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The scientific and social context of Hugo de Vries' *Mutationstheorie*[1]

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INTRODUCTION

Hugo de Vries conducted the research that would culminate in his mutation theory in the 1880s and 1890s. This was a period of social and cultural upheaval. Many intellectuals believed that European civilization was 'going to the dogs', and feelings of cultural decline and pessimism spread in speech-making artistic and literary circles; yet exactly the opposite sentiment can also be discerned. A more forward-looking and positive attitude characterized the position of many who were no less aware of the rapid changes that society was undergoing. Dutch historians have recently shown that this optimistic stance was more characteristic of how the *fin de siècle* was experienced in The Netherlands (e.g. Van Sas 1991).

Dutch intellectuals were agreed that society was about to change drastically. The consequences of the country's relatively late but rapid industrialization were beginning to be felt, economically as well as socially, and the first stirrings of worker movements convinced many that society was in a state of crisis. The classical liberal ideology of minimal state intervention seemed to have definitely outlived its effectiveness. Social reform was deemed to be inevitable. However, while it was acknowledged that the social order was in a critical state and that the future was uncertain, a distinct sense of optimism emanates from most publications in which these matters were discussed. Dutch intellectuals believed that a new and better order would result from the crisis—an order in which all strata of society would be given their due rights and in which the state would acquire a new role. Depending on their political affiliations, different authors voiced widely differing views on how this new social order was to be attained and what it would look like. Among the diverse socialist, liberal and conservative alternatives proposed, those of the liberals are of particular importance here since most

[1] This paper is a revised and abbreviated version of Theunissen (1994b).

academics, including Hugo de Vries, were liberally inclined (De Rooy 1987; Stuurman 1991, 1992).

The first indications of dissatisfaction among liberal intellectuals with the tenets of classical liberalism can already be found in the 1860s and 1870s. The movement gained momentum in the 1880s when a group of progressive liberals associated with the Maatschappij tot Nut van 't Algemeen (the Society for Public Welfare) decided that the Society had to change its course in order to meet the demands of modern society. To attain the Society's aim, 'the promotion of general public happiness', it was not enough, they felt, to give public lectures and publish cheap brochures on 'useful knowledge' for its members, for the members (most of them belonging to the middle classes) were already convinced supporters of the ideal, while the intended target of the Society's efforts, the 'common people', was consistently missed. According to the progressivists, the Society should concentrate more directly on finding solutions for the imminent social problems and take the lead in the reform movement (Helsloot 1984: 79–81; De Rooy 1987).

The attempted take-over of the Society failed, but radical progressivists then redirected their attention to establishing their own journal. From 1887 onwards the *Sociaal Weekblad* appeared, in which they could voice their hopes and concerns regarding the new social order. Basic issues were the question of state intervention, the worker problem and the responsibilities of the higher classes towards society. In all these matters, the progressivists distanced themselves from the position of the classical liberals and advocated a position that was distinctly more to the left of the political spectrum. At the same time they tried to stem the tide of socialism. While the progressivists acknowledged the need for a more substantive role for the state in society, and for giving the working classes their due rights, they were agreed that the growing socialist movement had to be kept in check. Social reform was necessary, but socialism and Marxism would result in the complete disintegration of the social order.

It is against this background that we can see that Hugo de Vries' *Mutationstheorie* was not only intended as an exposition of his scientific insights into the phenomena of heredity and evolution, but also to give articulate expression to his position in the Dutch debate on the reform of society at the turn of the century. He was never active in the political scene and never voiced his political views in any detail. It seems safe to assume, however, that De Vries, like most academics, was more moderate in his views than the radical liberals, yet more progressivist than conservatives who merely aimed to restore the old social order. Where the future of society was concerned, De Vries was definitely on the side of the optimists, although he offered no political solution to the imminent problems of society, but added an element of his own to the discussion, namely the crucial importance of science for social progress. As we shall see, De Vries' approach to questions of heredity and evolution is in line with his conception of the pivotal role of science in society. Moreover, in his opinion the results of his investigations supported his views on the foundations of the social order.

