Antonio Saltini

AGRARIAN SCIENCES IN THE WEST

translated by Jeremy J. Scott

VOLUME FIVE

Agriculture and the Discovery of Microbes

Nuova Terra Antica

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Translated by Jeremy J. Scott

To Tommaso Maggiore and Francesco Salamini,
two giants of the agronomical sciences in Italy, for their continuing interest
in the progress of this project, their advice and their commitment
to promoting knowledge of the final work.

Nuova Terra Antica

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I
Microbiology arises from the Study of Fermentation and Infections

On the Threshold of an Unexplored Universe

Anyone taking a scientific approach to the production of food cannot fail to note how this depends upon the action of whole families and species of different microorganisms (bacteria, actinobacteria, ascomycota, basidiomycota, protozoa, etc.), whose behaviour can either favour or impede agricultural production. Organic remains decompose in soil and become a source of nitrogen and mineral salts for crops; plants are attacked by a whole range of diseases; the digestive system of herbivores depends upon role protozoa play in various processes of rumination; the existence or productivity of livestock can be threatened by infections; ensiled cheeses undergo transformation; wine must ferments. The entire range of processes that result in plant and animal produce involves - at different phases and in different forms – the microorganisms which can transform living or inanimate organic material; facilitate or compromise the completion of a living creature's biological functions; modify the composition of inert organic substances. And, in each case, their action determines the economic value or otherwise of produce.

Louis Pasteur later in life, when the attack of paralysis had taken its toll; though he had recuperated, the great man no longer had the same remarkable capacity for work and relied on the disciples he himself had trained to carry out the programmes of experimental research his constantly active mind continued to devise. In effect, trained in the methodologies that had first been developed to study the fermentation of wine and beer, then the diseases afflicting silkworms and livestock, Pasteur's pupils would form the first great school of microbiology. Two of them, Roux and Chamberland, were those who worked on Pasteur's last great challenge, the study of rabies, when the severely debilitated scientist undertook an exploration of viruses, the last great unknown in the study of life. The photograph is by the famous French photographer Nadar (Gaspard-Félix Tournachon) .

Agriculture might be defined as that body of procedures whereby humankind governs the development of plants and animals in such a way as to enhance the accumulation within them of the organic compounds that make them useful as food. Thus, from its very beginning, those involved in this activity have had to work with or against the phenomena causing carbohydrates and proteins to accumulate in plants and animals during their life cycle, determining their quality as food or else making them unviable as a

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microbiologists for decades to come.

One issue of particularly important practical application was that which the Frenchman examines in chapter five: the different heat conditions required to sterilize organic infusions prior to their contamination with air-borne samples. As he comments, to neutralise the germs present in a sugar solution or in urine, boiling at 100°C was sufficient, whilst the sterilization of milk required the liquid to be kept at 110°C for several minutes (a necessity which meant one also had to have a receptacle that made it possible to go beyond normal atmospheric pressure). As he stresses, this prolonged treatment to kill off the microbe spores did not, however, affect the essential properties of the product – a observation which is at the basis of UHT sterilization, very different to that involved in heating milk to 80°C (the process to which Pasteur would give his name, and which he had recommended as a means of stabilising the product for transport and short-term conservation).

To confirm the outcome of the experiments described in the early chapters of his *Mémoire*, the Frenchman also carried out a further two series of different tests: one to demonstrate the continuing sterility of infusions placed in open flasks with long twisted necks, and the other to show the contamination of nutrient solutions with air taken at different altitudes. (In both cases, these experiments are further demonstrations of that extraordinary experimental skill which enabled the young scientist to so quickly resolve an issue that had exercised natural scientists for centuries.) Described in chapter VII, the first series of experiments is designed to overcome the resistance of even the most stalwart champion of spontaneous generation, and involved placing a nutrient solution in a glass flask whose neck had been heated and drawn out into a sort of serpentine. The contents in this flask were boiled and the steam left to come out for a minute or so; then, without sealing of the opening, the flask was placed in a oven along with contaminated solutions. In spite of the fact that it was open to the circumambient air – and was in temperature conditions suitable for microbe proliferation – there was no development of microbe colonies within the flask. The experiment was repeated a number of times and always produced the same result; thus it demonstrated that, even when open to the atmosphere, the infusion would not develop microbe growth if – between itself and the open air – the pathway was so contorted that the dust could not reach the liquid. In such cases, the sterile solution remained just as uncontaminated as if it were in a sealed flask. This was an elegant demonstration of the lack of foundation for Gay-Lussac's claim that the presence of oxygen was necessary and sufficient for fermentation to take place.

