Antonio Saltini

AGRARIAN SCIENCES IN THE WEST

translated by Jeremy J. Scott

VOLUME SEVEN

Agrarian Sciences in the Twentieth Century: The Challenge of Population Growth

Nuova Terra Antica

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Translated by Jeremy J. Scott

In memory of Nino Orsini, who was one of the first – way back in 1977 –
to take an interest in the first edition,
and provide invaluable advice and crucial insight; to the very last, a true friend.
And also in heartfelt thanks to Giuseppe Concaro, Roberto Capurro,
Matteo Bosso, Giuseppina Tonet, Giovanna Franchi, Alessandro Cantarelli,
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and Giovanni Biadene – all of whom have made such a contribution
to this final volume by supplying information and illustrations,
and by helping the project to overcome the economic setbacks
that not infrequently threatened its completion.

Nuova Terra Antica

William Bateson (right) with Wilhelm Johannsen in his garden in Merton (England) in 1924. Bateson was the first major figure in Britain to champion the ideas of Mendel, battling against all those fellow Britons who were unwilling to see Darwin's claims to priority in this field disproved by an obscure Bohemian monk; the leader of such adversaries was Walter Raphael Weldon, who was supported by such lieutenants as Francis Galton. Working in Cambridge, Bateson – with the collaboration of a keen group of women assistants that included his wife and sister – carried out a huge series of precise experiments which demonstrated the unassailable truth of Mendel's laws; all this at a time when the Bohemian's ideas were not part of any university syllabus.

of the agrarian sciences, the cross-breeding of plants was one of the methods various pioneers had used to obtain new varieties, and the Swedish scientist had seen that the means made available by a scientific understanding of heredity vastly increased the possibilities for such hybridization. Demonstrating the solid basis of his ideas, Ehle undertook the cross-breeding of a number of important crops, the result of which experiments provided ample confirmation of the polygenic nature of the 'characters' that play a role in productivity. The characteristics that are generated by numerous genes – whose effects are cumulative rather than mutually exclusive – reveals continual variations and thus seem to contradict Mendel's schema; however, this no longer appears to be the case once one has identified the number of genes co-responsible for the presence of a specific characteristic and can thus define how they are combined. Taken together with Johannsen's distinction between genotype and phenotype, the demonstration that a characteristic depends upon the action of numerous genes explains why it is so difficult to disguise between the peculiarities which are the effect of genes and those which result from environmental factors; to see that what might appear as the result of the latter are actually due to substantial genetic differences.

Genetics gained full recognition amongst agrarian sciences in 1913, when at the tenth International Conference on Agriculture – held at Ghent – a report on the new discipline was presented by Philippe Lévêque de Vilmorin (grandson of the French pioneer of plant selection) and Auguste Meunissier, director of the laboratory which Vilmorin had set up at his own farm in Verrières (the very first in France to describe itself as a *laboratoire génétique*). Part of that report reads:

«The principle of the genealogical selection of cultivated plants, proposed in 1856 by Louis de Vilmorin, has received splendid confirmation from recent knowledge of Mendel's work and the publication of Johannsen's study of "pure lines".

Two fundamental principles emerge from Mendel's experiments, which for the past twelve years have been repeated by a number of scientists on a large range of plants and animals:

1. Mendelian characters – or, more exactly, hereditary factors – are independent of each other;

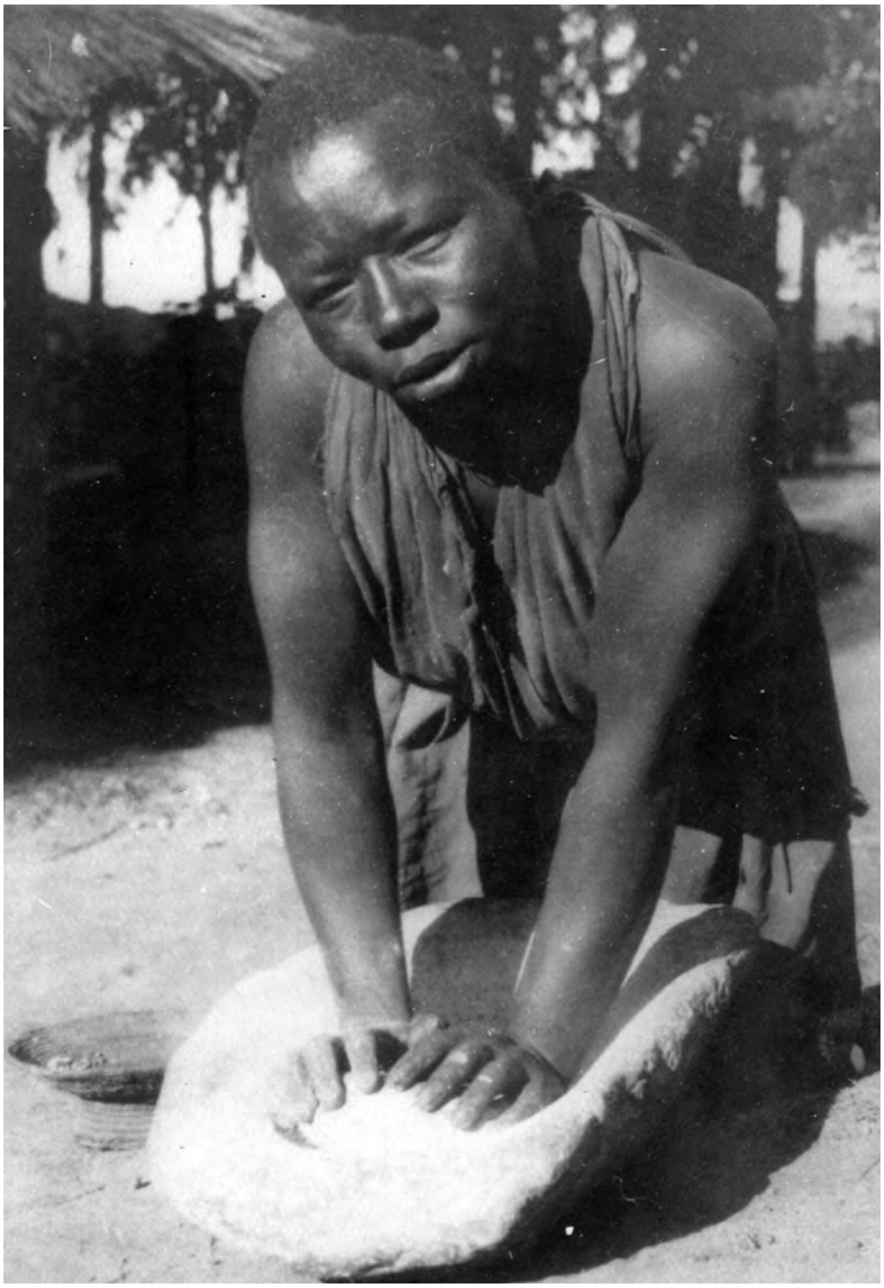
2. When an individual has received one of these factors in only one of the gametes of which its pollen and eggs are formed, this individual produces an equal number of gametes with and without that factor.

Furthermore, these numerous experiments have clearly demonstrated the fundamental difference which exists between two categories of factors that play a role in the development of a living individual. On the one hand there are hereditary factors – or "genetic factors" as they are now called – which are transmitted to the seed or embryo by means of gametes; on the other, there are "non-genetic" or environmental factors (light, heat, atmospheric pressure, etc.), which have a great influence upon the individual but not upon its descendants.

The Fondazione Morando Bolognini came into exist when the last member of that old aristocratic family left his castle and agricultiral estate of Sant'Angelo Lodigiano to the Istituto Nazionale della Cerealicoltura, and the place still houses a range of interesting material relating to the first scientific studies of plant varieties. The most significant of these is the large walnut display case which a master cabinet-maker produced for the Gnecchi family of Cologno Bresciano, owners of one of the first Italian companies that worked in the field of plant breeding: exhibited at the 1900 Paris Expo, the case contains their entire collection of wheat varieties, the basis for the production of hybrids that were considered essential to rejuvenate the nation's patrimony of cereal crops. 232 cm long and 215 cm high, this elegant piece of furniture has six shelves behind two doors, each shelf containing nine square trays (10 x 10 cm and 13.3 cm high) filled with the caryopses of different varieties, over which is displayed a bunch of the ears of that particular wheat. Collected when perfectly ripe – and then probably treated with some sort of preservative gum – each of those ears still has the bright yellow colour of freshly-harvested wheat.

Scientific Discoveries, Practical Applications

The first advances in genetics had come about through work on autogamous plants – that is, those whose female organs were pollinated solely by the male organs of the same plant: Mendel, in fact, had based his discoveries on the particularities of the pea, Johannsen had done his experiments on beans and Nilsson Ehle had used wheat. A new area of research was then opened in 1908-1911 by George Harrison Shull, who – working at the Carnegie Institution's Cold Harbor Spring laboratories - carried out the first genetic experiments on maize. These revealed that allogamy – free cross-fertilisation between plants of the same species – means that different chromosomes are reunited in gamic reproduction within the same plant, making each such plant heterozygous. By artificially forcing autogamy onto maize plants, the American researcher proved that one can obtain genetically homogeneous lines, but that the vigour and strength of the resultant plants was substantially reduced. That vigour was, however, restored by allowing the recombination of genes through allogamy. This was the reason behind what Darwin had called "hybrid vigour", a phenomenon whose identification was of fundamental importance for the future agricultural exploitation of this species of plant. Those first experiments would result in Shull being credited with creating a method for the hybridization of maize, one of the discoveries of greatest significance for the increasing yields achieved by twentieth-century agriculture.



A kneeling woman kneads the dough for the family's daily bread; her position is identical to that seen in Egyptian and Pre-Columbian sculpture. Her physiognomy appears to be Black African rather than Ethiopian; the former were still brought to Ethiopia as slaves.

