor induced by the Prussian war of 1871, suddenly noticing the disaster building in the southern vineyards. Two projects were funded by a national *Phylloxera* commission that had been set up under the directorship of the renowned chemist Dumas (Pouget 1990, p. 30). The first was a three-month visit by Planchon during autumn 1873 to the vinegrowing areas of the USA in order to examine all the potential anti-*Phylloxera*-weapon candidates present in US viticulture. Riley, of course, hosted Planchon, and shepherded him through all the most important US winegrowing districts. Many valuable things were learned, especially during an extended stay in and around the Missouri vineyards, St Louis and the Bush nursery. Plants, techniques and cultural data for US vines all returned to France with Planchon (Planchon 1875).

A second project also focused on the US vines. At that time, the systematic taxonomy of the US vines was a great unknown. Nomenclature varied wildly, and no one could ever be sure what vines they were dealing with. In early 1874, Alexis Millardet, professor at the University of Bordeaux and France's greatest botanist, was commissioned to produce order out of the chaos of US vine classification. He began work immediately, systematically and, ultimately, successfully.

Seeing the government funding as a conclusive tilt toward *Phylloxeriste* thinking, Guérin-Méneville, one of Planchon's strongest *Phylloxera*-effect opponents, made a plea for renewed funding of physiological research (de Ceris 1873, p. 674). But it was not to be. Guérin-Méneville died shortly afterwards, leaving the fight to the increasingly contentious Trimoulet. By late 1874 the game was up. Planchon and the other ontologist, *Phylloxera*-cause, *Phylloxeriste* workers had won. Dumas, in a letter to Falières, chides the latter for not being tough enough on the physiologists in his recent book:

> You have been too indulgent to the promoters of the dangerous idea of the *Phylloxera*-effect; this idea has caused the ruin of a great number of vines and reduced to powerlessness the most authoritative among those who wish to devote themselves to this so grave question.
>
> (Falières 1874, p. 1)

Unfortunately, after having committed themselves to *Phylloxera* as the unique cause of the malady, Dumas and the government then resisted accepting the promise of the US vines. Thus began *la défense* – the attempt to defend the old vines and the old ways against the devastating US invader.

La défense

Once the bug had been accepted as the unique cause of the malady, thought immediately turned to stopping it, preferably by stopping it dead in its tracks. Since the goal was to defend France against the foreign invader, this phase of the battle with the insect soon came to be called *la défense*. Especially in official circles in Paris, the explicit goal was to defend and preserve the traditional wine varieties, traditional growing practices and, wherever possible, traditional winegrowing regions. Coupled with the widespread anger against them, this goal ruled out any use of the US vines, whether as graftstocks or as direct producers of wine. Animosity against US vines as the carriers of the disease was not only prevalent in the viticultural regions, it reached all the way to the top. The Academy of Sciences, which had been charged by the government with directing the battle against the insect, 'at first was not at all favorable to use of the American vines; its prejudices were prolonged for a long time afterwards' (Convert 1900, p. 513). Cornu and Dumas, speaking for the Academy of Science's national *Phylloxera* commission, set it out thus:

> The commission considers the *Phylloxera* as the cause of the maladie of the vine. It proposes for a precise goal the conservation of the French vines, their principal types being the product of secular practice, it is important above all to save them.
>
> (Cornu and Dumas 1876, p. 1)

Given their goal to conserve a completely *French* viticulture, and their animosity toward the US vines as disease 'carriers', the commission ruled out from the first any serious official experimentation based on the US vines. With this attitude, they 'incontestably held back' the eventual long-term solution (Pouget 1990, p. 89).