Again from the Institut Pasteur: two double-necked flasks linked by a rubber tube through which the flow of a gas or liquid was governed by tap. With great imagination and skill, Pasteur devised the equipment necessary for each experiment, coming up with the most remarkable ways of fitting it together. The flasks rested on matweed cushions when in the sterilization tub, to prevent them coming into direct contact with its heated metal base.

From the same vine-farm of Villié Morgon the implements used in working the soil: a two- and a three-toothed hoes and spades with rectangular and trapezoidal blades; there are also four very unusual parts of the collection, which seem to be half-hoe, half mallet. The length of the handles varies from 100 cm for the mallet in the centre to 66 cm for the three-toothed hoes on the right. Disproving the rigid adherence to local traditions, more than one of the pieces of equipment here come from outside the immediate area – a testament to the curiosity of the founder of this family dynasty. The photograph is by Jean Collonge, whose father – also Jean – was the owner of the farm and a leading figure in the viticulture of the Villié area, as well as being one of the most significant writers on viticulture and oenology in late-twentieth-century France.

of why, in a specific wine-cellar and a specific barrel, one or other of these deteriorations should occur. Was the proliferation of one microorganism rather than another merely a matter of chance? Though this question could generate fanciful speculation, a solution to the problem was essential to Pasteur's research programme, and the Frenchman approached the issue with his usual blend of experimental skill and theoretical clarity. With regard to the multiple types of organisms that make up the microbe population within wine must, he writes in Paragraph C:

«What a profusion of all types of germs find their way into a vat during the grape harvest! What a range of different changes one sees in this or that leaf, in this or that grape which, for a thousand reasons, might have split open; which are the seat of different types of fermentation and putrefaction! And how dumbfounding the number of germs carried in the air, which then become attached to the slightly cereous external surface of the grapes!

Unless, by its very composition, wine is such that it permits the development of only a few of these germs, they [their sleeping spores] *will, depending upon specific conditions of temperature or the state of aeration in the liquid, multiply at some given moment or other.*

There are categories of germs that are suffocated forever in the fermenting vat and in the wine drawn from it. On the one hand, these are all the infusoria, bacteria, klopodes [a word at time identifying many species of protozoa] *or nematodes, and on the other, all the spores of airborne moulds. No infusorium will be found in wine because the liquid is acidic and this acidity kills them off. As for mould spores, they cannot germinate because – they and the adult creatures that result from them – require oxygen to survive [...].*

The bill-hook typical of the Beaujolais region, which is one of the closest to the type described by Columella.

So what life forms will proliferate? Those which are specific to ferments, those strange creatures that, without air, can live deep within organic materials, from which they draw oxygen that exists in combination with other elements. It is this which results in their nature as "ferments", according to the general theory of fermentation to which I was led just a few years ago (a theory which I still believe to best reflect the most thorough examination of the facts).»

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This couple of adult silkworms, now conserved at the old Istituto Bacologico in Padua, still show the colours of what was probably one of the most splendid of all Italian breeds of the insect, though the female (*above*) – her belly swollen with eggs – is rather less brilliant. As in so many species – from insects to mammals – the male is the one that is more brightly-colour, the display serving the same role in mating rituals as the tusks of an elephant or the magnificent horns of a deer.

reserve and then only used if microscope examination showed there were no parasite corpuscles in the parent bodies. It is this method of individual verification of the health of eggs that Pasteur would propose in the final pages of the *Études* as one of the means for totally eradicating the disease.

But at the same time as showing farmowners and peasants how they might obtain healthy strains of silkworms by testing the parent insects, Pasteur was also concerned with the complementary problem of how the larvae bred from those healthy eggs might remain so from generation to generation. For if there was no measure to prevent contamination of the healthy lines, all the efforts to select uninfected eggs would simply result in larvae that began their life uninfected but became so as they developed. To tackle this problem, Pasteur once again drew upon the collaboration of Adrien Jeanjean and of the Comice Agricole of Vigan. Various particularly remote silkworm farmers were selected and supplied with eggs whose healthy state had been ascertained through examination of the parent butterflies. Carefully tended by expert members of the Committee, these nurseries produced rich crops of cocoons.