THE PHYSIOLOGY OF HEREDITY

De Vries was trained as an experimental plant physiologist in Julius Sachs' laboratory in Würzburg. In the 1880s his accomplishments in this field were rapidly gaining him an international reputation. In the mid-1880s, however, he broke off his career in mechanistic plant physiology and switched to the field of heredity. Why did De Vries

Fig. 17. Water colour of *Oenothera lamarckiana*, 1912 (Library of the Biological Centre, University of Amsterdam: Archive Hugo de Vries).

decide to burn all his boats and move into a new field? And what exactly was it that he hoped to accomplish?

There were several reasons for the turnabout in De Vries' career. His longstanding interest in natural history questions played a role—De Vries was, neither by education nor by inclination, the *pur sang* experimentalist that he has always been taken to be. Further, he may have found it necessary to change course because in the mid-1880s his Amsterdam colleague, the physical chemist J.H. van 't Hoff, more or less 'invaded'

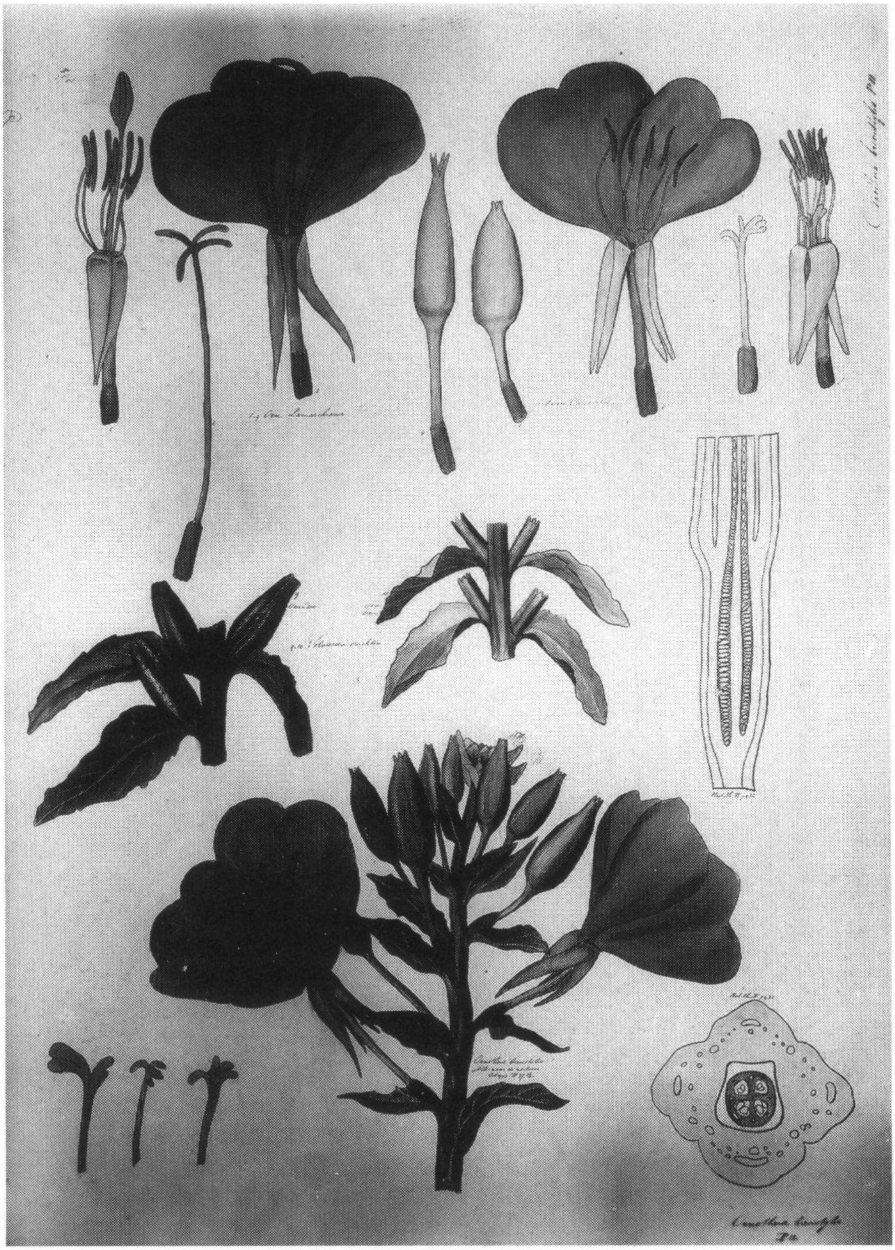

Fig. 18. Lecture plate showing the flowers and buds of *Oenothera brevistylis*, one of the many mutants De Vries discovered appearing in the species *Oenothera* (University Museum De Agnietenkapel, University of Amsterdam).

