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Scientific Breeding in Central Europe during the Early Nineteenth Century: Background to Mendel's Later Work

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Abstract. Efforts to bring science into early 19th century breeding practices in Central Europe, organised from Brno, the Hapsburg city in which Mendel would later turn breeding experiments into a body of timeless theory, are here considered as a significant prelude to the great discovery. During those years prior to Mendel's arrival in Brno, enlightened breeders were seeking ways to regulate the process of heredity, which they viewed as a force to be controlled. Many were specialising in sheep breeding for the benefit of the local wool industry while others were showing an interest in commercial plants, especially fruit trees and vines, and later cereals. Breeders explained their problems in regulating heredity in terms of (1) climatic influences (2) disruption due to crossing (3) sports or saltations. Practical experience led them to the concepts of 'inheritance capacity' and the 'mutual elective affinity' of parents. The former was seen to differ among individuals and also among traits; the latter was proposed as a means of adding strength to heredity. The breeders came to recognise that traits might be hidden and yet transmitted as a 'potential' to future generations. They also grew to understand that heredity would be strengthened when a quality was 'fixed' within a lineage by 'pure blood relations.' Continued selection of the desired quality might then lead to 'a higher perfection.' But the ultimate 'physiological' question about breeding, 'what is inherited and how?,' found no answer. Major figures in this development included Abbot Napp, the one who asked this question and who was due to receive Mendel into the monastery in 1843, and Professor Diebl whose lectures on agriculture and natural science at the Brno Philosophical Institute Mendel would attend in 1846. Here we analyse their progress in theorizing about breeding up until about 1840. In discussing this development, we refer to certain international contacts, especially with respect to information transfer and scientific education, within the wider context of the late Enlightenment.

Keywords: André, Bartenstein, breeding, Brno, Diebl, Enlightenment, fruit, genetic laws, heredity, inheritance capacity, Mendel, Moravia, Napp, Nestler, sheep, vines

Introduction

Baron Emanuel Bartenstein (1769–1838), president of the Brno Sheep Breeders' Association (SBA), never missed a chance to inspire his fellow members to fresh effort. Opening their annual meeting in 1837, he reminded the mixed gathering of breeders, land owners and administrators, industrialists, government officials and academics, rich in experience of wool production and its exploitation, how much knowledge of sheep breeding and wool had expanded since the association's foundation in 1814. He recalled the fruitful achievements of the membership, whose informed contributions had enlightened their meetings up to the very present, in the 'spirit of truth and refined education.'[1] Stressing the uniqueness of the SBA, without equivalent in any other country on the European continent, he expressed his confidence that its activity would continue for several further years. He appreciated the presence of participants not only from throughout the Hapsburg monarchy but also from German lands beyond its borders, who had travelled long distances, with considerable expenditure of time and money. For the programme of the current meeting he had included questions designed to 'penetrate even into the most essential aspects of Merino sheep breeding and wool commerce.' Although he thought it highly probable that much of the truth would continue to elude them, he was confident that 'we shall surely move in many respects closer to the truth.' That very day they were due to address the difficult topic of heredity, to revisit a radical development in terminology from the previous year's meeting to which Bartenstein had made a major contribution.

Sheep breeding as it progressed and developed a scientific basis in Moravia in the early 19th century has been reported in earlier publications, revealing how it was co-ordinated from Brno, the site of Mendel's discovery a few years later.[2] Its history, linked with a growing appreciation of the nature of heredity, before and during Bartenstein's presidency, up to 1837 and a little beyond, can now be analysed in four phases: (1) breeding seeks a scientific basis; (2) 'genetic laws' are defined, and a law of hybridisation is sought; (3) university teaching promotes advances in breeding theory; (4) heredity is recognised as the central problem. This analysis integrates information scattered in some of our

[1] '...bei unseren jährlichen Zusammenkünften der Genius der Wahrheit und der feineren Bildung über den Häuptern der Versammelten schwebte...' [lit. '...the spirit of truth and refined education hung [in the air] above the heads of those assembled at our annual meetings...'] (Bartenstein et al., 1837, p. 204).

[2] Orel, 1977, 1997; Orel and b; Wood, 1981, 1998, 2000a,b; Wood and Orel, 1982, 2001, pp. 171–187, 191–274.

earlier publications with new material drawn from primary sources. We use the term 'theorizing' in relation to breeding, to describe the process by which certain SBA members attempted to define a framework of underlying generalisations and explanations to underpin the new empirically developed procedures. A quest for 'sound theory' (*gesunde Theorie*) and 'pure principles' (*Grundsätse in Reinen*) was pursued.[3] From the outset, members would encourage one another to devise experiments to test the truth of their theories. We follow this analysis with; (5) a section on the wider historical-cultural background to the developments we have described. We then return to the Moravian situation for; (6) a final discussion and conclusions section, in which we refocus on the search for a theory of heredity and introduce Mendel into the picture.

Breeding Seeks a Scientific Basis

Efforts to bring order into Moravian breeding had an early, if tentative, beginning. In 1765 the central authorities in the Hapsburg monarchy drew up plans to organise learned societies to promote agriculture in every province. A Moravian Agricultural Society (MAS) was established in 1770 but struggled to exert its intended impact. Meanwhile a growing interest in the natural sciences stimulated a private initiative among a group of educated citizens of Brno who, in 1790, began to hold meetings as the *Friends for the Furtherance of Natural Sciences and Knowledge of the Country*, modelled on an association of the same name established in Berlin.[4] A distinguished outsider Christian Carl André (1763–1831), author of books on natural sciences became one of the *Friends'* leading members. He had moved to Brno in 1798 from Saxony, to take a teaching position at the first Evangelical School in Brno. Both societies benefited from the enthusiastic support of Count Hugo Franz Salm-Reifferscheidt (1776–1836), Moravia's leading industrialist, wealthy and widely educated. In his castle at Rájec (Raitz), not far from Brno, Count Salm had a fine library of 59,000 volumes, rich in works on natural science and technical subjects, but also on art history, the occult, alchemy and freemasonry. After visiting England to study the development of natural sciences and the application of the latest discoveries in agriculture and industry,[5] he co-operated with André in organising

[3] Wood and Orel, 2001, pp. 6–7, quoting the Vienna-based Bernard Petri (Irtep, 1812) and André (1816) from Brno.

[4] Exner, 2002.

[5] d'Elvert, 1870, ii, p.111.

the fusion of the two societies. That was in 1806 when he became the new society's president, with André as secretary. The name of the new society was settled in 1811 as *The Royal and Imperial Moravian and Silesian Society for the Furtherance of Agriculture, Natural Sciences and Knowledge of the Country* (MAS). By that time André had become Salm's economic advisor, a position that gave him added influence, as well as freeing him from dependence on teaching for a salary.[6]

At the opening meeting of the MAS, André presented a programme of future activities that would characterise the society as a centre for both scientific and economic advancement. 'Without science,' he wrote, 'it is impossible to achieve any progress.' Paying special attention to the 'most useful auxiliary sciences,' above all mathematics and chemistry, he used discoveries by Newton and Copernicus to illustrate the value of attacking fundamental new problems in natural sciences in new ways: 'May these examples strengthen our honest zeal and enrich us, even though it may take centuries for works to emerge from our circle that are capable of earning the astonishment of the cultural world, and its gratitude for their public value. Whether today or tomorrow we are perhaps providing indispensable elements without even a hint of their future impact.'[7] Science in the late 18th century had been defined, in an agricultural context, simply as 'an accumulation of acquirements by a long succession of individuals. . .preserved throughout all ages by the art of writing. . .'[8] Members of the MAS would expand this definition considerably.

As the major textile centre for the Hapsburg monarchy, Brno became known as the 'Austrian Manchester.'[9] André's arrival there opened his eyes to the possibility of improving the quality of wool by bringing a greater scientific input into sheep breeding, for the benefit of the industry and thus the prosperity of both city and region. Recognising the economic potential of the most up-to-date breeding techniques developed and established in England, for the more efficient production of meat, he sought to promote their application to wool improvement. To spread his ideas on this matter, and also other important scientific developments with possible economic potential, he began in 1811 to edit a weekly journal *Economic News and Proceedings* (*Oekonomische Neuigkeiten und Verhandlungen* (ONV)), published in Prague and distributed across much of Europe in 6000 copies. The first issue of

[6] Franke and Orel, 1983, p. 52.
[7] André, 1815, original in German.
[8] Anderson, 1799, p. 4, quoting Jackson of Exeter.
[9] Freudenberger, 1977, pp. 25, 170, 189.