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was to draw up effective methods of combating the infection – and that understanding was what he aimed to achieve through his work in Alais. However, his primary concern here for experimental research and practical application meant that pursuit of that biological knowledge was preceded by attempts to come up with effective means of prophylaxis: by the time Pasteur could offer a detailed description of the parasite's life cycle, he had already drawn upon more rudimentary knowledge to devise effective procedures to eradicate it. This means that, in a rather counter-intuitive fashion, the account of that life cycle within the Études comes after the description of the techniques that might be used to defeat the infection, making the results of his biological research appear to be an appendix rather than a necessary conditions for the latter. However, this is not as contradictory as it seems. As we have seen in the first chapters of the *Études*, the scientist had, from the very beginning, focused upon the parasite's means of growth and reproduction as providing the key to defeating it, thus as his work progressed his account of those mechanisms became ever more complete. What we get at the end of the study – in the third chapter of the first part of the volume – is the fruit of progressively more elaborate experimental data; as the techniques used over the course of the four years improved, Pasteur would, by 1869, have achieved such skill in the microscope examination of the parasite that he could perform experiments which were much more complex than those which came at the beginning of his research. Furthermore, after four years he had a vast collection of drawings and photographs which had accumulated as his studies progressed, making it possible for him to carry out comparative analyses that would have been impossible at the start of his work on pébrine. As already mentioned, these illustrations are another factor that adds to the interest of the publication he produced after his research, the wide range of them in the final volume being the work of Pierre Lackerbauer, the draughtsman who had produced the images that accompany Pasteur's *Étude sur le vin*, who here also takes advantage of the very last developments in photography.

(The photographs of microscope images make the book of great historic interest. Ever since the days of Leeuwenhoek, drawings of the corpuscles seen under the lens had been a traditional feature of works of microbiology, and in the nineteenth century improvements in lens quality had resulted in significantly more precise illustrations, such as we see in the *Étude sur le vin*. However, the use of photographic equipment to capture what was seen under the microscope lens was a complete innovation in the field of scientific research. Hence, the photographs of microscope images that appear in the *Étude sur la maladie des vers de soie* mean that this work is a milestone not only in microbiological research but also in the development of scientific publishing.)

Enrico Verson's microscope, manufactured by Hartnack et Cie of Place Dauphine (Paris). This has two eyepiece lenses and two objective lenses, whose combination provides four different degrees of magnification. Created for a large laboratory, this piece of equipment reflects a period when huge advances were being made in microscope technology. The stand is 26 cm high, the eyepiece tube 18.5 cm long and has an external diameter of 2.5 cm. The two eyepiece (on top) lenses and the two objectives were produced by the Viennese lens manufacturers Reichert.

The plan of experiments that Pasteur pursued in his last months at Alais when studying the live cycle of the parasite was based upon one certain established truth and one hypotheses that he was trying to verify. The fruit of long research into the mechanisms of infection, that established truth was the dispersive nature of the parasite: once it had taken hold in the larva's digestive tract, it then gradually spread to other organs. As for the hypothesis, this posited that in each of the organs in which they became established, the germs of the parasite went through the same sequence of phases. This idea was based on the observation that the parasite could, in fact, take on a number of different forms, and thus it was logically coherent to assume that it went through a fixed order from initial to mature stages. Whilst logically feasible, the notion would however be disproved when advancing studies of protozoa showed these could develop to different stages in their life cycle in different organs, or even in different hosts. (Thus, in order to understand the life cycle of each, it was necessary to chart the sequence of morphological phases in relation to the parasite's transfer from one organ to another, from one host to another.) Nevertheless, given the knowledge available at the time Pasteur was doing his work at Pont Gisquet, his hypothesis was (by analogy with parasites that had already

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Poultry and Fish Farming

If one is willing to plough through the eleven tomes of the *Istituzioni*, one does occasionally come across an interesting description of a piece of farming equipment or farming practice. However, the ratio of reward to effort is such that one can easily imagine the disappointment of those who had subscribed to this magnum opus, and of the publishers who had undertaken to see the project through to the end. Amongst the more significant pieces of information are the author's comments on industrial-scale poultry farming and what he has to say on fish-farming. In the second part of the sixth volume (paragraph 2363 of Book XXVIII), he writes:

«Forced – or, if one wants, mechanical – fattening of poultry is performed using a funnel. The poultry-farmer forces the chicken he is holding in his lap to swallow the neck of the funnel, which is fixed to a box that is closed at one end by a lid and is full of a dense mix of flour and milk used to feed the bird [...] When the box is closed, a plunger-like diaphragm fits tight against all the sides, and when pushed forward by the indented bolt compresses the pulp [...] making it come out of the funnel. This is necessarily forced into the throat of the chicken the poultry farmer is holding firm while, with his foot, he presses on the rod that rotates the gear wheel which causes the abovementioned indented bolt to move forward. With his right hand (the left is holding the chicken's head fixed to the funnel), the farmer can tell when the throat is full enough, at which point he ceases to operate the pedal and thus halts the flow of pulp from the funnel [...]

Using the Martin apparatus, the chickens do not move from the large Coop – or rather rotating shelf – on which they are held in place by a leather thong tied to their feet. On a platform, which he raises or lowers in order to reach the different levels of the large Coop, the operator grasps the head of the chicken before him with his left hand and forces into its beak an elastic rubber tube that is linked to a box similar to the one described above [...]. Then, when the operator presses with his foot on the rod or pedal, he makes the pulp come out and pass through the mouth of the bird into its stomach.