De Vries' special field, the physico-chemical investigation of osmosis (Theunissen 1992).

De Vries' principal reasons for taking up the study of heredity and evolution were of a different nature. Julius Sachs, from whom De Vries received his training in plant physiology, had at the beginning of his career constantly emphasized that agriculture might reap great benefits from physiological research (Pringsheim 1932). In fact, his success in raising experimental plant physiology to the status of a discipline had, to an important extent, been due to his capitalizing on this particular argument. After having secured an academic position, Sachs would continue to have an eye to practical concerns, although his real interest then revealed itself as lying in pure research. The connection with agriculture probably had a predominantly strategic importance for him. It was also thanks to his ties with agricultural circles, for instance, that he managed to obtain for Hugo de Vries a government assignment to write physiological monographs on some of Germany's principal crops in 1875.

Thus De Vries was led naturally to the study of agricultural problems as one of the concomitants of experimental plant physiology. While his own principal commitment was, like his mentor's, to pure research, his involvement with applied botany ran much deeper than Sachs'. De Vries published more than a hundred articles and books, both popular and scientific, which discussed the potential usefulness or direct practical value of the results of pure botanical reseach. The stream of publications did not stop when he had reached the security of his professorial chair at Amsterdam University but continued, at a relentless pace, for the whole of his academic career. Without doubt, De Vries' objective in this was partly the same as Sachs', namely to prove academic botany's right to exist, although there were other motives involved in his prolonged effort.

One of these was not related specifically to the practical usefulness of botanical knowledge in agriculture, but rather to the cultural value of science in general. Science, according to De Vries, had a civilizing effect; the spread of knowledge contributed to 'the uplifting of the people' and the 'increase of happiness'. These are well-known topics which occur frequently in the works of Dutch intellectuals during the whole of the 19th century. They had their roots in an enlightened ideal of culture and civilization that began to spread among the educated, non-orthodox middle classes at the beginning of the century. Until the 1870s the Society for Public Welfare, mentioned above, acted as the main vehicle for the propagation of this ideal (Helsloot 1984).

Prominent among the Dutch scientists who advocated the cultural value of science was the zoologist Pieter Harting (Theunissen 1995), and De Vries probably drew his inspiration directly from him. Following Harting's example De Vries gave scores of lectures for the general public and wrote numerous popular articles for public journals and newspapers. He even took over Harting's role as a public educator in the literal sense, by succeeding him as editor of the widely read *Album der Natuur*, a popular science journal. Like Harting, De Vries contributed prolifically to this journal. He expressed his motive for these efforts succinctly as follows: 'It is indeed the aim of all branches of science to promote the happiness of one's fellow men' (De Vries 1899: 25).

Apart from his writings for the general public, De Vries also brought out scores of articles more exclusively aimed at agriculturists and horticulturists. There is hardly any aspect of applied botany that did not receive attention at least once in these publications. Their central theme was that scientific botany should form the basis of the development of agriculture. Sound botanical knowledge was an essential prerequisite for any attempt to increase the yield, prevent diseases or to rationalize the methods of crop growing. This may sound self-evident, but for De Vries these claims formed part of his more broadly defined views regarding the role of science in society. Science did not only promote the people's spiritual wellbeing; it also held the answers to many of the practical and social problems facing society. A properly science-based agriculture and horticulture would 'turn out to be the most powerful instrument to alleviate a great many social miseries' (De Vries 1896: 67). In the long run, De Vries also expected biology to provide solutions for many other social problems, such as the problem of human intellectual (in) equality and its consequences for education and the social order, of the rights and wrongs of social Darwinism, of racism, etc. For De Vries, scientific progress and social progress went together.