From the start, *la défense* relied on physical and chemical strategies rather than biological ones. Efforts to plant vines in sand and apply submersion techniques accelerated during the early 1870s, reaching a peak use by the turn of the decade. Although both techniques were clearly efficacious, their use was severely limited. Submersion required an enormous infrastruture of dikes, gates, pipes, steam-powered pumps and, most clearly, an abundant supply of water. Although plans were made early on to build a huge canal between the Midi and Bordeaux's Gironde estuary precisely for the purpose of supplying water for immersion, the government dithered for nearly 20 years before even beginning construction. At no time did the area immersed total more than 40 000 hectares (Garrier 1989, p. 73).

Planting in the sand was equally fraught with difficulties. Since sand is biologically inert, all the vine's nutritional requirements had to be supplied by fertilization. Traditional fertilization methods involved pumping rich river-bottom silt on to the field. This technique was immediately discovered to be no longer an option: as soon as the sand was diluted with the silt, the *phylloxera* colonized the planting. Chemical fertilizers were the only possibility, and they were expensive. Another problem came from the sea. Since almost all the useable sandy regions were shorelines along the Mediterranean Sea and Atlantic Ocean, wave action frequently washed out the plantings, uprooting the vines and carrying them off to sea. And coastal wind was a problem, too. 'The strong coastal breezes and especially the mistral are the great enemies; they uplift the sand and uncover the vine roots' (Gachassin-Lafite 1882, p. 139). To prevent this, a mulch of reeds was planted between the rows. Once the reeds were established, the sand was considerably stabilized. Vernette, of Béziers, designed and developed a special machine that disced open four furrows into which small rooted pieces of reed could be dropped as the machine was dragged over the dune (Ordish 1972, p. 95).

But perhaps the greatest problem with planting in sand was that the wines no longer had their traditional character, those qualities that grew out of the local conditions of soil, terrain and climate. Nonetheless, the technique worked, it produced a drinkable beverage, and winegrowers could profit from the enterprise. (Even today, one sees small vineyards along the beach roads near Aigues-Mortes, complete with signs advertising 'Wines from vines grown on their own roots!' as if this compensated for the wine's totally ordinary quality!)

Although the method was successful, total sand plantings topped out at about 20 000 hectares (Garrier 1989, p. 73). Taken together, immersed and sand-planted vines never accounted for more than 4% of the overall French vineyard surface. But then, *la défense*'s main focus never was these physical methods; rather, from the start it put its hope in chemistry and the search for an effective chemical insecticide.

The search for insecticides counted some strong allies. Dumas, Cornu and Mouillefert, the 'most ardent and zealous' among '*les chimistes*', 'figured among the most influential members of the Superior *Phylloxera* Commission' (Pouget 1990). From their position, they were able to do some real harm, especially hindering attempts to experiment with the American vines:

> Persuaded that only insecticidal treatment, to the exclusion of all other procedures, was capable of battling effectively against the *Phylloxera* and making it definitively disappear, they adopted an intransigent attitude and proclaimed obstinately their hostility toward the American vines and their partisans, the 'Americanists'.
>
> (Pouget 1990, p. 41)

Serious trials of insecticides were mandated by the national commission. Montpellier's Professors Durand and Jeannemot first set up a trial field at a nearby vineyard called Mas des Sorres in 1872, and by the Summer of 1873 had established the first fully scientific, replicated and controlled agricultural field experiment ever attempted. In 1874, the national commission set a prize of FFr 300 000 for anyone who could come up with a practical insecticidal remedy; suggestions were invited, vetted and then sent to Montpellier for trial. During the following three years, a huge number of suggestions for methods to try were received by the academy; 696 were forwarded from the academy to the Montpellier professors; out of the proposals forwarded, 317 were actually tried (Commission Départmentale 1877). Given the eccentricity of some of the suggestions deemed sensible enough to forward for trial (goat's urine, shrimp bouillion, garlic peels), one wonders about the suggestions the academy deemed *unworthy* of forwarding on to Montpellier! Planchon was scathing in his denunciation of the whole prize-seeking, public suggestion process: 'The remains of this dossier of stupidities reveals a sad day for the state of mind of the great public in terms of its scientific instruction' (Pouget 1990, p. 31). In the end, nothing worked and the vines all died.