From Book XXVII of the *Istituzioni*: an image of industrial poultry farming in its infancy. Using a pedal pump, the worker forces the pulped feed into the chickens via a tube that has been inserted in its throat. When he can feel that the animal's gizzard is full, he passes the bird to his assistant, who gives him another.

Fig. 343.

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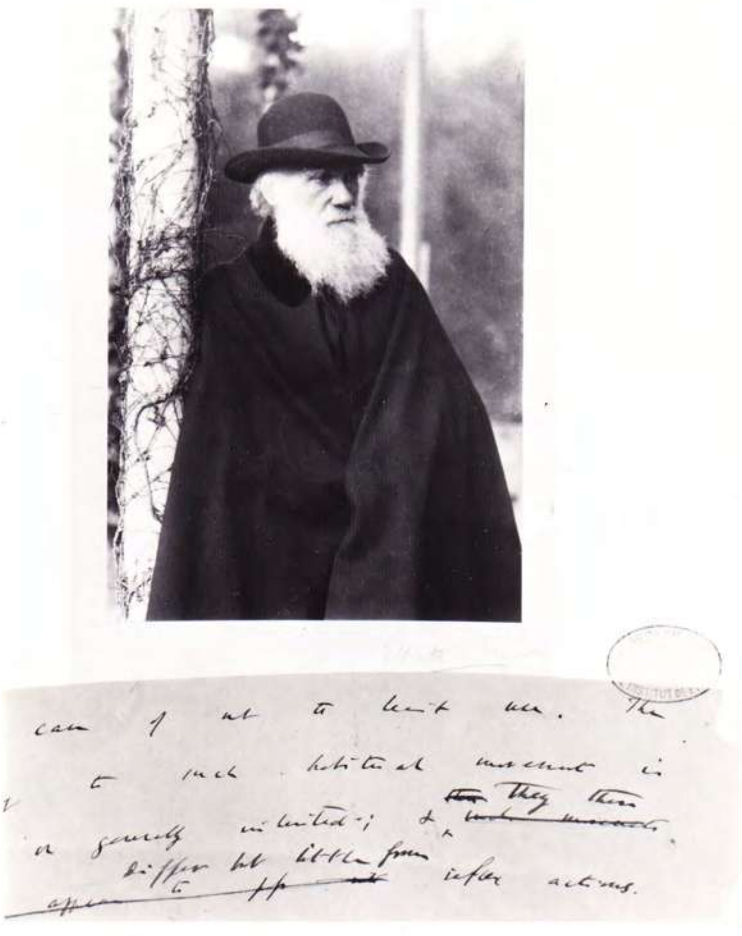
VI
Selective Breeding of Crops and Farm Livestock

The Modifications undergone by Living Creatures



A striking portrait of Darwin from the archives of the Paris Académie des Sciences, of which he was a correspondent member. After a youth spent in travels that subjected his body to the toughest trials and hardships, Darwin would in his later life suffer a number of infirmities, for which he hoped the mild climate of Kent might provide some relief. The daring participant in the adventures of H.M.S. Beagle ultimately became a rather sedentary figure, dividing his time between research and gardening – perhaps making the occasional visit to a pigeon-fanciers' conference in London (but taking all due precautions to avoid catching a cold).

From the very dawn of their discipline, great agronomists have been aware of how the living beings that provide humankind with food, fibres and labour might be modified. As we have seen, Varro and Virgil outlined the ideal types of animal from which farmers should breed their livestock; Columella would then improve upon their descriptions of desired characteristics, suggesting how selection and cross-breeding might be used to improve stocks; Gabriel d'Herrera laid out precepts for the selection of varieties of cereal crops; Luigi Alammani would, in the single expression *"nature gives way[...] to human industry"*, summarise what ancient naturalists had said on nurturing different species of garden vegetables. With the birth of modern science, botanists would make enormous efforts to draw up a "natural" taxonomy of plant varieties – that is, a system whose categories responded to the natural links between different families, genera and species (essential if one was to understand the effects of human intervention upon the characteristics and physiology of crops). And in order to identify the primitive forms of what had become our cereal crops, Polycarpe Poncelet would come up with the ingenious suggestion that one should simply leave those plants

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In striking contrast with the image opposite, this picture tells a very different story of the relation between humankind and livestock. Taken in Burundi by Florita Botts in 1977, the photograph shows a cow whose horns are substantially bigger than those of the wild bovids humankind initially domesticated. Those early animals themselves had large horns, but elsewhere selection had tended to reduce them because they were seen as possibly harmful and of no real economic advantage. The animal in Burundi, however, is the fruit thousands of years of selective breeding by tribes of pastoral farmers for whom the size of the horns was seen as reflecting the prestige of the beast's owner; as a result, they have become so huge that they have ceased to function as a means of self-defence for the animal and are nothing but an impediment to movement (and ultimately a substantial source of wastage when the animal is slaughtered). Comparison of the two images is a perfect illustration of one of the key principles advanced by Darwin.