ONV opened with an editorial on 'how to reproduce imported Spanish sheep, those yielding the finest wool, without a decline either in wool quality or health.' Subsequent issues carried articles describing sheep breeding methods for meat production pioneered by Robert Bakewell (1725–1795) in England, and how the same techniques had been applied, in an adapted form, by Ferdinand Geisslern (1751–1824) in Moravia, for enhancing wool production. The methods were (1) selective breeding for defined traits in both sexes, (2) close inbreeding ('breeding in-and-in') to fix these traits, i.e. to produce a strain of consistent breeding quality, (3) progeny testing as a further aid to ensuring uniform quality and avoiding inherited imperfections.[10] The traits targeted for improvement at this time were mainly concerned with the grade of the fleece (i.e. its monetary value) although body form was also coming into consideration in relation to both fleece weight and fitness. In 1816 the grade of a fleece was being judged according to its weight after washing, its uniformity over the body surface, its greasiness and, above all, the fineness of the fibre (staple). On this basis, it was possible to classify fleeces into 82 grades, varying in price from 39 to >650 florins per 100 head.[11] Practical considerations later revealed that other wool features were important to the factory weavers, most notably the tensile strength of the fibre, which affected subsequent prices.

By means of his journal André informed breeders about how various aspects ('traits') of wool quality and body form might still be improved. Within a year, he was proposing the establishment of an association where sheep breeders could meet together and interact with others connected to the wool business. The Association of Friends, Experts and Supporters of Sheep Breeding for the Achievement of a More Rapid and More Thoroughgoing Advancement in this Branch of the Economy, and of the Manufacturing and Commercial Aspects of the Wool Industry that are Based upon it was finally established in 1814, as a section of the MAS.[12] It was the first animal breeding society on the European continent, and the only one in which specialists in sheep breeding could meet together with experts from the worlds of industry, science, commerce, administration and education, in free communication. Soon abbreviated in title to the *Sheep Breeders' Association* (SBA), it attracted experts from long distances to its annual meetings. André published the proceedings in instalments in the weekly issues of ONV,

[10] Wood and Orel, 2001, pp. 191–216, 222–229.

[11] Wood and Orel, 2001, pp. 200–202.

[12] *Verein der Freunde, Kenner und Beförderer der Schaftzucht, zur noch höheren, gründlichen Emporhebung dieses Oekonomie-Zweiges und der darauf gegründeten, wichtigen Wollindustrie in Fabrikation und Händel.*

which also carried articles inspired by the meetings, and his comments upon them. Being published in Prague, ONV attracted a wide readership. In promoting scientific rationality and natural law, it can claim to represent an important element in the Central European Scientific Enlightenment. The editor and his correspondents laid consistent emphasis on the concept of *Veredelung*, corresponding with the English words 'improvement' or 'refinement.' They also wrote commonly of practice-based knowledge (*Erfahrung*), and, as time passed, they began to look for explanations in terms of theory.

Through ONV André also kept track of agricultural and horticultural developments abroad. The latter aspect encouraged him in 1816 to establish a *Pomological and Oenological Association* in Brno, as a further section of the MAS. Its declared aim was to apply artificial fertilisation for the creation of new fruit and vine varieties. The name of the group was later shortened to *Pomological Association* (PA).[13] It continued active for many years, in parallel with the SBA, with some overlap in membership.

For the time being, however, wool production continued to be the major economic issue. At André's suggestion his son Rudolf André (1798–1827) spent several months in residence with Geisslern on his estate at Hoštice, 60 km to the east of Brno. Enthusiastic to reveal Geisslern's sheep breeding expertise to a wider world, the younger André published in 1816 a textbook describing 'principles derived from nature and experimentation.'[14] He had become convinced that breeders in Moravia had the skill not merely to maintain the high quality of the imported Spanish sheep but also to improve them beyond Spanish quality. He was credited with 'describing in detail and to the fullest extent the most important and most difficult aspect – the business of improvement – which up to now no author has treated satisfactorily.'[15] The book continued to be used for the instruction and examination of shepherds until at least 1837.[16] Through the techniques that the younger André explained, the Merino sheep of the region were transformed, becoming increasingly uniform in the quality of their fine wool, and changing in appearance to a more stocky form with a heavily wrinkled skin.

[13] Orel, 1977.

[14] André, 1816, original in German.

[15] Anon, 1816.

[16] Bartenstein et al., 1837, p. 202. 'The public examination of shepherds was performed on 1 May by Professor Diebl according to R. André's textbook. It was held in both provincial languages [Czech and German] in the presence of the secretary of the society and some sheep breeders.'

The book spoke of the application of science in breeding, a claim that found support in the early SBA minutes, together with published articles. By this was meant the obtaining of predictable results from specific procedures with increasing certainty, the refining of procedures still in development, backed by clearer definitions, if possible on a quantitative basis (e.g. by optical measurements of wool fineness), and the challenging and controlling of nature. As knowledge expanded, the two Andrés, father and his son, became fascinated with the idea of defining 'laws,' i.e. extracting generalisation from breeding records, that would make breeding more predictable, and of searching for causal explanations, to be confirmed by experiment. 'Science' as they defined it was all of these things.

Genetic Laws and a Law of Hybridisation

The old adage that 'like engenders like,' said to have been the basis of Bakewell's breeding success, is an obvious example of a 'law' subject to frequent exceptions in relation to racial/varietal characters, as every breeder, including Bakewell, well knew. Martin Köller (1779–1838), one of Geisslern's close associates, made an attempt at modifying it as follows: 'Noble sheep without hereditary defects (*Erbfehler*), crossed with ewes without hereditary defects, produce offspring also without hereditary defects.' He claimed this to be 'the law and process of nature.'[17] Later breeders would modify it still further as they came to realise that just because a sheep did not show a defect, it could not be assumed it was not carrying it.[18]

In the younger André's book we can find further statements written in the manner of laws based on experience. Two that deal with the question of racial purity, reveal an attempt at theorizing in terms of 'pure blood relations' and a potential for a higher perfection.

> With care and attention, a merely noble flock can be raised to the pure race if one refrains from intermixing alien bloods and, through an appropriate control of pairings, brings together specific characteristics, with respect to the body build[19] and wool of these animals, which will then be transmitted to the progeny and preserved in the same degree. In this way something constantly unique

[17] K in Mähren, 1811, original in German.

[18] Festetics, 1819, see below.

[19] The body build favoured in the Merino was that which was associated with the highest yield of the finest quality wool in an animal of robust constitution.

> arises, something fixed in the organisation of these animals, something derived totally and exclusively from pure blood relations [*aus lauter Blutsverwandten hergeleitete*], which is characteristic of the lineage.[20]
>
> The whole art lies in keeping animals pure and unmixed and particularly in showing skill and judgement in individual pairings in a masterly way ... Such animals possess the natural capacity (*Fähigkeit*), the potential (*Anlage*) for a higher perfection ... and one should merely assist Nature to develop the extra potential towards perfection, and thereby victory is achieved.[21]

We may note the absence of any suggestion here of an influence on a breed's characteristics coming from the Moravian environment. All emphasis is placed on the blood (of both sexes) and the potential it carries. The young André's confidence in doing so was informed by Geisslern's personal experience.

Progress in breeding methods is recorded in the minutes of the annual meetings of the SBA in 1818–1820, and in published articles from members, stimulated by their experience at the meetings. The search for breeding theory, beyond what the younger André had written in 1816 in his book, is also recorded. Were some characters better inherited through one sex than the other? How was 'perfection' to be defined? Was 'originality' the ideal state? How could the breeder ensure 'constancy' of a breed's characteristics without degeneration?

Especially challenging was the report for the meeting in 1818.[22] An unnamed Count C., most probably from Stuttgart, the city to which the elder André would move in 1821, had instructed a representative to attend this meeting and learn all he could about 'the excellent sheep races in Moravia.' With a letter written to the elder André after the meeting, Count C. enclosed a copy of the representative's report, which André found appropriate to publish in ONV. In an editorial note he explained that the author was 'a doctor of philosophy who has been working for 4 years in animal economy.' To the doctor's four-page report, André added 14 notes of his own, occupying another eight pages.