Thus De Vries' answer to the question of what society really needed was: more science, and more practically orientated science at that. Botanical education and research at the American universities were for De Vries an enlightening example of how scientific research could be organized:

> [In America] the useful subjects and studies are ... appearing more and more to full advantage, while what is useless for society is pushed back. This is a process of purification, which keeps the American universities young, because it keeps speculative digressions and a predilection for useless subjects in check, while the direction of the other subjects remains practical. In this way ... botany is considered as one of the most important academic subjects since it constitutes the basis of agriculture and since progress in botany implies progress in agriculture, which is the main source of the nation's wealth (De Vries 1906a; vol. 1: 478).

Elsewhere De Vries explained that the university should 'cultivate the most intimate connection between theory and practice, between abstract science and actual life', for 'throughout the world of research this connection is felt to be the real stimulus of the work, the very basis of its existence' (De Vries 1904: 395).

De Vries did not mean all this to imply that science should be aimed exclusively at the solution of practical problems, however. He claimed that, while academic subjects and disciplines derived their right of existence from their practical use, scientific investigation itself had to remain pure, for 'more and more, experience teaches that the combination of a direct practical goal with the interests of pure research is not a feasible one' (De Vries 1896: 67), for 'the former has the result as its goal, the latter the investigation of the laws which produce the results'. While the scientific experimenter had to take many precautionary measures which might seem superfluous to the practical worker, 'such apparently useless scientific efforts must build the foundation for later, practically relevant experiments' (De Vries 1901–3, vol. 2: 53–54). In short, only pure science could provide a solid base for practice, and progress would quickly be hampered if research were degraded into practical problem solving.

Returning now to the question of how De Vries came to take up the study of heredity in the early 1880s, we can see that his switch from plant physiology to genetics is less surprising than it may at first have seemed. It did not involve a complete change of course, nor did it come about abruptly. A first indication of this is provided by De Vries' terminology, for he spoke of the 'physiology of heredity' to designate his new field of interest. Questions of heredity belonged to physiology proper, in De Vries' opinion, and it was clear to him from the beginning that the subject had to be approached with the same methods.

Similarly, De Vries' preoccupation with the practical importance of scientific botany is as characteristic of his work in physiology as of that in genetics. He rarely began his physiological inquiries with the objective of solving a particular practical problem, yet in the end he never failed to establish a connection between his results and practice.

New physiological data on plant nutrition, on their water circulation, their sensitivity to temperature changes, etc., were translated into popular form for the benefit of (future) practical workers (De Vries 1876); studies of cell turgescence were used to analyse the problem of rain-flattening in corn (De Vries 1880a); the practical implications of an investigation of the influence of temperature on seed germination are self-evident (De Vries 1880b). From this latter example it is only a small step to the question of which seeds react best to such influences, and thus one is confronted with the phenomenon of variability.

That this is indeed a plausible scenario of how De Vries became interested in the variability of plants is indicated by his activities in the second half of the 1870s. In 1875 he was commissioned by the Prussian Ministry of Agriculture to write a series of monographs on the germination and growth of several important crops. Inevitably, this assignment must have confronted him with all kinds of questions relating to plant breeding, improvement of races, variability and selection. For the success of cultivation is not simply a matter of providing optimal physiological conditions, but also of choosing the best races and the best seeds. Consequently, De Vries set up his first own breeding experiment (with corn, in 1876), and in these years he also began to visit plant breeders to study their methods (De Vries 1900b: 274, 1906b: 423). In 1881 he started teaching a course on 'Darwinism, heredity and variability' at Amsterdam University (Visser 1992: 169). His first publication on the subject appeared in 1882, a second in 1884, and a series of 19 articles was published between 1886 and 1889. It will come as no surprise that these publications were, without exception, aimed directly at agriculturists and horticulturists. They were all published in the *Maandblad Hollandsche Maatschappij voor Landbouw* [*The Dutch Agricultural Society's Monthly*] and their aim was to inform these practical workers of recent developments in the study of heredity, variability and selection, especially in relation to plant-breeding practices.