Having defined the geographical area of plant domestication in Mesoamerica, Vavilov then lists 49 plants which he says were first cultivated there. In order, the seven sections of this list include: 8 plants cultivated for their seeds (cereals, *leguminosae* and *Chenopodiaceae*); 6 cucurbits; 3 species of tuber or root crop; two spices; 3 species of fibre-yielding plant (including two species of cotton); 17 fruit plants; 10 species of plants used in various manufactures (from agave as a source of fermentable liquid to tobacco). The Russian highlights the importance of some of the species in this list:

«The use of the phytogeographic method has shown clearly that this is the primary center of corn (maize) and its most closely related wild species, teosinte. This center is also the native home of the chief American species of bean, squash, pepper, and numerous tropical fruits. Here the cultivation of cacao had its origin; this is probably also the home of the sweet potato. Upland cotton, the variety upon which the cotton growing of the world is based, had its origins in southern Mexico. Here maize has played a role similar to that of wheat in the centers of origin of the Old World. Without it, the Maya civilisation could have never existed. The very restricted territory of southern Mexico and Central America is full of cultivated endemic plant varieties, differing strikingly, in this respect, from the vast North American continent where all agriculture, both past and present, is based upon imported varieties.

Our investigations in South America, conducted in 1931 and 1932, have compelled us to make important corrections in the former conceptions of centers of origin as recorded in American literature. The most outstanding region, which was undoubtedly a center of independent and original agriculture, is the high montanious area of Peru, Bolivia and part of Ecuador, which was formerly the center of the so-called Megalithic or Pre-Inca civilisation. This territory, insignificant in area as compared with South America, is remarkable for its collection of cultivated endemic animals and plants.»

Finally – on page 40 of the English publication – Vavilov moves on to the eighth and last of the centre of origin he has identified for the world's domesticated plants:

«VIII. South American (Peruvian, Ecuadorean, Bolivian) Center of Origin of Cultivated Plants (the chief endemic plants of the high montanious district- Puna and Sierra).»

Having defined the geographical area concerned, the Russian lists 45 plants. In the first section he gives 5 root or tuber crops, foremost amongst which is the potato, the very linchpin of agriculture in the Andes (Vavilov also associates 14 secondary species with the basic species of Solanum andigenum). Contrary to what happens in the lists

Archaeologists and geneticists agree that the Tehuacán valley – in the wide region of central-southern Mexico which extends from the temples of Mitla to those of Monte Alban – was where Mesolithic hunter-gatherers first developed plants of maize from the teosinte plants that had been the object of primitive methods of cultivation. The region is one of the poorest in the country: using oxen that are clearly a crossbreed of bovine cattle and zebu (*Bos taurus indicus*), the *campesinos* here still sow seed of genotypes which, of all currently cultivated maizes, are closest to the plant's ancestors. With no ability to irrigate or dress their fields, the peasant farmers obviously obtain very low yields, meaning their large families exist just above the poverty line.

million) to 2000, when the figure topped 6,000 million. Here again, this third massive increase in the size of humankind went together with a revolutionary shift in the use of agrarian resources. Various factors had prepared the ground for this leap - advances in modern agronomy, increased knowledge of plant nutrition and the application of chemistry to the production of fertilizers and anti-parasite treatments – but the single most significant factor was knowledge of genetics.

The truly exceptional nature of this change is revealed when one appreciates that whilst the scientific prerequisites for it to happen were in place at the beginning of this period, the state of world agriculture was far from favourable. In a world just emerging from a global conflict there were food shortages not only in Europe, where the war had undermined agriculture and led to drops in production, but also in Africa and Asia, where the geopolitical reorganisation of the post-war world order had resulted in independence that coincided with a sharp increase in rates of population growth, without any concomitant advances in agricultural systems: colonialism had bequeathed these countries an agriculture geared not to the satisfaction of local needs but to the production of crops desired by European markets, hence Asian and African farms were incapable of meeting domestic demand within these new nations.

From the 1950s onwards, genetics would be one of the key instruments that science employed to increase the world's agricultural production, becoming the main factor in humankind's third agrarian revolution, which would become known as the "Green Revolution". In citing the creation of new varieties of cereal as the cause of the sharp upturn in agricultural production, the historian risks making an arbitrary deduction, for there is no denying that the metamorphosis that one sees in the world's agriculture over the period from the 1950s to the 1980s was due not only to the spread of new varieties of wheat, rice and maize but also a huge increase in irrigation and the fact that fertilizers and anti-parasite treatments were used in vast areas of Asia, Africa and Latin America for the first time. However, within this synergy of factors, it is clear that the role played by those new cereal crops was so substantial that the Green Revolution – that is, the "genetics revolution" – is unique in the history of the relations between humankind and the world's resources.

In a 1997 book that aimed to establish the framework for a strategy that might provide further stimulus for advances in world agriculture, Gordon Conway would follow

One of the most striking illstrations of how millennia of excessive exploitation can change a natural environment is to be seen in Palestine. When pledged to Moses by the Almighty, this "Promised Land" was a place of rivers and woods, of meadows easily put to the plough. Now, after four millennia of deforestation, over-grazing and rapacious crop-farming, it has become a sequence of rocky ridges or even outright desert. The latter is the case on the slopes of Galilee; here photographed on 26 October 1978, this place is now home solely to a few Bedouins, whose tents can be seen on the barren slopes.

nitrogen from the atmosphere, the amount of that element in the soil would, according to Hopkins, be sufficient for 700,000 such harvests.