The report revealed that the 1818 meeting had opened with contributions by Count Emmerich Festetics (1769–1847) from Hungary, Baron Johann Marcus Ehrenfels (1752–1843) from Austria and Mr Moro, an Austrian expert from the textile industry. These three speakers stimulated a discussion which, according to the reporter,

[20] André, 1816, p. 9, original in German.
[21] André, 1816, pp. 95–96, original in German.
[22] Anon, 1818.

constituted the 'theoretical part of the meeting,' aimed at examining controversial principles. In fact the 'theory' centred largely on practical breeding techniques, about which opinion was often sharply divided. Festetics, supported by Baron Bartenstein, president of the SBA, defended the view of the 'highly esteemed' Professor Albrecht Thaer (1752–1826) in Berlin, that sheep should first be selected for wool density and for wool fibres of high tensile strength (*Starkhaarigkeit*), and then crossed to rams with fine wool. This was in contrast to the policy proposed by Ehrenfels who preferred to select sheep first for fine wool and then cross them to rams with dense, strong wool. According to Ehrenfels, Thaer expected that improvement of a flock by his method would take 10 years, whereas Ehrenfels prophesied 2 years by his own approach, a claim received by his fellow participants with scepticism. Such 'theory' as was advanced in support of each of these practices, was not supported by experimental evidence. Only experience would tell the most effective course for their fellow breeders to take. Moreover, we may note that the difference was not as extreme as might seem at first sight, for it was becoming known that wool fineness was directly related to fibre density, Merinos having the densest ('closest') wool of any breed.[23]

Another controversy at the 1818 meeting arose when Bartenstein and Festetics defended consanguineous mating. They argued along the same lines as the younger André had done in his book in 1816; that the inbreeding procedure was valuable for ensuring the continuity of the pure Merino race, to retain the characteristics of the original imported Spanish stock. In response Ehrenfels claimed that inbreeding had quite the opposite effect, actually causing degeneration, for which reason he challenged the common opinion that Spanish Merinos constituted a pure race. He claimed that the sheep produced in Spain were not a pure uniform stock but 'mongrels' (*Bastards*), and that the constant quality of their fine wool was determined by the local Spanish climate, experienced over many generations. Outside Spain such sheep were liable to 'natural climatic degeneration' (*die natürliche klimatische Rückbildung*), also referred to as climatic 'reversion' (*Rückschlag*), the first effect of which would be a decline in wool quality, which inbreeding would only accelerate.[24]

The elder André's reaction was to look for compromise and recommend caution. He stressed that controversial practices require a level of expert knowledge and a capacity to reason not open to everyone. To avoid confusion such practices must be clearly and precisely formulated and described using agreed terminology.

[23] Anderson, 1800, p. 164.
[24] Anon, 1818, p. 298.

Referring to the word 'crossing,' as an example, he was convinced that when Ehrenfels described Spanish sheep as 'mongrels,' he did not have in mind crosses between sheep of different races but only the 'refreshing' (*Auffrischung*) of an already improved flock with better individuals of the same race. André agreed with Ehrenfels that when inbreeding was carried out without regulation it must be detrimental. It was a 'physiological natural law' that 'unqualified pairing in nearest consanguinity is followed by weakening of the organism.' At the same time inbreeding offered great advantages in the right context.

To focus attention on some of the unresolved issues connected with inbreeding, the elder André published a series of questions that still needed to be answered: Is the concept of inbreeding in sheep already clear? What does weakening mean? Does weakening affect constancy of wool fineness? Is weakening associated with susceptibility to disease? Does weakening affect the constancy of individual traits in succeeding generations? How long (for how many generations) does wool fineness remain constant? What will happen to wool fineness in the distant future? Are the current farm experiments on these matters being undertaken carefully and accurately? Are they provided with adequate numbers of animals? Are the production data truthfully recorded in the stock register? When results are evaluated, is due attention given to climatic variations and nutrition? How precisely is the quality of traits recorded in the progeny of parents in all aspects?

Recognising the complexity of every one of these queries, André added, 'I would have to write a book, were I simply to pursue and debate these questions.' His conclusion was that only by recognising the potential for considerable misunderstanding about the valuable procedure of inbreeding with selection, and the subtle problems that still needed to be solved, would members be able to interpret experiments under way and thus approach nearer to the truth. This was because, as he warned, 'we are penetrating here into the innermost secrets of Nature.'[25] In order for members to reach an understanding of one another's position on the matter, they needed to define exactly what they meant. Only then could their actions be considered scientific.[26] André expected them to explain their different views and investigations about inbreeding

[25] Anon, 1818, p. 303, original in German.

[26] See Anderson (1799, pp. 2–4) for an earlier statement of this principle, quoting 'Mr Locke who began his essay on human understanding, by shewing (*sic*) the necessity of adverting to the precise meaning of words. The same thing ought to be done respecting agriculture. . .'

in further detail in ONV. Ehrenfels promised to send his explanation, but the sceptical André was afraid that he would write too briefly, resulting in further misunderstanding, noting in Latin '*dum brevis obscurus fio*.'[27]

Responding to André's call to consider inbreeding in further detail, Festetics summarised his views by defining four empirically based *genetic laws,* stating:

- Animals of healthy and robust constitution are able to propagate themselves and pass on their characteristics.
- Traits of grandparents not reproduced in their immediate progeny may reappear in later generations.
- Animals possessing the same suitable traits can sometimes have offspring with divergent traits. Such progeny are variants, freaks of nature, unsuitable for propagation if heredity is the aim.
- The precondition for a successful application of inbreeding is scrupulous selection of stock animals. Only those animals possessing the desired characteristics with notable distinctiveness can prove effective when inbred.[28]

The last point was firmly endorsed by André whose wish to achieve the applied scientific aims of the MAS, 'better illuminated and richer in profit,' caused him always to pay close attention to the techniques of the more successful breeders. Differences in stock quality could be a telling indicator of the value of the actions of their owners. André is here affirming the role of careful scientific/technical attention in the building of a profitable commercial enterprise. Count C's reporter at the meeting recorded the evidence of SBA experts who evaluated the quality of wool samples from a number of sheep exhibited there. Particular interest was shown in two rams and two ewes from the Austrian farm of Ehrenfels, exhibited as examples of 'the Electoral race,' which he had earlier obtained from Saxony, where they had been bred directly from the descendants of Spanish imports. Wool labelled 'Electoral' was then attracting a price one third higher than any other type of wool in the London market. Almost certainly to Ehrenfel's surprise, the experts pronounced his wool inferior to that of sheep exhibited by Geisslern and Festetics.

To those who really knew the wool business it was clear that attaching the label 'Electoral' to a sheep was not an automatic indicator

[27] Anon, 1818, p. 303. This is a modification of Horace's '*Brevis esse laboro, obscurus fio*,' 'In trying to be concise, I become obscure.'

[28] *genetische Gesetze der Natur;* Festetics, 1819; see also Orel and Wood (1998).

of the quality of its wool. True, there was a form of Merino sheep known by that name in Saxony, comprising some of the smallest and thinnest individuals of the Merino race, some of which yielded wool of exceptional fineness. It was equally true, however, that the Electoral wool, as marketed in London and elsewhere, was not only the product of a particular sub-race of Merino sheep, maintained under Saxon conditions. The quantity of wool produced under the Electoral label was much too great to be attributed to these sheep alone. It was simply the best wool picked out from fleeces derived from different German, Austrian and Hungarian sources, graded mainly in Leipzig and exported under the single label.[29]

Stimulated by the wool quality comparison, the elder André took the opportunity to ask a further series of questions designed to expose further gaps in theoretical knowledge about sheep breeding. These were questions relating to racial concepts yet to be properly defined, those of 'originality,' 'constancy' and 'perfection:' What does the 'original race' actually mean? Is it restricted to sheep *freshly imported* from Spain? Are all sheep imported from Spain of the same quality? What is 'original wool quality' of Spanish sheep when it is known that there are some sheep in Spain that produce wool of much lower quality? What are the constant traits of original Spanish sheep? How do we define wool from the most perfect Spanish sheep? Can we speak of 'absolute' and 'relative' perfection in wool production?

André saw clearly that there were questions arising out of his son's book, based on Geisslern's experience, which still demanded critical attention by the SBA. While he accepted that the 'original race' meant the 'pure noble race' imported from Spain, a flock of which was expected to 'breed true' for its exceptionally fine wool, he also recognised the possibility of 'recreating' it by selective breeding from the progeny of out-crosses to Moravian sheep. The theory to ensure the success of this difficult and time-consuming procedure was not yet known.