Earlier insecticidal efforts had been made by Baron Paul Thenard, son of the pioneering chemist Baron Louis-Jacques Thenard. After trying a long list of things, Thenard the son settled upon carbon disulphide (CS_2), a volatile chemical solvent just then becoming available in French industry. Thenard and colleagues worked out a mechanical system to inject the chemical around the plant, then proceeded to treat a large parcel. Sure enough, the pests died. Unfortunately, so did the vines (Laliman 1872, p. 20). Thenard retreated to reconsider. His next trial a year later had more favourable results; after treatment, the insects perished, but the vines did not; indeed, they slowly began to recover from the bugs' effects. CS_2 and its salts became the weapon of choice among the chemists.

CS_2 is an oily liquid with a nauseating odor – anyone familiar with a school chemistry laboratory is familiar with CS_2. Because it is heavier than air, it settles into the soil, setting up an asphyxiating layer that soon kills many bugs, especially *Phylloxera*. But it does not kill *all* the bugs, again especially *Phylloxera*. Thus it is only a palliative in the long run; applications must be renewed at least annually, and, in some locations, two applications a year are required. Finally, and this is the saddest part of all, continued use of the insecticide without taking exquisitely careful steps to strengthen the vine after treatment 'has the effect of weakening the vine in a certain measure, and sometimes even opposing its rapid restoration' (Plumeau *et al*. 1882, p. 78).

But Thenard's work was only a beginning. Reliable general success with CS_2 did not happen until after the series of experiments and workshops conducted by the Compagnie des Chemins de Fer de Paris à Lyon & Marseilles, the famous PLM railway. PLM's motive, at least in part, was to make up for revenue lost as a result of decreasing wine shipments, by shipping CS_2 to the winegrowers from the new chemical factories along the lower Rhône. In the spring of 1876, PLM instituted a series of experiments on the uses of CS_2 and its salts. The experiments were headed by Antoine Marion, Professor of Chemistry at Marseille. Marion's work was well-financed and careful. Within two years, not only had Marion and colleagues worked out an effective protocol for application of the gas, they had also instituted a series of workshops in a travelling 'extension' course, worked with PLM in setting up an efficient distribution system, and written a detailled set of instructions for applying CS_2 (Compagnie des Chemins de fer 1878; Marion 1879).

Although successful, the gas had many problems. It required a skilled workforce to apply it; only the best and most fertile soils were open-textured enough for the gas to work, which left out all but the best estates and holdings from its use; it was only a palliative, and required at least one application annually, but usually more; and finally, it was expensive, far too expensive for a smallholder to afford. A grower with 'only a modest production of table wines' could not support the cost of the insecticide because 'when its cost was added to all the other costs of production, the treatment cost more than the price of the wine' (Lachiver 1988, p. 422). Only the rich estate owners could afford to save their vines. But this then set the smaller growers against the rich landowners, 'and the conflict took on the look of a "species of class warfare"' (Bouhey-Allex, quoted in Laurent 1958, p. 347).

Social strife was made worse by the laws of 15 July 1878 and 2 August 1879, which prohibited importation of US vines into still-healthy areas, and mandated defensive use of CS_2 in areas that *Phylloxera* was invading. Resistance to this process, at least initially, occurred nearly everywhere. But it was worst in Burgundy, a region whose vineyards are extremely small and scattered among a vast and wildly diverse number of owners, even by French standards. As Morrow notes: 'In Burgundy the peasants simply hated the features of the act which required chemical treatments if the majority of winegrowers in a commune demanded that they be tried' (Morrow 1972, p. 33). In some places there were riots. In July 1879, at Bouze, demonstrators carried on even in the presence of the Prefect and the gendarmes. It was worse at Chenôve, where 160 growers chased the treatment team out of the area, 'saying that they were scoundrels, more to be feared than the *Phylloxera*' (Laurent 1958, p. 333).