Human intervention upon evolution: the selection of mutations

In the Introduction, Darwin explains the correlation between the theory advanced in *On the Origin of Species* and the principles that had guided his study of the development and evolution of domesticated plants and animals. Humankind, he argues, does not have the ability to modify the actual constitution of animals. However, by moving them from one environment to another, or by changing the conditions in which they live, humans can interfere with the mechanism of hereditary transmission, causing the emergence of new morphological characteristics. Then, from amongst these new characteristics man could select the ones that best serve his purpose, over time gradually directing the evolution of the species. From generation to generation, the accumulation of even minute variations led to domesticated species becoming increasingly different in physiognomy to the stock from which they had originated; and ultimately, over the course of centuries, they would become radically different to their forebears.

«From a remote period, in all parts of the world, man has subjected many animals and plants to domestication or culture. Man has no power of altering the absolute conditions of life; he cannot change the climate of any country; he adds no new element to the soil; but he can remove an animal or plant from one climate or soil to another, and give it food on which it did not subsist in its natural state. It is an error to speak of man "tampering with nature" and causing variability. If organic beings had not possessed an inherent tendency to vary, man could have done nothing. He unintentionally exposes his animals and plants to various conditions of life, and variability supervenes, which he cannot even prevent or check. Consider the simple case of a plant which has been cultivated during a long time in its native country, and which consequently has not been

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VIII
The Arithmetic of Genetic Transmission

A Moravian Monk and a Long-ignored Discovery

In looking at Darwin's *Variations* we finally came up against the boundary beyond which that scientist's insight could not penetrate: the arithmetical rules that govern the redistribution of traits in hybrid progeny of dissimilar parents. As we saw, Darwin himself chose to support the "Canterbury gardener's" assertion that it was impossible to predict the results of crossbreeding different varieties of pea plant. However, at the very time that claim was being made, combinations of traits in those plants were the basis for experiments which would allow a Moravian monk to discover laws which, together with the key points in the British scientist's own theories, would provide the foundation for modern genetics. Indeed, it was three years before the London publication of *Variations* that Johann Mendel had first read to the Natural History Society of Brünn (modern-day Brno) the two papers which outline the core of his mathematics of heredity, material which had then been published the following year in the *Acts* of that society under the title *Versuche über Pflanzen-Hybriden*.

A portrait painted by Zenker in 1884 – the year of Mendel's death – which shows the abbot with the symbols of his authority: a cross, a ring, a crook and a mitre. The image was probably posthumous and based upon a photograph. Mendel was a man of wide-ranging interests, and during his time as abbot he was active – as associate or founder member – in three natural science societies and four agrarian associations: the Austrian Zoological and Botanical Society, the Vienna Meteorological Society, the Brünn Society and the German Pomological Association.

An indefatigable reader of new publications on zoology, botany and biology (particularly those produced in the German-speaking world), Darwin had thus had two years to correct the mistakes that would ultimately appear in his *Variations*; if he had done so, that work would have formulated a comprehensive and exhaustive account of the key phenomena of heredity. Furthermore, another seven years would pass between the first and second editions of the Englishman's *Variations*, still without the laws outlined by Mendel making their appearance in the work. The fact is that the journal in which the monk's paper had been published was simply too modest for it to be known outside Moravia, nor was Mendel's name sufficiently well-known to attract Darwin's attention. It seems very likely that, if Mendel's work had been known to the British scientist, it would have stimulated serious reflection and commentary, thus bringing the paper to the attention of international scientific community that would, in fact, continue to ignore the Moravian's work for more than thirty years: it would only be around the turn of the century that two eminent botanists, Hugo de Vries and Carl Correns, would rediscover this forgotten text and realise its importance.