From this evaluation of the elements available in soil on the basis of the average quantities of these chemical elements present in the earth's crust, Hopkins shifted his attention to what he calls "normal soil", obtaining figures that were no less encouraging. In fact, this "normal soil" was said to contain enough phosphorus for the development of 133 harvests of wheat measuring 25 bushels per acre (1.68 tons per hectare), whilst the figures for potassium, sulphur, calcium and magnesium were 1,765, 171, 4,800 and 3,000 harvests respectively. In support of Hopkins estimates, Usher cites the famous agronomical experiment carried out at Rothamsted, in which wheat was grown on the same plot of land for 77 consecutive years without any addition of fertilizers: whilst there was a drop in productivity over the first few years, this had then levelled off at around 12 bushel per acre (0.806 tons/ha). In other words, it was argued, this famous plot of land could have gone on forever yielding crops of this size without any further drop in productivity. The American economist also cites two other facts. Firstly, recent studies had shown that plants drew part of their nutriment from the layer beneath that usually turned by the plough (hence that stratum's chemical reserves had to be considered alongside those of the arable layer); secondly, plants do not draw the chemical elements for their nutrition directly from the mineral reserves in soil but rather from the solutions thereof that permeate its porous substance. Thence, he concludes his argument by claiming that the most up-to-date knowledge regarding soil chemistry had turned Liebig's theory into a nineteenth-century curio, something which could only prove misleading if used as the basis for deductions employed in historical research.

«Instead of defining fertility in terms of mineral content, it is now deemed essential to consider the "condition" of the soil, in respect to compound particles and their collodial properties; the mass and condition of the organic matter in the soil; the microorganic population of the soil,

VIII
Soil Physics and Plant Physiology

Soil Temperatures

Having completed his discussion of the relation between plants and nitrogen resources, Russell passes on (in chapter 17) to look at the exchange of heat energy between soil and the surrounding atmosphere.

The wavelength band of the sun's rays as they hit the soil is fairly broad, but centred about 0.5 microns, while the ground – whose average temperature is between 280° and 300° K – reflects into the atmosphere radiation of a wide range of wavelengths, varying between 3 and 100 µ, but centred around 10 µ: the largest part of this lies between the wavelength of absorbed water vapour (6 µ) and that of absorbed carbon dioxide (20 µ). At Rothamsted experiments were carried out to measure the amount of energy solar radiation transmits to soil in temperate latitudes, the resulting figures being 0.15 kjoule per square centimetre per day in December and 1.76 kjoules per day in June. At that test site, the ground temperature could vary (in the month of July) by as much as 20 degrees during the course of a day, while at a height of 120 cm above the ground, air temperature (with a certain delay) followed that of the ground; the two were identical during the night. However, during the course of the day there was increasing disparity between

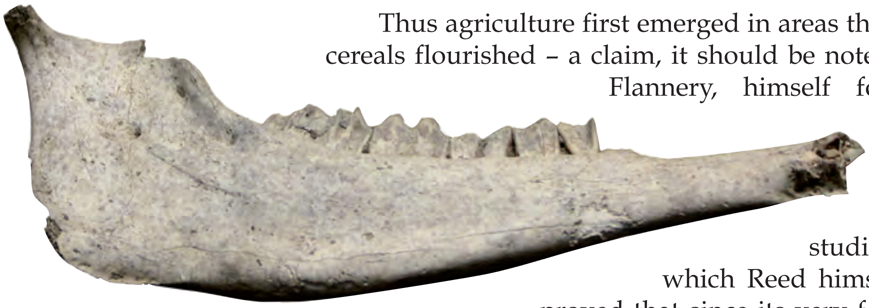
Whilst most plants will grow if there is water and not at all in completely dry conditions, intermittent humidity allows the survival of a few xerophyte species, and in water-logged conditions only hygrophilous plants will grow. The history of man's millennial engagement with the resources of the earth reveals that it has been no easier to drain off stagnant water than to irrigate arid areas. At the beginning of the ninteenth century one third of the plain lands in Italy suffered from either the permanent or temporary presence of stagnant water. The advent of steam power would then lead to the arrival of efficient pumps, which were used over the first half of the century to drain swamps and marshes. For such machines to expel water from an area of marshland, the liquid had to flow to the pumps through a network of ditches extending over its entire surface, and then be fed to large rivers through adequate canals. The largest area of such marshland in Italy was in the Ferrara region, whose swamps would thus be the stage for the nation's most dramatic episode of land drainage and reclamation. A leading part in this was played by a huge number of *carriolanti* (*carriola* = wheelbarrow) workmen who dug out the vast mass of earth which had to be removed in order to create the drainage network necessary to dry out more than 100,000 hectares of marshland. This photograph shows work on the canal that fed into the Volano branch of the river Po all the water pumped out of the Polesine di San Giorgio area by machines that were installed at Marozzo in 1874; the daily capacity of these pumps was the second largest

the region was a diploid wheat - *Triticum monococcum* – whose ancestor, *Triticum boeoticum*, had been widespread in an area that embraces Turkey, Syria and Northern Iraq and even extends into Greece and Transcaucasia. Given the size of that area there was substantial variety in the strains of *boeoticum*, with ecotypes that were adapted to the dry and arid conditions of the Euphrates foothills, ecotypes that flourished in the Anatolian uplands and even ecotypes that grew on mountain slopes some 2,000 metres above sea-level.