Rather than lose their vines, vignerons took the only action they could: they smuggled US vines – and their attendant *Phylloxera* – into their vineyards to replace the dead or dying French vines. For them, *la défense* was over. Laurent's summary of the situation cannot be bettered:

> Public opinion was profoundly divided about action in face of the plague. The 'sulfureurs', among whom numbered the proprietors of the grand crus, are partisans of forced defense and manifest to excess the most vigorous hostility to the very idea of foreign vines. The 'americanistes', who comprise all the small proprietors of ordinary vines, having abandoned all defenses, or practicing them only half-heartedly in their best regions, desire on the contrary the reconstitution of the vignoble using the American vines.
>
> (Laurent 1958, p. 344)

By the early 1890s, incidental success of '*la reconstitution*' – replanting France with the American vines – had eliminated insecticidal use on all but the finest properties: 'This means of defense, having caused many disappointments in most types of soils, ceased to be applied' (Zacharewicz 1932, p. 279). In the end, everyone agreed that, if French viticulture were to be saved, it wasn't going to be saved by the methods of *la défense*.

La reconstitution

Luckily enough, alternatives to *la défense* were being tried and tested out in the provinces, even as it was being proclaimed official policy in Paris. These alternatives all involved the vines from the USA in one way or another. American vines eventually functioned in three roles: as *direct producers*, giving wine from US plants grown on their own roots; as *graft stock*, US roots supporting French vine tops; and as parents of genetic *hybrids*. Each role had its successes and failures. In the end, decisions about which role to feature in a given region rested upon evaluating a trade-off between aesthetics, economics, and biological viability. What made the decisions so very difficult in each case was the fact that 'success' was a moving target. At first, when nearly every *vigneron* in a region was devastated, success meant simply surviving, making some wine – any wine – a bit for your family to drink, with maybe a little left over to sell. Then, once that goal had been accomplished, and progress had been made in the university laboratories, or at the research station, or in a private concern in the next *arrondissement*, success meant better wine, better production, or even production in pieces of your property that couldn't grow the first wave of vines.

At first, nothing was known about the US vines. This was the period quite rightly called *'l'expérimentation anarchique des vignes américaines'* (Pouget 1990, p. 51). Disasters were commonplace. When Planchon returned from his visit to the USA in 1873, he recommended a number of vine varieties as suitable for direct production, as graftstock, or both. Unfortunately, among his recommendations were several varieties with high percentages of *Labrusca* – an American species from the cool north-eastern woods – with parentage such as '*Concord*' and '*Clinton*'. These vines were rapidly shown to have three crippling faults: they couldn't bear up under the heat of southern France, the 'region of the olive' (Sahut 1888, p. 17); secondly, they were not sufficiently *Phylloxera*-resistant under French conditions; and finally, their wines 'were undrinkable' as Laliman so succinctly put it (Laliman 1872). Unfortunately, well before the first two of these flaws were solidly established, enormous resources had been expended obtaining, planting, and growing the doomed vines. In the two winters of 1872 and 1873, over 700 000 cuttings of these *Labrusca*-based vines were imported from St Louis. Many *vignerons*, devasted once by the *Phylloxera*, were now destroyed again, once and for all, by the 'Concord' disaster: 'These two varieties . . . have thus been the cause of ruin for most of those who imprudently adopted them' (Sahut 1888, p. 17). Years of experience revealed that the best American direct producers were those which, like '*Herbemont*' and '*Jacquez*', had a large proportion of the southern American species '*Aestivales*' parentage. Unfortunately, even these vines were fastidious about where they were grown, and their wine never achieved better than ordinary quality. Still, they were a reliable source, such as they were.