However, if Darwin knew nothing of Mendel's work, the Moravian monk was not unaware of his famous contemporary's work on natural selection: in the rich collection of biographical information and details regarding Mendel which Silvio Martini publi-

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Another image of journeymen workers, this time enjoying a midday pause during their long working day. One can clearly see: the journeymen themselves, armed with scythes; the women who bound the crop into sheaves; the so-called *campieri* [overseers], with double-barrelled shotguns. Though this event marked the culmination of the agricultural cycle they had come to study, and thus was the key event of an entire economic system, the three young men did not actually witness it in person, given they left the island in May. In fact, the lush fields and mild climate of the island doing the winter months would lead them to mistake Sicily for a place of perpetual springtime – an error which significantly distorted the economic assessments that come at the end of their report. However, this mistake does not invalidate the social and political value of their analysis, which remains of unequalled insight into the unresolved problems facing the island.

proposals that were, to all effects and purposes, irreconcilable with those being advanced by their adversaries. Yet despite – or perhaps because of – all this "sound and fury", the resultant political debate would, in concrete terms, "signify nothing". And it was this realisation – together with a determination that their own ideals should be applied in the practical resolution of political problems - which led Cavalieri, Franchetti and Sonnino to make a decision that reflects both a certain student daring and a real desire to contribute to social progress within their new nation. Just like the great explorers of the day, the three would set off on a voyage of discovery, travelling to Sicily to gain first-hand knowledge of the island's social and economic situation. And as they believed that the social problems facing Sicily were bound up with issues relating to land ownership and exploitation, they decided to focus upon agriculture; a study of the agrarian problems facing the island would, they felt certain, inevitably cast light upon the social, economic and political causes of the unrest and violence to be found there. To achieve their goal more successfully, they also decided that they would not reveal to anyone the ultimate political reasons behind their "study trip".

As we have had occasion to mention, the Sicilian Girolamo Caruso was at that time Cuppari's successor in the chair of Agronomy at Pisa University. Nevertheless, there is no evidence that he had any influence upon the choice of destination, or upon the topics the three young men chose to examine and the conclusions they would reach. However, it is true, that upon their return, they – like Caruso – would see the widespread introduction of *métayage* contracts as crucial to regeneratiion of the rural and social fabric of the island.

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be split between two authors, making a coherent conceptual division more feasible: Franchetti would describe social and administrative conditions on the island, Sonnino would look at forms of land exploitation, agrarian contracts, agronomical practices and the range of produce.

As the publication of the report by the parliamentary Committee of Enquiry was imminent, the two young men had to race against time. However, they refused to abbreviate the material at their disposal, which would have compromised the comprehensive scope of their analysis; hence their text would only appear in January 1877, three months after the parliamentary report (an incomplete text presented to the Parliament the last day forseen by the law, the july 3 1976, but the complete work only the following September). Nevertheless, this delay simply served to highlight the political significance of that they had to say. Succumbing to pressure from political circles on the island, the authors of the parliamentary report had omitted any analysis of the social reasons for the breakdown of law and order in Sicily, exercising their own *omertà* with regard to the *omertà* that made so many complicit with organised crime. The report by Sonnino and Franchetti, therefore, not only provided an insightful analysis of Sicilian society but also stood as a condemnation of the omissions in the report published by the public Committee of Enquiry.

True to their initial intention, the men had proceeded from an investigation of the island's agricultural economy to a comprehensive analysis of social and economic relationships, also looking at the organisation of the public administration and the judiciary. The approach was perfectly suited to the subject of the enquiry, for – with the exception of its sulphur mines – Sicily was still a place where the organisation of society was primarily agrarian. To see this was the case, one only had to look at the mass of farm labourers, tenant farmers and sharecroppers to be found in the small villages of the island – people who cultivated the vast cereal fields or fruit orchards for landowners who still exercised

More receptacles from the same wine cellar: from left to right, a tub for transferring wine from vats to barrels; a series of *caratelli* (kegs) that were used to provide journeyman mowers with wine. The tub is 24 cm high (plus three 6-cm feet) and its upper and lower diameters are 44 and 35 cm; the four elliptical-section kegs are between 17 and 24 cm in height, and the diameters at the base are between 24-11 cm maximum and 14-6 cm minimum

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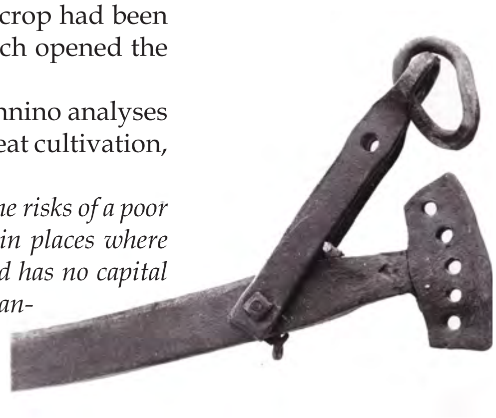
from his landlord (at usurious rates of interest); meet the obligations imposed by a number of supplementary clauses in the contract; sell the share that remained to him at a time when prices were particularly low. Even if he had obtained a bumper crop, the peasant farmer – usually without any means of transporting his crops to a market where he could have obtained higher prices – thus found himself in a position such that he could not get through to the following year without further usurious loans. And if the crop had been poor, he might find himself having to sell up his poor hovel – a loss which opened the way to a life of abject poverty.