One aspect of breeding on which the participants could agree, because they could determine it with 'scientific' accuracy, was the target towards which they should aim their selection. The major distinguishing feature of the 'pure noble race' was the exceptional fineness of its wool, which could be defined by scientific measurement with a micrometer, a frequent subject for discussion by the SBA at that time. At the 1819 meeting the younger André demonstrated a microscope specially adapted from a French design of micrometer for evaluating wool into

[29] Wood and Orel, 2001, pp. 161–162.

seven grades of fineness, an advance receiving enthusiastic praise from Festetics: 'It will be judged as marking the beginning of a new episode in the science of breeding, that in 1819 grades of wool quality were established and defined with mathematical precision.'[30] The role of scientific/ technical expertise in the building of a successful commercial enterprise is again being stressed. It was a constant theme of SBA meetings.

Absolute perfection in any particular sheep remained elusive; there seemed always room for improvement. The younger André had made clear in his textbook that there could be no final limit to the improvement of a race, taking into account 'the potential for a high degree of perfection' (*die Anlage für eine hohe Vollkommenheit*).[31] To make the improvement procedure more effective, he had recommended that all animals in a flock should be numbered, with all parents and their progeny recorded, as standard procedure. The conclusion we find ourselves drawing from the elder André's (1818) questions on 'originality,' 'constancy' and 'perfection' in sheep is that these issues had not yet, in his opinion, been properly considered.

Just as the elder André was wrestling with problems in sheep breeding, he was finding equally subtle questions to be answered in plant breeding. Second to his interest in sheep and wool was the establishment of the PA. From its inception in 1816, he was publishing its proceedings in ONV. As secretary of the MAS he was also communicating news from the Horticultural Society of London, established by Thomas Andrew Knight (1759–1838), and the PA at Altenberg near Leipzig where his friend Georg Carl Ludvig Hempel was secretary. In 1820 André asked Hempel to publish an article in ONV explaining the application of artificial fertilisation for creating new cereal varieties. In his paper Hempel stressed that 'higher scientific pomology' had the potential to allow the breeder to create new varieties of fruit trees according to preconceived ideals. The only barrier was the absence of an explanation of *the law of hybridisation* applied to sexually reproducing plants. Was there a law that would allow the breeder to predict the results of a given cross? Hempel expected that the definition of such a law, at some time in the future, would contribute to an increase in plant production.[32] His essay stimulated members of the PA to apply Knight's methods of artificial fertilisation and selection for creating new fruit and vine varieties. Sedláček von Harkenfeld (1760–1827), second president of the PA, was one who experimented with

[30] Festetics, 1820, p. 33, original in German; Wood and Orel, 2001, p. 232.
[31] André, 1816, p. 95.
[32] Hempel, 1820.

inter-varietal vine crosses. Later he would publish a report, based on experience, stating his conviction that new varieties produced this way would be capable of yielding better wine than from known varieties, 'even from abroad.'[33]

The sheep breeders had also made crosses to generate variability but had found that chaos had been the result without stringent selective inbreeding. It was common experience that whereas the first generation from an inter-racial cross (hybrid) might be quite uniform, the second generation could be highly variable and unpredictable: 'It is a universal property of hybrids that in their progeny there appear traits reminiscent of the parental forms with great variability.'[34] It was well recognised, however, that the hybrid progeny had the potential to provide a rich foundation for selection in new directions. When, a few years later, certain crosses were made between the Negretti and Escurial races of the Merino in Austrian Silesia, they would lead to a highly successful union. Partly based on Geisslern's stock, this Escurial-Negretti *Vollblut* (Thoroughbred) race combined the best in fibre quality with a heavy and uniform fleece, and was greatly admired, both in the German-speaking world and beyond, even as far as Australia.[35]

University Teaching of Scientific Breeding Promotes Advances in Breeding Theory

In 1821 the elder André was forced to leave the territory of the Hapsburg monarchy because of his liberal views. As an Enlightenment figure, a true innovator, his personal philosophy extended to notions of individual liberty and social justice, as well as scientific rationality and natural law. He moved to Stuttgart where he became scientific advisor to the king.[36] His contribution to open debate with free expression of differences of opinion was greatly missed, but progress through experimentation with open communication of results, continued its momentum, which, as one member later commented, 'according to natural law cannot be stopped.'[37]

After André's departure his former colleagues in the SBA and PA reported their activities in a new weekly journal 'Memoranda' (*Mittheilungen*), produced by the MAS. Both SBA and PA were attracting

[33] Sedláček, 1826.
[34] Elsner, 1826, original in German; see also Wood and Orel (2001, p. 251).
[35] Wood and Orel, 2001, pp. 184, 185, 188–189.
[36] Wilhelm, 1867.
[37] Waniek, 1845, pp. 263–264, original in German.

important recruits to their ranks, from different sections of Moravian society, and the membership of the two associations continued to overlap. At the 1822 meeting of the SBA, the lawyer and estate owner Franz Anton Teindl (1768–1859) claimed that correct breeding principles established in Moravia had already raised 'the culture of sheep breeding to the status of science.'[38] In 1823 Johann Karl Nestler (1783–1841), who previously collaborated with André senior in publishing his journals, came to occupy the Chair in Natural History and Agriculture at the Moravian University of Olomouc.[39] By 1827 he had introduced the subject of scientific animal and plant breeding into the syllabus of his teaching. Meanwhile Cyrill Franz Napp (1792–1867) had been appointed abbot of the Augustinian monastery in Brno where responsibilities were immediately thrust upon him in connection with the management of the monastic estates, from which the principal source of revenue came from sheep.

When Napp arrived in Brno in 1824 he found the economy deeply dependent on the clothing industry. The manufacturers and merchants had good cause to appreciate the value of high quality wool and to support every means of obtaining it. The prosperity of their rapidly growing city was becoming increasingly dependent on locally bred sheep. Improvements in this direction were paralleled by the production of new varieties of fruits and vines, field crops and ornamental plants, all increasingly in demand from an urban population growing in size and relative affluence. In Brno we see the growth of a truly entrepreneurial community. Napp himself encouraged this spirit, above all in commercial breeding activities through his influential membership of various societies and their committees. Within a year he had became a member of the MAS, and 2 years later a member of its committee.[40] He joined both the SBA and the PA. In 1827 he was elected president of the PA, his personal breeding interest being pomiculture. The secretary-ship went to Franz Diebl (1770–1859), self-taught in agriculture but rich in practical experience. Through the influence of Napp came the appointment of Diebl as Professor of Agriculture and Natural History at the Philosophical Institute of Brno.[41] Each of these three figures, Nestler, Napp and Diebl, played a vital part in promoting the growth of knowledge of breeding in both animals and plants. Their contributions to discussion, in both the SBA and PA, invariably had a practical intention; they also shared a progressive interest in theory.

[38] Teindl, 1822.
[39] d'Elvert, 1870, ii, pp. 280–289.
[40] Orel, 1978a.
[41] Orel and Czihak, 2000.

In 1829 Nestler published his university lectures on scientific breeding as a serialised paper, under the title of 'The influence of generation on the properties of progeny.'[42] He saw every reason to believe that 'in the majority of plants and animals generation is the most important, and in many cases the only, way of multiplying.' As a naturalist he treated animal and plant improvement in a common framework, considering their sexual systems to be homologous. With regard either to animals or plants, he considered that 'fruitful generation with heredity (*fruchtbare Zeugung mit Vererbung*) of all essential characteristics is possible only between two sexes which, in the natural history sense, belong to the same sort (*Art*).'[43]

At the Brno Philosophical Institute Professor Diebl concentrated his attention on plant production, stressing the significance of breeding new more productive plant varieties. Naturalists, he explained, consider only constant (i.e. essential) traits to be inherited. But there are also traits that under special conditions do not reveal themselves, although they may later reappear when conditions change again. Acknowledging the latest information on plant physiology he believed that such traits appear 'through hybrid fertilisation,' still an unknown 'force.'[44] In his textbook on Plant Production, in 1835, he described the application of artificial fertilisation to obtain new combinations of traits, reproduced as new varieties.[45] We thus see an apparent change in his attitude to inheritance between 1829 and 1836. His caution about the origin of non-essential traits in 1829 (whether due to changed conditions or 'hybrid fertilisation') had evaporated by 1835. Evidence from artificial fertilisation was by then proving beyond doubt that even traits defined by naturalists as non-essential could be firmly inherited.