Thus we may conclude safely that it was the subject's practical relevance which motivated De Vries' choice of 'the physiology of heredity' as his new field of interest. He must have seen it as a means to improve the cultivation of crops and thus as a contribution to the 'alleviation of the miseries of society'. This practical perspective was also basic to De Vries' *Mutationstheorie* published in 1901–3. The final aim of his research was a practical one, of direct relevance to public welfare.

THE CONTROL OF MUTATIONS

In his *Intracellulare Pangenesis* of 1889 De Vries gave an exposition of his theoretical views on heredity and variability, and at about the same time he started large-scale breeding experiments. The ultimate goal of De Vries' hereditary studies, although he expressed it repeatedly in his works, has until recently been overlooked by historians. It seems that it has simply been taken for granted that De Vries' objective was to disentangle the laws of heredity, more or less in the sense of what we consider these laws to be about at present. Since such an aim sounds perfectly sensible and self-evident from our modern perspective there has been little reason for further analysis of De Vries' motives. De Vries, however, soon came to see the laws that we take to be the 'laws of heredity' as relatively obvious and unproblematic. It was much more important, in his view, to find an explanation of variability (mutation, in his terminology) and evolution. The crucial point is that 'heredity' and 'variability' were completely different matters for him. The bulk of De Vries' research revolved around variability and evolution, and explaining the mechanisms involved was his most important scientific goal (Theunissen 1994a).

De Vries did not stop at this; his scientific aims served a higher purpose. What he really aimed for was control—control of mutation and thereby control of evolution. He made no secret of this far-reaching aim. For example, even before he had started his own systematic investigations of hereditary phenomena, in 1887, De Vries wrote: 'No sooner than the moment that science and practice have solved this riddle [i.e. of the causes of variation], are we entitled to claim that the production of new varieties has been brought under man's complete control and that he has fully freed himself from chance' (De Vries 1887).

Some 13 years later, in his *Mutationstheorie*, he confidently declared:

> We may expect that knowledge of the laws of mutation will at some future time enable us to produce mutations artificially and at will and, in this way, to develop plants and animals with completely new characteristics. ...
>
> The question is, how the different characteristics have originated and can originate. In other words: the mutation, the process of mutating itself, must become the object of investigation. And when we have succeeded in finding the laws of mutation, we will not only be able to gain a much deeper insight into the mutual relationships of the living organisms, but we may also hope to be able to intervene in the mechanism of species formation. In the same way as the breeder now controls variability, it should become possible to control mutability (De Vries 1901–3, vol. 1: v, 131).

Elsewhere he announced: 'New races and also new species! This will henceforth be our slogan, first for science, but then also for practice, for the flourishing of agriculture and the prosperity of all nations!' (De Vries 1901: 204). At the end of his career, in his farewell lecture, he repeated these claims: 'Mutations occur frequently, but always by chance ... The investigator has to try and free practice from this dependence on chance. He has to search for the laws which enable him to control the phenomenon and to produce desirable and favourable mutations at will' (De Vries 1918: 16–17).

There was more to this than mere rhetoric, even though De Vries never produced any tangible results. It is clear from occasional references in his published works that he did indeed try hard to unveil the 'laws of mutation' in order to fulfill his mission of controlling mutation. In the *Mutationstheorie* he reported that he was investigating the direct effect of external circumstances on the plant's mutability and suggested that abundant food or light might increase the 'susceptibility' for mutations (De Vries 1901–3, vol. 1: 353–354). At a later date he presented an overview of possible approaches to the problem and reported again that he had several promising experiments under way (De Vries 1913: 339–341). In later publications he stated that optimal external conditions did indeed increase the frequency with which known mutations occurred (De Vries 1912: 6, 1916, 1925: 675–678). The specific causes of mutation remained as elusive as they had been from the start, however, and at the end of his career De Vries publicly acknowledged defeat (De Vries 1918–27, vol. 7: 'Vorwort'); yet even this acknowledgement, which he might just as well have omitted, underscores the seriousness of De Vries' involvement.