In the second chapter of the second part of the two friend's report, Sonnino analyses the essence of the economic arrangements in the concession of land for wheat cultivation, observing:

«This contract means that the figure who has to provide guarantees against the risks of a poor crop – something that is always a possibility when growing cereals, especially in places where there is a lack of irrigation – is the small farmer who actually works the land and has no capital resources himself. And without capital it is impossible to provide any sort of guarantee against those risks. For it to be possible for the peasant to accumulate enough capital to provide cover against risks in poor years, lease conditions would have to be very moderate, and the rent would have to be calculated on the basis of the yield in poor years rather than good years. However, given that the form of these contracts leaves the way wide open for competition among workers, owners and bosses take advantage of this to impose strict agreements and to raise rents ever higher, cutting to the very minimum – or even less – the recompense that the peasant farmer receives for his labour.»

Varieties in such land concession contracts depended upon local customs and upon whether the peasant himself owned a draught animal. However, within the wheat-growing areas of the interior there were two main forms: a *terratico* contract, which was one of straightforward land rent, and a *metateria contract*, which was a form of share-cropping in which the owners took a percentage of the yield. A perceptive observer of the *métayage* system as it existed in Tuscany, Sonnino carefully analyses the clauses and obligations in both forms of contact, looking at: the division of the crops on the basis of the size of the yield; the clauses that applied; the advances that the peasant had to request from the person ceding use of the land. In his second chapter, describing the characteristic features of agriculture in what he described as a "southern and intermediate area"

The primitive implement for regulating the depth to which a Sicilian plough cut into the soil. The form makes it clear this was beaten into shape on the anvil of a local blacksmith.



Equipment that is an even more surprising combination of prehistoric technology and machine-age engineering: a seed-drill designed to be fitted to a traditional mule-drawn plough. The main structure is that of the ploughs which were undergoing early forms of mass production in Sicilian metal shops, while the seed-drill is like those which had flourished in Britain in the last decade or so of the eighteenth century. The equipment, therefore, was arriving in Sicily with a delay of over a century. Created initially to seed rows of wheat or turnips, in Sicily this wheelbarrow-like device was for local crops that required soil scuffling during cultivation: white lupines, beans, chickpeas. Whilst the regulator for the draught bar was clearly made by a blacksmith, the two pairs of gears that worked the drill were obviously made in a factory ironworks; most likely it was brought from England on a sail ship which then left the island loaded with Marsala. The equipment was put together in the smithy of Sig. Grassi at Misterbianco, on the far southern slopes of Etna; it is 150 cm in length and 79 cm high. The wheel has a diameter of 46 cm and the seed hop a diameter of 20 cm.

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A famous painting that captures the atmosphere of livestock farming in Lombardy: *At the Hitching Rail* by Giovanni Segantini, a Trentino-born artist who had a passionate interest in the combined existence of animals and mankind in the Alpine valleys of both Italy and Switzerland. At the first rays of the sun, the animals set out for common pasture land on a plateau surrounded by snow-capped mountain. At sunset each family tied their own animals to a hitching rail where they would be milked – once in the evening, once again in the morning – before being released again to graze. The animals have the mottled coat of livestock that is not the product of precise selective-breeding. The colour of the coat of the cow in the foreground, with her head lowered, is typical of the bred known as Brown Swiss.

Diseases and Veterinary Pharmacology

Perroncito is also the author of the following section of the *Enciclopedia*, dedicated to *Animal Pathologies*, which gives a comprehensive account of the changes in livestock health brought about by the various kinds classes and species of animal and plant parasites (from insects, spiders and worms to protozoa and eumycetes). This coverage of diseases is completed by a discussion of "*contagious ailments*"; the label covers those diseases that in the 1880s – thanks to the work of Pasteur and Koch and the contribution of a range of biologists and veterinarians (including Perroncito himself) - would be recognised as due to the action of bacteria, entities whose multiform existence had been revealed by the microscope some time before their nature and properties had been understood. Produced by an authority on the diseases caused by worms, the most significant part of Perroncito's discussion is that in which he examines the morphology and parasitology of helminths, taeniae, flukes and trichinae, also providing an account of the hygiene measures necessary to prevent animals becoming infected. The entire coverage bears witness to the advances in a discipline which had arisen from the combination of Redi's basic ideas with new discoveries that bore them out.