The change in attitude to inheritance had been progressive. Publishing activities by professors Nestler and Diebl led the SBA to exchanges of evidence and opinion published in the pages of *Mittheilungen*. Nestler, who valued the technique of inbreeding to fix the type, rejected the concept of racial constancy introduced by Johann Christian Justinus in 1815 for horse breeding, stating that 'constancy without deviation can never be found anywhere'[46] The SBA members had come to recognise three causes of imperfect heredity (1) climatic influences, (2) disruption due to crossing animals with different essential characteristics, and (3) sports or saltations. The remedy was to be found

[42] Orel, 1978b; Nestler, 1829
[43] *Vererbung* could equally be translated as 'inheritance.'
[44] Diebl, 1829.
[45] Diebl, 1835.
[46] Justinus, 1815; Nestler, 1836, 1829.

in selective breeding, to control the variability from whatever source it came. As confidence grew in the effectiveness of selection, not only to maintain but also to improve desired qualities in sheep, more attention was given to making crosses to increase the basis of variability on which selection could act in new directions. The procedure was believed to provide an enriched breeding stock from which, through carefully chosen pairings between male and female, quality could be advanced to new levels. Disruptions in heredity due to crossing could be controlled and exploited. At the 1831 meeting, Ehrenfels, still active in the SBA at the age of 79, spoke up to lay stress on the 'genetic force' as the major 'lever of nature:' 'Climate, nutrition and generation remain the levers of Nature in the formation of matter. In the interaction of these three potentials, generation, the genetic force, is the most powerful.'[47]

Another participant at this meeting, hearing Ehrenfel's comment, reacted with enthusiasm, noting how 'man can deliberately remove something or add something, moderate or shape differently' the bodies of selected animals.[48] The intention was to generate novel types with potentially valuable combinations of features, for example to improve wool, body form and meat quality together, or to associate superior wool with a high fleece weight. The plant breeders were engaged in the same kind of activity, attempting to combine different quality traits in different varieties.

Heredity is Identified as the Central Problem

Progress in sheep breeding was examined critically at the meeting in 1836. Following usual practice, the participants attended an evaluation of sheep exhibited for the occasion, and watched while shepherds were being examined according to the younger André's textbook (1816). Appreciating the fine quality of the best ram on show, Bartenstein raised the question of whether the quality of its wool would certainly be transmitted to its progeny. The members of the expert committee answered positively that it would be so if the ram were paired with *adequate* ewes. Because Bartenstein and his members based their practice on the younger Andre's book (founded on Geisslern's practice), it is clear that 'adequate' ewes could only mean ewes of the same blood, as well as of the necessary quality. In this context, Bartenstei'n chose to use the term 'inheritance capacity' (*Vererbungsfähigkeit*),[49] which recalls the

[47] Ehrenfels, 1831, original in German.
[48] Mayer, 1831, original in German.
[49] Teindl et al., 1836, p. 303.

younger André's earlier mention of pure bred animals having the 'natural capacity. . .for a higher perfection' (see above). In using the new expression, incorporating the word '*Vererbung*,' the breeders were breaking new ground. Up until then, they had associated an animal's capacity to reproduce its type in terms of its overall reproductive potency, the more effective partner in a cross being referred to (in English) as 'prepotent.' Bartenstein prefers (i.e. sees the commercial need for) an entirely new, more closely defined term for this quality (the 'genetic force' possessed by any particular individual), one that does not automatically embrace the idea that an individual's capacity to transmit its traits is necessarily associated with any other superior quality. It may be recalled that the first of Festetics's genetic laws (see above) associates heredity with a healthy and robust constitution. Bartenstein's term *Vererbungsfähigkeit* refers only to an individual's capacity to transmit its traits. It assumes no link between reproduction and any other characteristic, even with fertility.

Bartenstein could see no room for complacency about progress in sheep breeding. He made clear his opinion that infinitely more remained to be discovered, many new problems to be solved, for the investigation of which he saw, at that time, unsurpassable obstacles (*unübersteigliche Hindernisse*). Above all there was the underlying theory of breeding to be exposed, by which he meant the theory of heredity, as revealed by the breeders' own experiences. Thus he makes the point that 'We can attain such knowledge only *a posteriori,* and it is our goal with profound perception, to examine the great mystery of the mighty workshop (*Werkstätte*) of almighty nature.'[50] He warned how very easily such an investigation could be diverted from its course, and turning to Professor Nestler, 'an outstanding expert,' he invited him to offer a beneficial and desirable topic to be discussed. Nestler replied by using Bartenstein's own words. He stated that the most important topic of all for sheep breeding was 'the inheritance capacity (*Vererbungsfähigkeit*) of noble stock animals (*edler Stammthiere*), the most urgent question of our time.'[51] Nestler added that much was still obscure about the transmission of individual traits to progeny. Why, for example, are some traits inherited easily and others with greater difficulty? Nestler is thus applying the concept of *Vererbungsfähigkeit* not only as a means of comparing individuals but of comparing traits. Bartenstein's comment was to repeat his conviction that this was not so much (*sowoh*l) a theoretical question as one to be discovered from practical experience.

[50] Teindl et al., 1836, p. 304, original in German.
[51] Teindl et al., 1836, p. 305, original in German.

Nestler agreed that every keen sheep breeder was in a position to make precise and thorough observations on his flock, and to communicate these for the advancement of the common good. In so doing Nestler revealed his approach to the understanding of heredity in 1836 as being, like Bartenstein's, essentially deductive. He saw his own role as that of co-ordinator, to bring together the precise observations of the keen sheep breeders in order that patterns of heredity should emerge, as a guide to common action.

As the discussion proceeded, the participants began to make free use of the idea of inheritance capacity, as well as employing the terms 'heredity' ('inheritance') and 'inherit' (*Vererbung, vererben*). Count Dominik Eugen Wrbna, an SBA member from Vienna, voiced the concern of many when he commented on the inconsistency of traits in the progeny of crosses, a matter that needed to be investigated. In this context he stressed the value of progeny testing rams before their introduction into the reproduction process. The response of Napp was to consider the role of male and female in terms of their interaction. He was sure that the most certain inheritance came when the members of a mated pair were maximally compatible. The expression he used to describe compatibility was 'elective affinity' (*Wahlverwandtschaft*), a term coined earlier by chemists in relation to their observation that some compounds combined more readily together than with other substances. Johann Wolfgang von Goethe used the expression in his novel *Elective Affinities* to describe spontaneous sexual passion between man and woman. In the minutes we can read: 'Napp maintained that, according to his view the inheritance of traits from the producers to the produced is based on the mutual elective affinity (*der gegenseitigen Wahlverwandtschaft*) of paired animals. Therefore for each ewe, a ram with corresponding internal and external organisation (*Organismus*) should be chosen. This process deserves to be the subject of serious physiological study.'[52] We can only comment that those animals most likely to correspond in both internal and external organisation would be those most closely related, as Napp surely appreciated. So that 'mutual elective affinity' was, in practical terms, 'affinity by kinship.' Nestler responded to Napp's statement with a word of warning. He agreed that when two parents have 'mutual hereditary dispositions' (*Anlagen*) then they will be transmitted with a high degree of certainty to their young. It had to be remembered, however, that the same rule is valid for

[52] Teindl et al., 1836, p. 306, original in German. In 1835 Johannes Evangelista Purkyně (Purkinje) visited the monastery in Brno. At the time he was interested in physiological research on problems related to generation and heredity, and may have spoken to Napp about it.

unfavourable traits as well as beneficial ones. When sheep having traits in common are paired, their defects will also appear with increasing certainty in their progeny.