De Vries' contemporaries, especially in America, where the Progressive Movement was in full swing, had a keen eye for the practical implications of his work. In the United States, De Vries' mutation theory was adopted enthusiastically as a possible

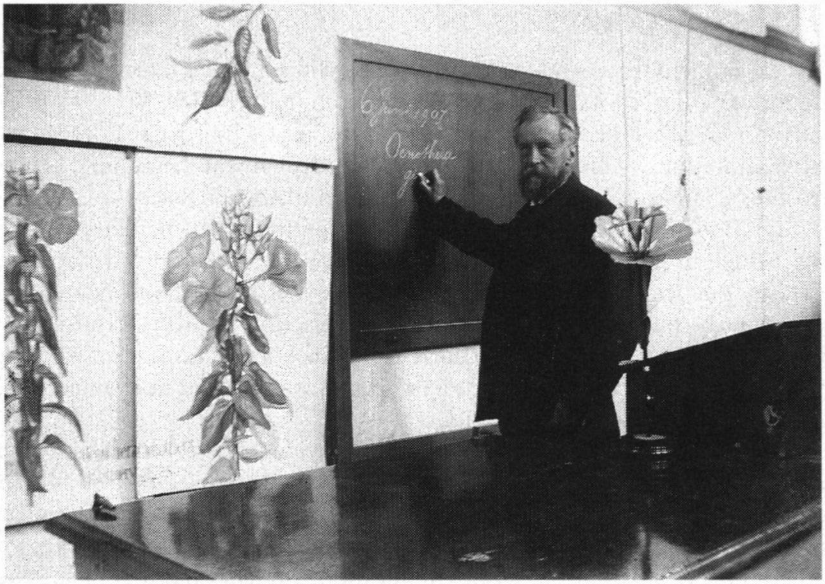

Fig. 19. Hugo de Vries lecturing for his students on *Oenothera*, 6 June 1907 (Library of the Biological Centre University of Amsterdam: Archive Hugo de Vries).

means of making rapid progress in the improvement of agricultural varieties (Kingsland 1991). Another example is provided by De Vries' connections with Jacques Loeb, a leading figure among the American progressivists, who had also set himself the aim of 'controlling life' (Pauly 1987). De Vries and Loeb saw each other as kindred spirits. Loeb invited De Vries to the United States and De Vries' travelogue of his visit shows that the control issue was the focal point of their discussions (De Vries 1906a, vol. 1: 135, 150, 184). At a later date, during a second visit to the United States, De Vries contributed his mite to Loeb's attempts at producing mutations experimentally: a sample of radium lent by Rutherford was transported personally to California by De Vries (Pauly 1987: 113).

There is, however, an important difference between Loeb and De Vries in that the former, following Ernst Mach, dispensed with the distinctions between pure and applied science, while the latter stressed the importance of this boundary and continued to see it as his first task to perform 'pure' research. Thus in his most important series of papers published after 1900, the reports on his experiments with *Oenothera*, De Vries did not mention practice at all. These papers contain nothing but 'pure' science, and this may have been an additional reason why the practical motives underlying these researches have been overlooked.

While Loeb soon shied away from society's overwhelming response to his views and eventually withdrew into the academic seclusion of the Rockefeller Center, De Vries never tired of explaining the practical relevance of his work to the general public. His attempts at disclosing the laws of mutation failed and he must have been deeply disappointed by this, although there were other results from his research which he deemed to be of direct relevance for agriculture and for society at large.

SCIENCE AND SOCIETY

De Vries' experimental research of the 1890s convinced him that mutations were the most important source of hereditary variation in nature (De Vries 1901–3). Such mutations could either be progressive or regressive. (A third category consisted of 'degressive' mutations, which were introduced to explain the hereditary behaviour of 'monstrosities'. This category, however, is immaterial to our discussion here.) A progressive mutation involved the formation of an entirely new hereditary particle, or 'pangene', which in most cases effected various changes in the outward appearance of the organism that carried it. If the changes were detrimental the new form would quickly disappear, but if they were favoured by selection the new form might replace the older one. De Vries equated the occurrence of such a successful new form in nature with species formation; by definition, a new species was created in a single step, by the occurrence of a beneficial new pangene.