But grafting on US roots was no less replete with difficulties. Grafting has three parameters of importance: ease of grafting, which reduces the percentage of take; affinity between American rootstock and French scion; and resistance to *Phylloxera* of the roots. Values on all three of these parameters varied wildly. The first attempts, using *Labrusca*-based varieties, failed due to insufficient resistance; the second, using *Aestivales*-based varieties, failed due to unacceptably low takes. As new pure US wild species were discovered – particularly *Riparia* and then *Rupestris* – each started its own roller-coaster fad. First, orders were sent to Missouri and several other states, for cuttings taken from wild vines of the target species. Once in France, the cuttings would be rooted in place, there to be grafted during their second season. Needless to say, take was highly variable, and resistance varied unexpectably as well. Not all wild *Riparia* vines were the same, and nor were *Rupestris*. A second wave of popularity developed around Millardet's idea of raising rootstock plants from pure US species seeds gathered in the wild (Millardet 1877, p. 31). This idea was soon criticized, and rightly so, for the excessive variability in resistance that was found in the seedlings (de Lafitte 1883, p. 535). In the end, Montpellier solved the problems by selecting from among its enormous collection of pure US species only those individual vines that were easy to graft, compatible with most French varieties, and highly resistant to *Phylloxera*. Best among the dozen or so that were eventually propagated and disseminated were '*Riparia Gloire de Montpellier*' and '*Rupestris du Lot*', both of which still see widespread service worldwide. In the end, the campaign was long and hard, but generally successful.

By the 1890s, the original tide of US vines – the direct producers and rootstocks taken directly from US wild species – had ebbed, and the second wave was starting to flow. This new wave consisted of vines created deliberately by cross-breeding various US and European selections. Two distinct roles were played by the newly created vines. First, second-generation *hybrid* rootstocks, designed for a better match with the typical French soil, so different from America's terrain, were being rapidly disseminated from the École in Montpellier and research stations in Bordeaux, the Charentais and Provence. Among these graftstocks were candidates suitably adapted to almost every terrain in France, and compatible with almost all the traditional wine varieties. But competing with the campaign run by Montpellier to graft traditional French vines on to US roots was an alternative programme emphasizing *hybrid direct producers*, an entirely new class of vines whose genetic foundation combined root and fruit elements from both US and French varieties. According to proponents, genetic cross-breeding would eventually produce a superior vine, with US health and French wine quality; in their view, grafting was seen as 'only a transitory cultural process, destined to disappear in the future' (Ganzin 1888, p. 23). Although this campaign's theoretical base was the University of Bordeaux, in practice many of the most valuable additions to the armentarium of available hybrid direct producer (HDP) varieties were developed by private individuals, most of whom were located in the south-east, particularly around the Ardeche.

Since Montpellier did not think that HDPs were a genuine possibility, they elected to stay with promulgating their grafting programme, contenting themselves with frequent sniping at the Bordeaux hybridizers. Differences between the two universities were based on their respective theories about inheritance. Montpellier, from the time of Planchon, had believed in a 'blending' theory of inheritance; thus, crossing a phylloxera-resistant US vine with a French vine could only weaken the resistance of the resulting offspring (Berget 1896, p. 53; Gouy 1903, p. 189). As Paul notes, 'this was the "*thèse classique*" of Foëx', Saintpierre's successor as director at Montpellier (Paul 1996, p. 70). On the other hand, Bordeaux's Millardet held a 'mosaic' theory of inheritance, a major French 'genetic' hypothesis prior to Mendel. On this view, an offspring individual is a mosaic constituted from discrete elements inherited from its parents. One of the more explicit theories of this sort was developed by Naudin based on hybridizing experiments he carried out during the early 1860s (Marza and Cerchez 1967). Millardet was certainly aware of Naudin's hypothesis. As his own work developed in the late 1870s and early 1880s, Millardet came to the conclusion that whole organ systems – e.g.

roots, foliage, fruit – were the heritable elements, the pieces of the mosaic; a vine type existed as a unity of these organic elements, which, during sexual reproduction, would be mixed and matched to produce newly unified individuals in the offspring-generation. Based on this theory, it was entirely plausible to believe that an offspring might combine root systems from its US parent with fruit systems from its French parent. Millardet's proclamation of the brave new hybrid world rallied generations of workers to his side:

> Thus, the year 1887 will mark a date ever remembered in the history of our devastated vineyards, our agonies and our struggles against the formidible plague which has assailed our viticulture since twenty years ago. By grace of the hybridation of our European varieties with diverse American vines, we are, from today onward, absolutely certain to obtain, in first-generation hybrids, either graft-stocks of an assurred resistance, and of an adaptation much easier than those which we have possessed until now, or direct producers, resistant to *Phylloxera* and to the most dangerous plant parasites, which are capable of producing at the same time wine completely correct in flavor.
>
> (Millardet 1888, p. 28)

Noisy conflict between the two university programmes lasted for at least 20 years. But even then it didn't go away; rather, it just got less noisy, even as it spread far beyond France. Indeed, it is quite fair to say that the principals of the two sides are still vigorously competing more than a century later (Galet 1988; Pouget 1990, p. 56; Paul 1996). The issues that divide the two camps are complex, subtle and have deep roots, roots that are firmly embedded in the ever-opposing camps of tradition and modernity. Today, although all but a small number of hybrid direct producers have been outlawed and driven from France, these vines have taken solid hold worldwide and are the foundation upon which viticulture rests in the USA and Canada, excep for a narrow tract of land extending inward from the Pacific Ocean, stretchig from Vancouver to San Diego.

Victory in France

By 1900 the battle to save the French *vignoble* from *Phylloxera* had reached an uneasy stand-off. French viticultural interests – from the national councils, to the laboratories and research stations, to the smallest *vigneron* – knew how to live with the devastating insect. There was no possibility of victory if that meant returning to what was before: traditional French viticulture was well and truly finished. Moreover, there was no possibility of victory if that meant having vanquished the bug: every few years, someone would try to grow the old varieties on their own roots, but the attempt would fail within a couple of seasons. The bug was always there, lurking, waiting for some lapse in vigilance. What had been achieved could only be called a truce, with a 'demilitarized zone' established around the US roots of the French vine. No one knew how long the truce might last.

The costs of the battle had been enormous. According to one authority, *Phylloxera* had 'cost us nearly as much as the war-indemnity payments we paid to Germany after the war of 1870' (Convert 1900, p. 337). Although costs varied considerably from region to region, a recent analysis put together from a welter of data taken at the time indicates that a reliable average cost per hectare would be around FFr 3000 (Garrier 1989, p. 131). But costs were far more than merely monetary. Fully one-third of the French *vignoble* had disappeared, never to be replanted. Thousands upon thousands of *vignerons* had left their land, many for the cities – Marseilles doubled in population during the period, even though its *département* lost population overall – while even more emigrated, hoping to start viticulture anew in the *Phylloxera*-free lands of Tunisia and Algeria.

But the most difficult loss was a millennium-old tradition and way of life, with its vast library of accumulated experience. *La nouvelle viticulture* demanded a smart, literate, decently educated *vigneron*, one who could read the literature, read the labels on chemical containers, read the signs of the new diseases on the old vines. Everything had to be learned anew.

Fortunately, not all the effects of the 30-year war were bad. The new viticulture was more productive, grape quality was higher, and the new cultural practices, once mastered, were easier, more efficient, and less-labour intensive. To take just one example: in the new viticulture, vines were planted in straight lines at orderly intervals rather than completely helter-skelter as classical tradition would have had it. Such order was demanded by the necessity to move equipment – sprayers, for example – among the vines without damaging either the plants or the machines. Examples such as this abounded. Put most simply, after *Phylloxera*, the French *vignoble* was rationalized.

In the end, nothing was the same. But as Missouri's Professor George Hussmann is widely reputed to have later observed, it would be difficult to decide whether in the long run the *Phylloxera* disaster was for good or for ill.