One of two Kunitz brothers from Pomerania, who bred sheep based on Geisslern's breeding stock,[53] spoke up to enlarge on the point made by Nestler earlier, that inheritance capacity differed not only between individuals but also between traits, some of which passed between generations more readily than others. Coarse wool was easily inherited whereas the maintenance of constancy in fine wool inheritance presented difficulties for most people. Furthermore some traits were clearly associated together in their heredity. Thus extreme fineness was always associated with a fleece of low weight, referred to in terms of 'wool poverty' (*Wollarmuth*). Such differences and interactions between traits meant that breeding stock had to be considered as a whole, in relation to 'the best possible balance (*möglichste Ausgeglichenheit*) of qualities in the fleeces,' above all to what was feasible in relation to 'uniform skin formation' (*gleichmässige Hautbildung*) and 'hair bulb production' (*Haarzwiebel Erzeugung*).[54] 'Uniform skin formation' included the regular folding of the skin into ridges to increase skin area, a Merino characteristic associated with greater fleece weight. 'Hair bulb production' referred to the density of hair follicles which in Merino sheep was recognised as uniquely high, causing exceptional fineness of the fibre.[55]

These points about variation and interaction of traits were providing genetic information of high practical value. Nevertheless the great complexity in inheritance capacity of interacting traits in sheep led Kunitz to comment, from the evidence of breeding experience, that 'man has, however, reached the limit' in determining the reason for this variation.[56] Other members, however, were still ready to try to analyse this variation, at least as far as trying to sub-classify it into catagories.[57] Bartenstein noted that it had still to be determined whether different traits were inherited from father and mother, and if so which of them.[58] With regard to heredity in general, Nestler commented that 'no opportunity for communication and discussion should be neglected,

[53] Janke 1867; Wood and Orel, 2001, p. 207.
[54] Teindl et al., 1836, p. 306.
[55] Anderson, 1800, p. 164.
[56] Teindl et al., 1836, p. 306.
[57] Teindl et al., 1836, p. 307.
[58] Teindl et al., 1836, pp. 308–309.

that might shed a clearer light on this all-important (*hochwichtig*) problem for animal breeding.'[59]

Closing the discussion on heredity in 1836 Nestler asked breeders to keep in mind the topics they had debated and to offer fresh thoughts about them by publishing in the journal *Mittheilungen*. The question of inheritance capacity was to be discussed further at the meeting in the following year, 1837.

On the morning of May 1, the opening day of the annual meeting of 1837, all participants had the opportunity to attend an evaluation of 52 breeding males and 102 ewes from 22 breeding farms in Moravia, Silesia, Austria, Bohemia and Hungary. In the afternoon Bartenstein gave his opening lecture in which he praised the fruitful association of his cultured audience within the SBA during his presidency of the past 24 years, as already described.[60] That year's meeting he was sure would be no different. Referring to an important matter already discussed in 1836, Bartenstein stressed that inheritance capacity must depend on purity of stock enhanced by selective improvement, a quality applying to both sexes. Bartenstein paid special attention to the creation of an improved, true-breeding flock, referred to as a 'race-flock' (*Rasseherde*). He agreed with certain views about heredity, published in *Mittheilungen* before the meeting, these being 'permeated with the accepted truth' that only race-flocks possess the capacity for inheritance. He concluded that through continued pairing and care each sheep flock should improve, in the course of time, to become finally a race-flock, and that after the traits of the flock have been transferred consistently to the progeny, then the flock becomes firmly imprinted (*fest imprägniert*).[61] Even as early at 1816 the younger André had stated in his book that this was possible: 'With care and attention a merely noble flock can be raised to the pure race if one refrains from mixing alien bloods and, through an appropriate control of pairings, brings together specific characteristics of body build and wool, to be transmitted to the progeny, and preserved to the same degree. In this way something constantly unique (*constant originelles*) arises, something fixed in the organisation of these animals, something derived totally and exclusively from pure blood relatives (*aus lauter Blutsverwandten hergeleitete*), which is characteristic of the lineage.'[62]

This then was the secret, as it had been before to Bakewell and his followers in England, to match the parents for their traits, to practise

[59] Teindl et al., 1836, p. 309.
[60] See Introduction; Bartenstein et al., 1837, p. 205.
[61] Bartenstein et al., 1837, p. 204.
[62] André, 1816, pp. 6–7, original in German.

rigorous selection and to fix the type by inbreeding. Individually controlled matings (*Sprung aus der Hand*) were the answer. Even so, racial stability could never be absolute. The Moravian experience confirmed that selective breeding was required even in the race-flock.

The procedures underlying the creation of a race-flock led Bartenstein to raise the question of the mode of origin in antiquity of the original Merino race in Spain. Clearly this seemed to him a perfectly natural topic to be discussed within the context of breeding, an aspect of natural history that revealed links between natural and man-created situations. As discussion moved in this direction, Bartenstein offered two hypotheses which, as he said, 'up to now defy a scientific resolution.' Either the Merino 'originated from Mouflon or Argali, as learned scholars claim,' or their origin was the result of human selection. He preferred the second hypothesis: 'The truth is acknowledged that through care and attention in domesticated circumstances, by persistent, consequential, natural breeding, one can give any animal type (*Thierart*) a completely new likeness (*Gestalt*), of which in recent times the Englishman Bakewell provided fresh proof. Concerning the emergence of the Merino race, I imagine a corresponding picture in nature, and believe that the present Spanish Merino stock appeared first as domestic animals by chance, only later acquiring through (human) intelligence their most respected characteristics and, in the course of time, secure inheritance (*sicheres Erbtheil*).'[63]

He thus admitted the antiquity of techniques for creating a race-flock. The only difference between then and his own time was in the rate at which the changes could take place. He sees the transition from free nature to domestication as 'natural breeding.' Proceeding further with his argument, he considers inbreeding to have been the normal, primitive mode of reproduction in these early moves towards domestication. 'In a world with few human beings and almost no commerce or social co-operation, domestic animals must surely have reproduced by inbreeding. Early on it could have been noticed that both husbandry and climate were important for animal species. Later, under the influence of chance and the factors mentioned, after a long succession of years, races of sheep unknown before were perfected.'[64]

Conscious beyond doubt that he and fellow breeders had no time themselves to rely on chance, Bartenstein returned to the topic of the heredity in selective breeding, and how, increasingly, it needed to be brought under control. The quality of their Merino flocks was still in

[63] Bartenstein et al., 1837, p. 205, original in German.
[64] Bartenstein et al., 1837, p. 205, original in German.

danger of what he called 'one-sided breeding' (*einseitige Züchtung*) when the breeder selected strongly for wool fineness but neglected other traits of equal importance: 'For progress in the refinement business, the challenge for sheep breeding must be for all wool characteristics to be assessed at the same time.'[65] This state of affairs had yet to be achieved. Even when selecting for a single trait, breeding success could be inhibited by the unpredictability of heredity. All too often it was evident 'that (outwardly) homogenous pairings produced heterogeneous offspring.' As noted, it was a problem that had led Napp, the previous year, to propose that ram and ewe had to correspond in both 'internal and external organisation.' External similarly alone was insufficient. Discussion followed on whether inheritance capacity depended on the age of the ram and whether it changed during the course of the mating period. These were both vital matters for breeders but no firm evidence could be offered to reach a conclusion about them in 1837. The sterility of the discussion led Abbot Napp to comment that 'the debate has completely deviated from the proper theme of inheritance capacity. It does not deal with the theory of breeding operations, rather the question is ''what is inherited and how?''(Was vererbt und wie?).[66]

Napp's earlier reference to 'serious physiological study' in respect to an animal's internal and external organisation makes it unlikely that he believed that his question could be answered simply by examining breeding records (both pedigrees and trait registers), the approach favoured by Nestler and Bartenstein. This is not to suggest that he was unwilling to try to make sense of the records. In every respect Napp revealed himself to be highly practical in his attitude to sheep breeding, still then the major source of income for his monastery. His practical attitude can be adduced from the rest of the extensive published minutes of this meeting, which dealt mostly with the care and feeding of sheep, and wool washing. Napp's strong participation demonstrated that, even with respect to such down-to-earth topics, he possessed wide knowledge. However, in regard to heredity his active mind roamed more widely.

Later in the year 1837 Nestler published a serialised paper entitled 'Heredity in sheep breeding,' in which he summarised SBA discussions in the previous 2 years. During this period it had become the practice, both by himself and by his colleagues, to consider heredity independently from the continuing mystery of generation.[67] As he attempted to define the concepts of species and race in the animal kingdom,

[65] Bartenstein et al., 1837, pp. 225–226, quoting Head Bailiff (*Oberamtmann*) Benesch, original in German.

[66] Bartenstein et al., 1837, p. 227, original in German.

[67] Nestler, 1837; Wood and Orel, 2001, pp. 253–254.

corresponding with species and variety in the plant kingdom, he needed to explain how nature seemed to work differently from the human breeder. He noted how nature produces, 'through forces beyond the hand of man,' natural species with undoubted constancy, and how man can exploit the reproductive process to modify the deviations in organic bodies 'with increasing or disappearing inheritance.' In this context of variability under domestication Nestler retained his faith in a deductive approach to analysing heredity. He saw the potential for tracing patterns of transmission of traits from parents to progeny using pedigree registers, either as 'hereditary history' (*Vererbungsgeschichte*) or 'developmental history' (*Entwicklungsgeschichte*), depending on whether study was made of the descendants of the present generation, or the pedigree was traced backwards. In accepting the idea of heredity with change, Nestler put into words what breeders had been proving since even before Bakewell's day. New races, breeding true to their type, could be brought into being by human agency even though man could never create a new species. The latter happened only 'through forces beyond the hand of man.'