The second of the cereals to be domesticated within the Middle East was emmer wheat – *Triticum dicoccum* – a tetraploid wheat which was a descendant of *Triticum dicoccoides*, whose original habitat Zohary gives as being the fairly restricted area made up of Israel, Southern Syria and Jordan, which centred around Galilee and the Golan Heights; later scholars would expand this area significantly. In spite of the restricted size of what he claimed as its original habitat, *dicoccoides* too, Zohary stresses, came in a wide variety of strains: this is demonstrated when one compares the more vigorous ecotypes that ripened early on the shores of the sea of Galilee, with the thinner and late-ripening varieties that grew on the eastern slopes of Mount Hermon up to an altitude of 1,600 metres. In Turkey, Transcaucasia, Iraq and Iran – where *dicoccoides* did not grow - there was, however, an almost identical wheat (*Triticum araraticum*) which, though tetraploid, had no genetic link with either *dicoccoides* or *dicoccum*: that the former cannot produce fertile hybrids with the latter two is clear proof that there is no genetic affinity.

The third cereal in the Middle East was barley – *Hordeum vulgare* – a diploid cereal whose ancestor can easily be identified as *Hordeum spontaneum*, a species that is common in the Near East, from where it spread as far as Turkmenistan and Afghanistan. In the vast area where it grows, that species is an essential component of the grassy mantle that goes together with open oak forests, and a common weed in cultivated fields (part of its secondary habitat also includes Mediterranean scrubland and uncultivated heath). Vulnerable to cold, it does not grow up to the same altitudes as those where one might find varieties of wheat.

Wild barley had a distichous spike – that is, with two ranks of caryopses. However, given that there are cultivated barleys that are hexastichous (with six ranks of caryopses), some botanists had argued that these latter could not be traced back to the distichous variety but descended from *Hordeum agriocrithon*; however, more careful study has shown that this latter is not an authentic wild species. For his part, Zohary argued that the hexastichous varieties were the fruit of cultivation – as is proved by the fact that fragments of clearly hexastichous barley have been found mixed with



More paleontological remains from the Neolithic settlement: the almost complete jawbone of a sheep or goat (the bones of the two animals cannot always be distinguished).
Below: a phalange from one of the two animals.

Thus agriculture first emerged in areas that were peripheral to those in which wild cereals flourished – a claim, it should be noted, which had already been advanced by Flannery, himself following in Binford's footsteps. The settlement which Reed mentions as the oldest agricultural site yet excavated is, in fact, rather far from Palestine - Cayönü, in Anatolia – and had been studied by Braidwood in an expedition of which Reed himself had been part. The excavations had proved that since its very foundation – 9,400 years ago – the village had been occupied by farmers; the unearthed caryopses of both monococcum and emmer wheat had the characteristics of cultivated strains. However, the inhabitants seem to have been ignorant of barley, both wild and cultivated. At its origins, the village was not a place of animal-herding, however, with the inhabitants still engaging in intensive hunting. Only in the second part of the six-hundred-year first phase of settlement would the cultivation of cereals be combined with the herding of pigs and sheep (and probably also goats, though their presence is not certain). In areas close to the sites of the Natufian villages, on the other hand, the first known agricultural settlements are relatively late. Amongst the earliest of these that have been studied, one that is of particular interest is that of Beidha, on the uplands between the Dead Sea and the Gulf of Aquaba, amidst what are now semi-desert hills. The inhabitants here primarily cultivated barley whose characteristics are so primitive that, although Harlan describes it as a cultivated strain, Helbaek, the other master of paleobotany, describes it as "cultivated wild barley".

From the genesis of crop cultivation, Reed then moves on to dedicate a few pages to the genesis of animal-herding. Here he makes only general observations, pointing to the existence of an entire library of zoological studies that bear witness to the ease of contact between man and animals – an ease that thus facilitated domestication – but himself stressing that this comfortable co-existence flies in the face of the deep-seated attitudes of hunters, who can see animals solely as prey to be killed. As far as Reed is concerned, the claim that groups of hunters converted into animal-herders is a piece of logical legerdemain. Instead, he argues that the earliest domestication of animals probably came about through the raising of the young of slaughtered females that were then taken to camps and raised by the women and children; Reed points out that he had advanced this suggestion some time before, but that it had not been very favourably received in anthropological circles. Here, in a volume of conference proceedings of which he himself is the editor, the scholar is rather more fervent in his support for such an idea – but the thesis is nowhere near as well argued as that concerning the migration of cereals and implements from Egypt to Palestine. If it was the children in human settlements who first became little herders of kids and lambs whose mothers had been killed, the American is faced with the far from easy task of developing this into a comprehensive "model" that explains how and when animal-herding became a mainstay of the adult economy.