Other places, other times, other battles

Phylloxera invaded other European countries only slightly later than France, starting sometimes as original infections from imported US vines, sometimes as secondary infections from imported French vine material. Italy and Spain were definitely hit during the early 1870s, as were Portugal, Germany, and Switzerland. Damage was inevitable, but frequently less devastating than in France. Portugal was probably the worst hit, with Italy next. Even Portugal's offshore *vignobles* in Madeira and the Azores were severely struck. Germany, most likely because of its cooler summers, which limited the bug's reproductive excesses, was least damaged. Italy was the most variable, with Sicily's *vignoble* destroyed by the late 1880s, even while Naples and its regions were spared until at least the 1930s (Morrow 1972, Chapter 5).

During the late 1870s, some French firms planted vines in Dalmatia and Slovenia; Croatia was targeted for a huge build-up (Anonymous 1880, p. 112). Over the following decade, the size of the yugoslavian wine industry went up by an order of magnitude, mostly in aid of exports back to France. The whole scheme collapsed between 1902 and 1905 as the *Phylloxera* arrived and conquered. A diaspora of ruined wine workers, their families and others dependent on the industry fled the region, with large numbers emigrating to the USA, Canada and Australia.

Countries in the Balkans and Greece were seriously infected shortly after the beginning of the twentieth century. Around the same time, Australia was mildly infected in Victoria and New South Wales, but strict quarantine and *cordon sanitaire* procedures kept other regions, particularly South Australia's important *vignoble*, clean from then until now.

Chile is the only significant wine-growing country that remains free of the insect.

Phylloxera was found in California in 1874 near the city of Sonoma. It rapidly spread to the other districts in the Sonoma and Napa valleys. Within 25 years the entire state was infested, and nearly 30 000 acres (12 140 hectares) – a sizeable percentage of the then-planted area – were destroyed (Bioletti 1901, p. 4).

All later-infected areas looked to French experience for guidance, although not quite so slavishly as Montpellier's Prosper Gervais claimed (Gervais 1904). Although the Italian authorities imported French hybrid rootstocks, because of some unique indigeneous terrain, success was not complete. Italian viticulturalists, in particular Paulsen in Sicily, had to develop their own special rootstock varieties. Portugal also bred some of their own, importing the parents directly from the USA. Californian viticulturalists tried the French rootstock varieties, and were generally satisfied with the results: every region had one or more useable stocks. In the end, by roughly the 1930s, worldwide viticulture followed only two alternative French-based paradigms: traditional varieties grafted on to US roots; or hybrid direct producers, genetic crosses between resistant US varieties and traditional wine varieties. And thus things settled down, apparently stable and dependable, until the shocking developments in California in the 1980s.

A frightening portent?

In 1980, Napa Valley winegrower John Baritelle found four stunted vines in one of his vineyards. Next season, the number had grown to 16, and Baritelle was beginning to be more than puzzled by the problem, especially since he could not find any definite signs of disease. By the 1982 season, the number of diseased vines had multiplied appreciably, and a worried Baritelle asked for, and received, a visit from vine scientists from the nearby Davis Campus of the University of California. In a scene eerily reminiscent of one originally acted out 115 years earlier in a vineyard near the Rhône, Davis's viticulturalist, Austin Goheen, 'dug up a vine on Baritelle's land and saw at once the telltale yellow colonies of tiny aphid-like insects on the roots. The case was a no-brainer. The vines were succumbing to *Phylloxera*' (Lubow 1993, p. 26). But what could have happened? Since all Californian vines, including Baritelle's, were of necessity grafted on to resistant rootstock, there must have been some mistake at the nursery, leading to a non-resistant rootstock being grafted by mistake, or something like that.

However, when *Phylloxera* started showing up at other vineyards, it became clear that it couldn't be a question of a mistake at the grafting nurseries. Something much more fundamental, much more dangerous, had happened. It took a lot of investigation, a lot of time, to reveal what.