During this period of 1836–1837 we can observe the great increase in the use of the word *Vererbung* and its derivatives compared with the practice less than a decade earlier. In the minutes of the annual meetings of the SBS in these 2 years (31 pages), the participants used the German noun for 'inheritance capacity' 17 times, and that for 'inheritance' 9 times, and the verb for 'inherit' 15 times. Bartenstein, the breeder who coined the term 'inheritance capacity,' used it four times during these meetings. 'Inheritance' he used three times and 'inherit' also three times. Nestler, the naturalist, used Bartenstein's new term five times, 'inheritance' three times and 'inherit' five times. Napp used all three terms once. If, for comparison, we examine Nestler's lecture notes (1829) we find only the expression 'generation with inheritance' (see above).

Continuing questions about selective breeding and heredity led Nestler to publish a paper on inbreeding, which he saw as the key to racial constancy.[68] He rejected the view prevailing among traditionalists that inbreeding was a 'spectre' to be feared. Meanwhile Napp in a published statement expressed his faith in the power of science, physiology in particular, which now offered new opportunities for the improvement of both plants and animals. He continued to be puzzled, as he stated that 'nothing certain can be said in advance as to why production (of improved plant varieties) through artificial fertilisation remains a lengthy, troublesome and random affair.' He remarked on the

[68] Nestler, 1839; Orel, 1997.

problem that all breeders faced when attempting to produce new varieties by artificial fertilisation, the impossibility of knowing what significance to attach to chance.[69] Problems remained that were still insoluble but it could not be doubted that much had been achieved in the previous 30 years.

Historical–Cultural Background

We have described how the city of Brno began to wake up to the importance of applying science for the benefit of agricultural production, the definition of science being modified during the course of time. As an accompaniment to industrial expansion and the needs of a growing urbanised population, this fresh approach to agriculture was inspired by the example of countries to the west, particularly England. We have noted how, in the cause of more efficient animal and plant breeding, Christian Carl André, secretary of the modernised MAS, established two specialised associations aimed at transforming breeding from art to science. The first dealt with sheep and wool production (established 1814), in support of the textile industry, the second with fruit tree and vine breeding (established 1816), to supply an expanding retail market. We may characterise the burst of ideas and action associated with these two associations as an aspect of Central European Enlightenment, a fitting prelude to the discovery of Mendel that was to follow. In this connection we have stressed André's key role in this development. He was personally driven by a passion for clear communication of economically useful knowledge. It was he who first brought to the SBA 'the spirit of truth and refined education,' later recalled by Bartenstein.

To place André's actions more clearly within the wider scope of Central European Enlightenment, we need to return to a time in his life before he arrived in Brno, to consider his experience as an educator and writer of student textbooks in Saxony. There he became exposed to the principle of *Philanthropinismus,* a method of children's education in which pupils were encouraged to acquire knowledge from direct and open-minded observation of nature, and freely to exercise their bodies as well as their minds. The first *Philanthropin* school was set up at Dessau in 1774 under the direction of Johann Bernhard Basedow. It owed its origin to Prince Leopold III Friedrich, Franz of Anhalt-Dessau

[69] Nestler, 1841, p. 337, quoting Napp, original in German; Orel, 1997.

('Prinz Franz'), inspired, it is claimed,[70] by visits to the British Isles where he came to appreciate the benefit, both economic and social, of the education provided at some of the English dissenting academies. In particular, he came under the influence of Joseph Priestley (1733–1804), whose far-seeing approach to teaching modern subjects, ignored at Oxford or Cambridge, helped to make him an important figure of the Enlightenment in England.[71] Priestley had earlier led the teaching at Warrington, 16 miles (25 km) west of Manchester, at its famous dissenting academy associated with the Lunar Society of Birmingham. He and his colleagues there practised a non-authoritarian form of education, based, whenever possible, as in the natural sciences, on experimentation. One of Priestley's students summarised his methods as follows: 'His object...was to engage the students to examine and decide for themselves, uninfluenced by the sentiments of any other person.'[72] Priestley's aristocratic German visitor became determined to adapt this approach to the needs of a school he planned for Dessau, 'to introduce the lofty ideals of enlightened *Bildung* (self-cultivation), the maturity to think for oneself, not only in universities but also in primary education,'[73] and he returned home with plans to devise a better approach to children's education than the forceful indoctrination of Prussian classicism. An important contact between the Warrington Academy and the *Philanthropin* development at Dessau was provided by the botanist Georg A. Forster (1754–1794) whose father was a professor at Warrington in French, German and Natural History, and who himself had been briefly there as a student, tutoring younger children, as his father's assistant. Prinz Franz had visited the Forsters in 1775 and from then on they lent their advice on the development of Franz's model school.[74]

The school at Dessau inspired several imitators in the German states. Christian Gotthilf Salzmann (1744–1811), who taught religious education at Dessau, applied a similar educational philosophy to the *Philanthropin* school he founded at Schnepfenthal, near Gotha, in 1784. André's connection began when he became a teacher at the Schnepfenthal school from its foundation. Earlier he had visited Dessau to learn all he could there, including the exercises for physical education they had devised. Within a year of teaching with Salzmann

[70] Umbach, 2000, p. 49.

[71] Porter, 2000, p. 406, 'Largely ignored by most historians of the Enlightenment, Priestly is central to the distinctive arc of British achievements.'

[72] Rössner, 1986, p. 30, quoted by Umbach, 2000, p. 47.

[73] Umbach, 2000, pp. 20, 45, 47; further insights on the educational background to the German Enlightenment are to be found in this interesting book.

[74] Umbach, 2000, pp. 101–102.

he was specialising in the natural sciences. His principal interest, mineralogy, led him to become a founder member of the Mineralogical Society of Jena.

The ideas of *Philantropinismus* also influenced basic education in the vicinity of Mendel's birthplace. André reported most favourably on the Education Institute founded in 1792 at the Castle of the Countess Maria Walpurga Truchsess-Zeil at Kunín (Kunewald). He recognised it to be a school directly influenced by the achievements of Salzmann's school in Schnepfenthal. By the 'diligence and skill' of Pater Johann Andreas Edmond Schreiber (1769–1850), the gifted children from that county were educated for practical life, and also in basic aspects of natural history. Their teacher was an authority on fruit tree breeding and had created a first class nursery with varieties obtained from France. The Institute, widely admired, began by 1800 to attract criticism from the District authorities who claimed that the teaching of natural history suppressed religious education (e.g. in relation to the fertilisation of animals). In 1802 Schreiber was dismissed and transferred to the parish of Dolní Vražné (Gross Petersdort). In 1814 the Institute itself was closed down. Mendel's birthplace Hynèice (Heizendorf) belonged to Schreiber's parish. This most educated and liberal minded priest, a founder member of the PA in Brno, had a great influence on Mendel's education in the 1830s, and in recommending him for higher education.[75] It was from Schreiber that Mendel had learned, even as a boy in the village school, the main techniques of fruit tree improvement.

André's move to direct his energies towards agricultural developments, particularly in relation to breeding, came after entering the employ of Count Salm. As we have seen, Salm's own enthusiastic progress in this direction followed a visit he made to England in 1801. Accompanying him was Vinzenz Petke (1753–1804), a Silesian from Troppau (Opava), one of André's close friends, a well-respected pharmacist from Brno, who acted as chemical consultant to the Brno textile industry. His multiple interests, extending into mineralogy and botany, as well as entomology, backed up by a broad knowledge of chemistry, had gained him the reputation of being a truly enlightened patriot. In d'Elvert's '*History*' (1870), Petke receives concentrated attention in 10 pages of text. From this account, we can see agricultural improvement in Moravia and Silesia arising from a general intellectual ferment, mediated by educational advances, as well as economic pressure from industrial expansion.

[75] Orel and Vávra, 1979.