The Multifaceted Economy of Natufian Villages

Yet another explanation of the birth of agriculture in the Near East was submitted to the Woodstock conference by Fekri Hassan, an Egyptian scholar at the Department of Anthropology at Washington State University. He declared himself dissatisfied with the recently advanced hypotheses, and took particular pains in rebutting the theory argued by Binford in 1968 (which had received rather wide acceptance). Pointing out that the end of the Pleistocene period had seen a substantial increase in sea-level, the American had observed that those populations which had been established on the coasts – where

If demographic policy and building speculation led to some of the most fertile land in ancient Palestine being covered in concrete, Israeli advances in irrigation technology have meant that citrus groves and orchards now occupy land that any traditional agronomist would have claimed was unsuitable for arboreal crops: classic agronomical doctrine argues that trees require deep soil with substantial supplies of water and high levels of certain chemical elements within the terrain. As shown by this photograph (taken on 20 October 1978), irrigation with water that has been enriched with the necessary fertilizers means that fruit trees can flourish on shallow stony ground like that one finds here in the region of Hasharon. Even so, increasing costs of irrigation would subsequently mean that citrus groves were replaced by avocado trees, which yielded a more profitable crop; later, avocadoes too would be replaced by high-priced market vegetables and flowers.

A New Relationship between Plant and Soil

The "new agriculture" developed in Israel moved gradually away from these precepts, ultimately formulating a theory of crop cultivation that deliberately rejected the role which two centuries of agronomical thought had attributed to soil fertility (be it physical or chemical). When one hears Israeli scientists talk about their own projects of research and describe the techniques of cultivation being used in the nation's agronomical institutions, one gets a glimpse of a new approach in which soil and its (physical-chemical) characteristics have lost any right to be considered amongst the factors that determine the success of agricultural activity. I myself first studied these new techniques during a visit in October 1978, when I was the guest of various manufacturers of irrigation equipment, and then had the chance to see how that technology had developed during a shorter stay in 1993.

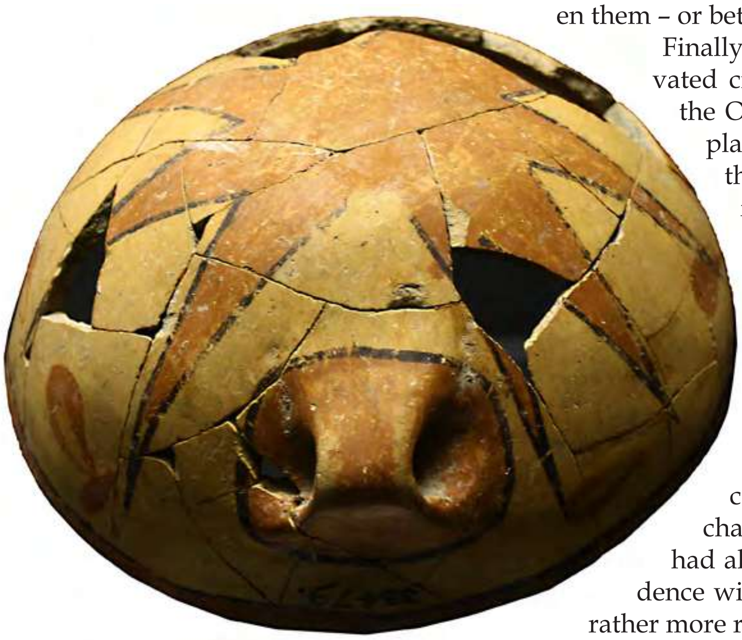
The key objective of the new science of agronomy as formulated in Israel is the balanced nourishment of plants through direct administration of nutrient solutions. Once one has defined the problem in terms solely of the most efficient way of supplying root systems directly with the necessary water and solutes, the soil in which plants grow becomes a mere physical support; the sole pedological characteristics of any significance are those which affect the ability of nutrient solutions to reach the roots. Once one adopts this measure, one's classification of soils becomes extremely schematic, with interest being solely in soil permeability and no longer in the wide range of other pedological differences that can exist between the various types of terrain.

This extraordinary "paradigm shift" in the approach adopted by Israeli agriculture was initially stimulated by two pronounced characteristics of the land in the country: scarcity of water resources and the poor nature of, generally shallow, skeletal soils (clearly the result of four millennia of over-grazing and rapacious crop cultivation). Assessed by the canons of classical agronomy, most of the land in the countryside would be unconditionally judged as incapable of profitable agricultural exploitation. Thus, a new approach to agronomy had to be developed by those who were planning the recipients within which to carry out a series of complex, yet perfectly regulated, biochemical reactions. What I had seen during my visit to Yorkshire were the various phases in a rigorously correlated process for the conversion of animal feed into meat and eggs. An understanding of how genes interact in determining an animal's metabolism; knowledge of the amino acids, sugars and vitamins contained in the feed used at each stage in the operation; appreciation of the effects that heat, light and darkness have upon the various types of birds within the company's facilities (producers of hatchery eggs; producers of eggs for human consumption; turkey and chick broilers) – all of these had been drawn upon to obtain maximum efficiency.