A perfect example of the precision in Perroncito's parasitology can be seen in the paragraph (in chapter three) dedicated to *Echinococci affecting Livestock*:

«*Swallowed with food and drink by horses, cattle, goats, sheep, camels, pigs and people, the ovules of the Echinococcus taenia hatch in the intestines and release embryos that then migrate through the body, settling in particular in the liver, lungs, heart, spleen and kidneys, in each of those places forming cysts or blisters that are called echinococci […]*

These verminous cysts can be of different sizes, their volume varying from that of a hemp seed to that of a chickpea or hazelnut and up to that of a child's head. The membrane enclosing them is very thin and soft, being easily ruptured; they contain a clear, serous liquid that flows quickly and is very poor in albumen, casein, fat and inorganic salts.

The membrane of the echinococci has a very characteristics structure, which means it can be distinguished from that of all other species of cystic worms: it is made up of two layers, one internal and one external […]

Four varieties or species of echinococcus are known, and can be found in both humans and livestock. These are:

The simple Echinococcus, which results in a single cyst that does not produce sporocycts.

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which caused the machine to tilt up and deposit the collected hay; at the same time, this tilting drove the opposite row of tines into the hay, and so it was they which then came into play. The windrower proper Brusotti says was originally known as a "horse-drawn rake". It had a carriage on two wheels, to the frame of which was fitted an axle with curved tines long enough to rake across the ground. Eccentrically mounted gears fixed to the wheel axle meant that the operator, via a lever alongside his seat, could cause those tines to lift and release the hay they had gathered. Used skilfully, both of these machines made it possible to form the hay into ridges that lay parallel to the direction of advance of the hay mower. The hay thus formed into windrows could then be formed by hand into ricks (to protect most of the hay against weather conditions) or loaded onto a cart that followed the windrower at work.

Threshing Machines: Humans, Animals and Water as source of power

The eighth chapter of Brusotti's review of the agricultural machinery available in the 1880s is of particular interest, offering broad coverage of the threshing machines then on the market. We have already seen how various contraptions were devised to perform the work of flails mechanically. However, despite the work of early pioneers in producing mill-wheel-powered threshers, until Andrew Meikle invented his mechanism one major problem had remained: how could human or animal labour be replaced by an inanimate source of energy? Meikle's invention basically comprised a rotating head

A traction engine and thresher machine in action at Luc-sur-Mer in Calvados some time in the late nineteenth or early twentieth century. Given the size of the engine's firebox, the fuel used was probably wood; the threshing machine too is unusually wide. Both pieces of equipment fall short of the functional elegance achieved in British machines; they were probably produced in one of the factories in France, Germany, Belgium and Italy that tried to compete with the latter by producing what were, in effect, imitations.

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These two images are not very far apart in time but do show the huge distance that was opening up in methods of beef-cattle farming. The early picture (from the *Illustrated London News* of 1862) shows a Smithfield Club which is clearly the preserve of the "gentleman farmer", whilst the later picture (taken by F. Buchanan, a photographer from Worthington, Minnesota) dates from 1890 and shows cowboys riding herd, any one of the men here having the chance to become a 'cattle baron' in his own right. When the 1862 photograph was taken, "gentleman farming" was enjoying a heyday that had only another decade or so ahead of it, whilst ranch herding was destined to remain a national status symbol. At the Smithfield Show, the livestock came from well-tended pasture and had been carefully transported to London in such a way the animals did not lose a single pound in weight; on the other hand, the herds from prai-

figures he seems to consider as comparable to Louis Pasteur is Paolo Mantegazza, a follower of Berti Pichat who never used a microscope or a telescope but enjoyed huge success in Italy as the author of endless volumes that purported to diffuse knowledge of a whole range of sciences. Besana may have known what he was talking about in his coverage of the technology of dairy produce, but his claim that one could not decide between the opposing theories on fermentation reveals him to have been a very mediocre scientist.

Refrigeration Ships and Tinned Meat

Having examined the theoretical debate regarding the process of putrefaction and the means for preserving food stuff, Besana passes on (in Chap 4) to a description of the procedures which long practice had shown could be used to conserve perishable goods. These he orders in four categories, depending upon whether they were based on the extraction of water, the extraction of air, the use of lower temperatures or the application of antiseptic substances. In the following chapters, he looks at how each of these four might be used in the conservation of grain, flour, cheeses, timber (an odd inclusion, given that it clearly does not belong in a list of food produce), vegetables and meat. In terms of both technological advances and economic importance, it is his discussion of the procedures used for the conservation of the latter that contains the most significant part of his treatment of this theme. In introducing his account of modern industrial practise and trade, he writes:

THE SMITHFIELD CLUB CATTLE SHOW AT THE NEW AGRICULTURAL HALL, ISLINGTON.—SEE PAGE 654.

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Abstract

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