Far less drastic changes were brought about by regressive mutations. Invariably, such mutations consisted in the loss of function of a single pangene that was responsible for one particular character of the organism. All Mendelian recessives arose in such a way, according to De Vries and, again by definition, he equated such changes with the formation of new varieties of the species in question. Typical examples of such varieties, De Vries would note in later years, were the mutated fruit flies of Thomas Hunt Morgan, most of which had come about by the loss of function of a 'pangene' affecting a single character (De Vries 1918: 8).

Finally the individuals of a species always exhibited much smaller, so-called 'continuous' or 'fluctuating' variations. These were not hereditary in the Mendelian sense, according to De Vries. They 'fluctuated' around a mean value and played no role in the formation of new varieties and species in nature.

Despite his failure to uncover the 'laws of mutation', De Vries still felt that the *Mutationstheorie* was directly relevant for practice. In the years following upon the publication of this work he spent a great deal of his time and energy in driving this point home to agricultural and horticultural experts. He devoted numerous articles, popular as well as scientific, and several book-length expositions to the subject (e.g. De Vries 1907b). The basic point of De Vries' reasoning was simple. Contrary to species in nature most agricultural and horticultural stocks did not consist of a single 'pure' form but were mixtures of a host of varieties, and perhaps even species. Such stocks had in many cases been cultivated for centuries, and the breeders had no particular desire to keep them pure. On the contrary, they regularly added varieties from different localities if these showed promising characteristics, they used seeds from other breeders if it suited their purposes, and so on. Also, new characters might have originated spontaneously in their stocks over the ages. Thus, in terms of pangenes, their cultures were a complex mixture, and on close inspection this mixed composition revealed itself in an enormous 'variability' in the outward appearance of the individuals belonging to a single stock.

Accordingly the most simple and rapid way to improve the stock, claimed De Vries, was to single out very carefully the individuals showing the best combination of characteristics. In this, care should be taken to select for clear-cut, discrete differences in characters, for slightly favourable differences might be due to non-hereditary fluctuating variability, conditioned by environmental differences. The selected individuals should then be self-fertilized, so that they would split up into 'pure' forms which remained constant on self-fertilization. This might take several generations, but they might also prove to be constant immediately. From among the constant forms thus obtained, the individuals showing the desired combination of characters should be singled out to replace the whole original stock. The crux of the whole process was to recognize the favourable discontinuous differences and to select only these for the continuation of the stock. In this way, according to De Vries, the improvement of agricultural breeds would proceed much more rapidly and safely than by mass selection of individuals with favourable characteristics.

De Vries' proselytising for his agricultural selection method was of course part of his campaign to promote his mutation theory, but his zeal had a broader basis than this. It was not simply to promote specific scientific insights that De Vries, time and again, turned to practice. His more general agenda had always been to show that science was beneficial to society, that it was one of the motors of social progress. In the case of botany this meant that a properly science-based agriculture and horticulture would eventually be able not only to meet the direct food demands of society, but to grow into an important economic force that would bring prosperity for all.

In a sense, De Vries' liberal convictions are evident in the particular way that he envisaged that the progress of society would come about. For by placing science at the basis of social progress, he implicitly distanced himself from political alternatives such as socialism and Marxism, according to which social reform could only be attained by a drastic intervention in the political *status quo*. At the same time De Vries acknowledged that the achievement of general prosperity could not be relegated to the free economic forces alone. The state had to lend a helping hand. The state should, for instance, provide the funding for the establishment of agricultural experiment stations and support the erection of special university departments for bacteriology, phytopathology, and so on; but in characteristic liberal vein, De Vries also appealed to the well-to-do classes of society to accept their responsibility for the advancement of pure and practical science, and thus to contribute to the alleviation of the needs of society (De Vries 1893, 1895, 1898, 1900a). On one occasion De Vries even went so far as to state: 'Whoever is willing to support our natural sciences in a highly placed government office or as a Maecenas, can accomplish more for their progress than the best scientist' (De Vries 1900a: 212).