For journalists visiting the world's greatest producer of lambs and wool, the New Zealand Ministry of Agriculture prepared this photographic souvenir. Thanks to the sun's heat at this latitude (around the Tropic of Capricorn) and steady but gentle rainfall, pasture is constantly fresh for the 70 million sheep that graze here; the careful choice of leguminosae species within the pasture also means that the gramineae do not require the addition of a single kilogram of nitrogen. Over thirty different species of sheep are bred – some great meat producers, some supplying wool that is exported to Iran for the manufacture of the world's finest carpets. Of the seventy million head of livestock not one is a milking animal.

en them – or between their respective progenitors – are sterile.

Finally, Pickersgill looks at the origin of cotton as a cultivated crop, stressing the difference between the species in the Old and New Worlds: while the former were diploid plants whose seeds were surrounded with downy fibre, the latter included diploid species without the downy fibre and three tetraploid species with that fibre. These three were *Gossypium hirsutum*, *G. barbadense* and *G. mustelinum*, the first two sources of the numerous cultivated varieties, the third a wild species growing in Brazil. The most difficult problem regarding the phylogenesis of this family of plants was that concerning the origins of the tetraploid species. This was probably due to a quite unique hybridization which produced the progenitor of all American cottons, which were then domesticated separately. Archaeological evidence from Peru shows that *G. barbadense* had already been domesticated by 2,500 BC, while the evidence with regard to *G. hirsutum* suggests domestication was rather more recent.



An example of the fine ceramic ware recovered from the Stentinello settlement: a single-handled bowl painted in black-edged red stripes. Dated around the middle of the 5th millennium BC, this is one of the earliest – and most significant – survivors of polychrome ceramic work from the whole of the Neolithic period; it is, therefore, amongst the earliest evidence of the use of colour to decorate pottery.

In concluding her paper, Pickersgill emphasises how the study of the wealth of plants cultivated in America reveals that, while it had enormously increased the number of strains and varieties, cultivation does not ever seem to have generated entirely new species. Detailed paleobotanical studies reveal that all the plants cultivated in the Americas derived from a wild species – a law whose sole exception was probably the coca plant (*Erythroxylum novogranatense*), a species which must have been derived from *Erythroxylum coca* when this latter was already being cultivated. But if there are almost no cases of humankind creating plant species in America, examples of double domestications of the same species are more common, Pickersgill adds: peppers, cotton and, probably, chenopods are all possible cases of plants domesticated in different places at different times. Thus the situation of plant domestication in the America is very different to that one finds in the Old World, where – as we shall see – authoritative studies suggest there was only one case of double domestication, and even that is uncertain.

Some interesting additions to Pickersgill's history of maize are offered by the British geneticist Garrison Wilkes of the University of Massachusetts. He again stresses that the difficulties in tracing that history with any precision are increased by the fact that maize cross-bred with teosinte, the species most botanists and geneticists had seen as the plant's progenitor: such interbreeding made it difficult to explain how it had been possible to nurture selected maize plants in regions where the wild plant might be growing in the same field, posing a real threat to the preservation of the characteristics one wished to encourage. And those difficulties appear even more daunting when one bears in mind that cross-breeding of the original plant with those derived from it probably extended the area where teosinte grew wild. From the valley of Tehuacán - generally supposed to be its home region – the presumed progenitor will thus have spread to various regions at different altitudes, creating the same problems of interbreeding for farmers who, sowing maize in locations where teosinte was non-native, *should have been* in the perfect position to preserve the mutations they wished to maintain in the cultivated plants.

species, in areas surrounded by lush vegetation of wild progenitors, the first mutations in the plants survived. The subspecies of the same plant can also be genetically incompatible; possessing mechanisms that hinder the development of hybrids, those hybrids they do produce are sterile. Within the genomes of such subspecies there can also be significant differences in the structure of fundamental enzymes, or of stored substances (in particular, proteins); and one can also find chromosome anomalies – that is, inversion or translocations that radically distinguish one subspecies from all the others. This body of differences provide precious clues to identifying the exact subspecies of a wild plant which was the progenitor of a variety of cultivated plant. If, with regard to a specific genetic characteristic, one finds within cultivated varieties a degree of polymorphism which reflects that in the wild subspecies, then one has to recognise that the cultivated plant has a number of genetic matrices. However, if in cultivated varieties there is no change in a characteristic relative to a gene which demonstrates a certain polymorphism in the wild subspecies, then this is evidence that the cultivated variety arises from a single act of genesis, a single episode of domestication.

A Neolithic grindstone and pestle from the Agrigento Museum. Over the course of millennia, the form of these paired implements would not change substantially from that first devised by the hunter-gatherers of the Nile Valley. The grain used to indicate the use of the stones has the amber colour typical of Sicilian durum wheat, a member of the family of tetraploid wheats which for millennia would dominate agriculture in coastal plains reaching from Egypt to Spain.