When Californian rootstock trials were initiated at the beginning of the twentieth century, acceptable varieties had eventually been found for each of the diverse terrains of the state (Bioletti 1901). Trials continued uninterruptedly, however, and 'by 1958, the collected data were used to recommend AxR #1 as well adapted to most of California's vineyard soils, climate, water conditions, and scions' (Granett *et al*. 1996, p. 10). AxR #1 is a cross between the traditional variety '*Aramon*', and a wild US *Rupestris* vine, made by Ganzin in the mid-1880s (Ganzin 1888). Although the rootstock enjoyed an initial vogue in France, it was soon discarded because it was 'considered insufficiently resistant to *Phylloxera*' (Galet 1979, p. 200). Yet this rootstock, rejected by the French as insufficiently resistant to phylloxera, was officially recommended by Davis and 'based on this recommendation, was used in 60% to 70% of the Napa and Sonoma county plantings that occurred in the 1960–1980 planting boom' (Granett *et al*. 1996, p. 10).

Just as their French ancestors had a century earlier, Californian growers denied the reality before their eyes, seizing on any possible explanation rather than *Phylloxera* for the growing disaster. Even Davis's scientists appeared to go into denial. After Goheen's discovery in 1982, it took seven long years of argument before Davis's viticulturalists 'like a deadlocked jury, had begun to tilt from the weight of incontrovertable evidence' (Lubow 1993, p. 60). In 1989 the Davis scientists noted that 'it was clear that AxR #1 was not adequately resistant to California *Phylloxera*' (Granett *et al*. 1996, p. 10). The phrasing of this remark suggests a new development in the century-old battle with the beast. It is not that the rootstock is not adequately resistant to *Phylloxera in* California; rather, it is not adequately resistant *to* Californian *Phylloxera*. According to the Davis scientists, the rootstock had not lost its original resistance, but rather the bug populations had evolved in such a way that the rootstock's original resistance was bypassed. In other words, a newly evolved version of the bug – a new *biotype*[2] capable of living on AxR #1 – began emerging as the dominant population of northern California. Thus, the AxR-rooted vines were doomed.

In the end, 50 000 acres (20 234 hectares) in Napa and Sonoma alone need replacing, at an estimated cost of somewhere around US$1 billion (Sullivan 1996, p. 7). Unfortunately this is only the beginning. AxR plantings comprise a vast amount of the total Californian *vignoble*, including vineyards in Lake, Mendocino, San Joaquin, Sacramento, Alameda and Santa Clara counties.

Darwin certainly prepared us for such an outcome. Evolutionary forces never cease, adaptation between prey and predator is a dynamic state, never ever stabilizing into a static relationship. Will the French grafting solution, discovered at the cost of much blood, sweat and tears 100 years ago, always work to keep the *Phylloxera* at bay? An affirmative answer would be foolhardy at present, since we simply don't know how and why the French solution worked. As Granett *et al*. (1996, p. 13) conclude: 'The stability of these rootstocks may not be eternal, and we should be prepared for *Phylloxera* strains that are better adapted and potentially damaging in the future'. Eternal vigilance, as always, is the cost of security.

Notes

1 Two French technical terms will not be translated in this chapter: '*vignoble*', which not only has a geographic connotation, but also, more importantly, conveys the notion of 'place where the same sorts of vines are subjected to the same sort of climate, terrain, viticultural practices and winemaking styles'. One can speak of something as large as 'the French *vignoble*', thereby distinguishing it from the Spanish *vignoble*; or something as small as 'the Chirouble *vignoble*' in order to distinguish it from other Beaujolais villages such as Fleurie. The second term is '*vigneron*', which refers to any small-scale winegrower/maker. Typically, the *vigneron* is a freeholder, but not always. The term is a term of art, connoting a mixture of social class, economic level, and political bent.

2 Technically, a specific biotype is associated with a specific genome. But the Davis scientists explicitly assert that their discovery of a new biotype is based 'on the behavior of *Phylloxera*, not necessarily on genetic differences' (Granett *et al*. 1996, p. 10).

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