Before making his life-changing journey Salm had consulted a fellow Moravian aristocrat who was famous as an enlightened multilingual traveller. This was Count Leopold Berchtold (1759–1809), with an estate not far from Geisslern's. In 1788, on the first of five visits to England, the Count famously stayed for an extended visit in Bury St Edmunds in close association with Arthur Young. As a welcome guest in Young's household, he was appreciated for his self-denying character, patriotism and exceptional intelligence. He had arrived in England armed with an almost endless list of technical questions, including many on agriculture, including sheep breeding, on the basis of which he wrote a book in English *An Essay to Direct and Extend the Inquiries of Patriotic Travellers* (1789), dedicated to Young.[76] Having such a knowledgeable traveller close at hand, it was natural that Salm should consult him before setting out on his own visit. Berchtold, who must have been delighted to advise a friend and fellow freemason intending to adopt the role of 'patriotic traveller,' was able to guide him towards making the most technically informative as well as influential contacts, in order to ask questions likely to evoke the most useful responses.

Salm's own visit revealed above all his hunger for information of technical advantage to his business interests. He contacted Sir Joseph Banks with whom he had information to share on Merino breeding which Banks was eager to encourage in Britain. Moravia could produce the wool but needed urgently to introduce English-style industrial textile production. Salm's determination to accelerate this advance led him secretly to smuggle back to Moravia drawings of British spinning machinery and other preparatory textile machines.[77] The visit also provided a chance for him to enrich his extensive castle library with English books. One year later his connection with Britain was further strengthened by marriage to a Scot, Mary Joseph MacCaffrey Keanmore (1775–1836). At about the same time he went into business with a native of Ireland who was living in Brno, the Austrian Field Marshal O'Brady. The British connection was thereby strengthened in multiple ways.

Discussion and Conclusions

Under the leadership of Salm and André, the MAS was set the task of making improvements in agricultural products required for industry

[76] Wood and Orel, 2001, pp. 102, 204, 205, 212–215, 220.

[77] d'Elvert, 1870, pp. 85–86; Freudenberger, 1977, pp. 174–176; Wood and Orel, 2001, pp. 220–201.

and commerce. In the formulation of practical breeding rules, André, as secretary, accepted a major responsibility in the early years. His clear thinking and diplomacy were well illustrated by the inbreeding controversy. With respect to the production of new plant varieties by hybridisation, valuable input came from his contacts with his friend Hempel, secretary of the Pomological Society at Altenberg, whose interests were then turning to the improvement of cereal crops. Both friends became foreign members of Thomas Andrew Knight's London Horticultural Society, and André reported its activities in ONV. Each advance in breeding theory raised new questions, only some of which could be answered before André was forced to leave Brno. As we have seen, he made lists of the most significant ones, to expose the more obvious gaps in theoretical knowledge. But his exit could not be long delayed; his enlightened views had made him powerful political enemies.

It was characteristic of the Moravian situation that further advances in theory came in association with university-level teaching of scientific breeding. It began, as we have seen, at two centres in the 1820s, first in Olomouc, quickly followed by Brno. As was normal in the monarchy, and also in many of the German states, agriculture was taught in association with natural history but only in Moravia did the syllabus include 'scientific breeding.' The professors concerned, J. K. Nestler and F. Diebl, were each led to co-operate closely with breeders. Nestler concentrated mainly on animal examples, Diebl on plants. Together they defined practical problems and the breeding procedures identified to solve them, those that could reliably lead to substantial economic benefits. As a result few sheep breeders now went to the expense of importing stock of the 'pure original race' from Spain, their shared experience convincing them that high Merino quality ('perfection') could be maintained, even exceeded, and rendered 'constant' in inheritance by selective breeding. Among the plant breeders, increasing value was being attached to crosses between varieties, as skills were shared in the demanding techniques of artificial pollination.

Every advance in breeding seemed to raise new questions about its theoretical basis. The concern of SBA members to know why it was that some individual sheep, either male or female, transmitted their traits more readily than others, and why certain traits were themselves transmitted more commonly, was recognised as having the highest potential practical significance. When, after evaluating the improvements made in breeding during the previous 24 years, Bartenstein, interpreted the central problem in terms of 'inheritance capacity,' Nestler recognised the value and the originality of this expression for investigating heredity as a separate issue from the enigma of generation. It was then, as the breeders

began to use the terms 'inheritance' and 'inherit' more freely, that the power of heredity over all other influences on variability became increasingly recognised.

The big problem facing them, and breeders everywhere, was the absence of a theory of inheritance. In 1836 Napp stated his opinion that the problem could be explained only by seeking its physiological basis, i.e. by discovering the nature and behaviour of whatever it was that was transmitted at fertilisation. When discussion on this topic continued in the following year, he formulated the key research question 'what is inherited and how?' He also drew a distinction between the internal and external organisation of an animal, thereby making some progress towards understanding why a 'potential' (*Anlage*) for a particular character was not always realised in the progeny of selected stock. While the concept of an inherited 'potential' was not new, Napp's explanation placed it firmly in the context of physiology. In connection with traits characterising the external form of an animal he believed there to be elements of *internal* organisation for the breeders to select, which could only be done by examining both the parents and the existing progeny of the generation under consideration. This was the acknowledged practice of breeders at their most successful.

Up until 1841 when Nestler was still alive and active, extensive communications continued to take place among breeders and teachers of agriculture and natural sciences from Moravia and beyond, even from outside the monarchy, pushing forward the search for reliable theory. A policy of openness had been created, leading to a scientific approach to breeding, during a sequence of events that was neatly summarised in 1842 by a senior SBA member Joseph Waniek: 'Differences of opinion, freely expressed in the meetings, stimulated experiments, that opened the way for new reflection, experimentation and progress which, according to natural law, cannot be stopped.'[78]

By the early 1840s, however, the output of ideas was forging ahead of any possible experiments to test them. New insight was needed on how to design and interpret the necessary experiments. There was also a major outside event that had brought all serious investigations on heredity in sheep almost to a complete halt. This was the appearance on the market of an abundant quantity of excellent and relatively cheap Australian wool, which led to big changes in agricultural land usage in Moravia and stopped the activity of the SBS. It was during this period that Napp accepted Mendel into the monastery (1843), and Mendel attended courses given by Professor Diebl (1846) who introduced his

[78] Waniek, 1845, pp. 263–264, original in German.

students to, among other topics, the creation of 'completely new varieties (of plants) through artificial pollination.'[79]

The dynamic character of a province eager for insight into new ways of improving agriculture was a clear reflection of the status of the city of Brno as a new and rapidly expanding industrial creation in a growing and highly entrepreneurial community. Among all centres of manufacturing in the Vienna Business Administration listed in 1760, Brno had been recognised as having the lowest opposition from traditional craft guilds, providing ideal conditions for industrial revolution.[80] Its development was also positively influenced by the creation of a good road network (1740–1750) and by Royal patents restricting manorial labour (1776) and introducing religious tolerance (1781), which encouraged labour mobility and the influx of foreign experts. The many strands which came together to begin the progress of industrial development in Brno have been fully documented elsewhere.[81] Within this centre of industrial revolution, the Augustinian monastery of St Thomas in Brno was accredited by offering service in support of economic and social development through teaching. When in 1843 Mendel joined this community, the friars were already working in several schools controlled by the Government.[82] Their activities included the provision of reliable teaching of agriculture, along with natural history.

Meanwhile a political-social change was underway. The revolutionary year of 1848, which began in March in Vienna, immediately found an echo in Moravia where, in the process of change, the MAS was reorganised and a new Natural Scientific Section established within it. The previously useful exchange of ideas between breeders and naturalists was interrupted and questions on the physiological basis of heredity left undiscussed. At the newly built Brno Technical Institut (*Technische Lehranstalt*), the Professor of Natural Sciences, Jan Helcelet, a medical graduate, showed no interest in the problems of breeders, nor even in heredity. The local naturalists grew increasingly dissatisfied at being subordinated to the MAS, dominated by aristocratic landowners, and, by 1861, had created an independent Natural Science Society (NSS) with the aim of cultivating pure science. When in 1865 Mendel lectured at two successive monthly meetings of the NSS on 'the general application of the law of formation and development of hybrids,' the relevance of his work was not appreciated. His audience

[79] Diebl, 1844.
[80] Rybnikář, 1998–1999.
[81] Freudenberger, 1977.
[82] Polčák, 2000–2001.

failed to understand his explanation of questions arising from the abundent interchanges that had taken place between breeders and naturalists in Brno in an earlier era.

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Abbreviations: FM – *Folia Mendeliana*, published yearly by the Moravian Museum, Brno since 1966. Mittheilungen – *Mittheilungen der k.k. Mährisch-Schlesischen Gesellschaft zur Beförderung des Ackerbaues, der Natur- und Landeskunde in Brünn*, published weekly from 1821. ONV – *Oekonomische Neuigkeiten und Verhandlungen Prag*, published weekly from 1811.

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