The Earth can feed its peoples. Here Breman depicts a scene of hope: the rice fields this woman is working are on the upper slopes of the Bugarama valley in Kivu province (the Democratic Republic of the Congo), where it has been shown that use of the right fertilizers can yield a crop that not only feeds the farmer's family but also provides produce for sale at market. Dressed in splendid colours, the woman works the soil in a far from desultory fashion, showing the sort of commitment one sees in those aware that their labour will bear fruit. Applied with skill, science can create such confidence in one's own efforts; instill the conviction that correct use of natural resources makes it possible to enjoy more than a hand-to-mouth existence.

the seed crops that will enable them to feed their children; crops which will generate harvests sufficiently rich in essential amino acids and microelements, whose inadequacy in poorer regions is felt with particular severity by children and pregnant women. Following the work by Oliver E. Nelson at Purdue University, which resulted in the discovery of the role of the *opaque-2* gene in increasing levels of lysine and tryptophan in maize caryopses, CIMMYT would in the 1970s work on the selection of new cultivars with a richer and more balanced protein content – a task that was particularly demanding because the gene which favours this outcome is linked with various others that can lower the plant's productivity. However, by the 1990s, work on the project had resulted in the creation of new maizes which provide all the essential amino acids for the poor peasant families for whom the cereal is a staple.

Is there, in effect, an unresolvable conflict between trying to develop more nutritious plant strains and at the same time maintain the full range of traditional stocks? In facing this question, the specialists at CIMMYT have tried to strip it of ethical dogmatism. Their concern is the economic and nutritional benefits that more productive seeds offer peasant farmers in the poorest areas of the world; the contribution that the international community should make to those farmers who, in the areas where our fundamental crops originated, continue to cultivate ecotypes that derive directly from the initial domestication of those plants. No-one who lives in those areas of the world that enjoy high standards of living has the right to expect that the entire cost of preserving ancient crop varieties – justly recognised as part of the heritage of humanity as whole – should be borne by those who live in the poorest regions of the planet.

Abstract

I - MENDEL REDISCOVERED: THE FIRST STEPS TOWARDS A SCIENTIFIC UNDERSTANDING OF HEREDITY

II - AN IMPORTANT STUDY OF CALIFORNIA'S NEW FRUIT FARMING INDUSTRY

III - AN INVENTORY OF THE WORLD'S GENETIC RESOURCES

IV - EXPERIMENTAL RESEARCH: THE SITUATION AT THE END OF THE 1950s

V - THE GREEN REVOLUTION: GENETIC SCIENCE AT WORK TO PREVENT WORLD FAMINE

VI - PEDOLOGY AND THEORIES REGARDING THE DECLINE OF CIVILIZATIONS

VII - CHEMISTRY AND MICROBIOLOGY: THE FOUNDATIONS FOR A NEW SOIL SCIENCE

VIII - SOIL PHYSICS AND PLANT PHYSIOLOGY

IX - FROM HUNTER-GATHERING TO CROP CULTIVATION: WHAT IMPULSE LED TO THE ADVENT OF AGRICULTURE?

X - THE NEOLITHIC REVOLUTION: FROM EXCAVATED EVIDENCE TO THEORETICAL "MODELS"

XI - MOLECULAR BIOLOGY AND THE NEW SCIENCE OF GENETICS

XII - ISRAELI DEVELOPMENTS IN IRRIGATION TECHNOLOGY INVALIDATE CLASSICAL NOTIONS REGARDING SOIL FERTILITY

XIII - LIVESTOCK FARMING: AN INDUSTRY CONVERTING PLANT PRODUCE INTO ANIMAL PRODUCTS

XIV - EARLY AGRARIAN SOCIETIES: THE INCREASING FOCUS OF THE DEBATE

XV - THE SPREAD OF AGRICULTURE AND ITS ROLE IN THE GENETIC AND LINGUISTIC GEOGRAPHY OF EURASIA

XVI - THE BORLAUG LEGACY: WHEAT, MAIZE AND TRITICALE AT CIMMYT

XVII - COUNTERACTING PARASITES WITHOUT DISTURBING THE NATURAL BALANCE OF THE ENVIRONMENT

XVIII - A HORROR OF CHEMICALS: THE TEACHINGS AND THEORIES OF ALTERNATIVE AGRICULTURE

XIX - THE WORKINGS OF WESTERN RESEARCH CENTRES

XX - THE SCIENCE OF LAVOISIER AND PASTEUR IN ASIA

XXI - THE CHALLENGE OF A GROWING POPULATION: CAN AGRICULTURAL OUTPUT DOUBLE OVER THE NEXT THIRTY YEARS?

XXII - THE FUTURE OF GENETICS: DEVELOP NEW PLANTS OR IMPROVE OLD ONES?

XXIII - PRESERVING THE WORLD'S RESOURCES: THE ARABLE LAND, PASTURE AND IRRIGATION NEEDED TO MEET FUTURE DEMAND