'Practice', for De Vries, did not only refer to agriculture and horticulture. Science was also important for the development of society at large. Manifesting an optimism and a belief in progress that is characteristic of the contemporary debate on the reform of society he stated:

> The laws concerning the variability of plants which we shall discover, will have to be applied to society and its very intricate processes of cause and effect. And is it not much easier to apply an insight to a new case, however complex, than to uncover the insight in the first place! This is indeed a beautiful ideal [because] to contribute to the happiness of humankind is the goal of science (De Vries 1899: 14).

Besides adding substance to his claim regarding the practical value of science, De Vries believed that the laws of heredity provided direct insights in the nature of society itself: '[they] open up perspectives for a social biology that is extremely attractive' (De Vries 1907a: 36). A key concept in the reform programme of Dutch liberals was education, not revolution. De Vries agreed wholeheartedly. In a chapter of the *Mutationstheorie*, entitled 'Die Mutationstheorie und die sozialen Fragen', De Vries argued that progress was not to be expected from a direct application of evolutionary theory to human beings (De Vries 1901–3, vol. 2: 108–112). Both right-wing and socialist versions of social Darwinism were at odds with the central tenets of the mutation theory. To begin with, there was no foundation for the assumption that society would benefit from an unchecked 'struggle for life' among its members, for it was clear that the human races should each be regarded as a fixed, genetically uniform elementary species, which had come into being long ago and had remained stable ever since:

> Man is a stable and permanent form (*Dauertypus*), like most species of plants and animals are at present. Thus while the laws governing such stable forms can be applied to the human situation, even if only tentatively in most cases, this is not the case where the laws governing the changes by which the stable forms have developed out of each other are concerned (De Vries 1901–3, vol. 2: 109).

Put differently, the members of each race possessed the same hereditary potential and therefore there was no substratum of hereditary differences which selective forces might seize upon to pick out the 'best'. The 'laws governing stable forms' were the laws of fluctuating variability, not the laws of mutation. Thus the variations in bodily characteristics, as well as in social and intellectual abilities within each human 'race' were entirely due to non-hereditary, 'fluctuating' variability (De Vries 1907a).

At the same time De Vries was adamant that there was no room for any socialist 'illusions' with regard to man's future development (De Vries 1907a). The laws of fluctuating variability indicated that humans were not equal and never would be. The bell-shaped (Gaussean) curve representing the fluctuations of particular characteristics indicated that each individual had its own potential, which was fixed at an early stage of development. The potential could be realized and exploited to its full extent, but it posed a limit to the height of development to be reached. Where bodily characteristics were concerned, improved external conditions (nutrition) might perhaps raise the mean value of the relevant curve in future generations, but in the mental domain the chances of improvement appeared to be minimal. Therefore the beneficial effect of education and training was narrowly restricted to the individual level; each new generation showed a complete regression to the mean value of the race. 'Humanity remains what it is ... [its] mean value does not increase, the entire race constitutes a *Dauertypus*, the length of its existence.' Not every individual should strive for leadership in his field, but 'search into his own bosom for the talents he was gifted with' in order to attain his proper place and function in society (De Vries 1907a: 35–6). 'Everywhere [the study of nature] shows us that one should not put one's trust in others, but learn to know and develop one's own talents and inclinations as much as possible, and it is evident that this will lead to progress everywhere and to contentment and joy in life' (De Vries 1905: 371).

Perhaps, De Vries mused in a more speculative vein, even religious feelings and political preferences were subject to the laws of fluctuating variability. Extreme leftists, right-wing die-hards, atheists and religious fanatics would then be nothing but the occasional yet inevitable extremes of an ever-stable scale. 'It would then be clear why [such] deviations from the mean have occurred throughout the centuries, why neither education nor civilisation, neither preaching nor inquisition, can in the long run change their numbers.' Since the 'mean value' of such inclinations would always remain the same, 'it is entirely without foundation to consider them to be as dangerous to society as some people do at present' (De Vries 1907a: 36). However this might be, De Vries concluded, the important point to be made was that the application of the laws of fluctuating variability to society 'will doubtless bring about a milder judgment [of one's fellows] and greater mutual respect and thus contribute to the increase of the happiness and contentment of humanity. And in this way our knowledge of nature not only enhances our material, but also our intellectual well-being. Knowledge is power; may it always be used to the good!' (De Vries 1907a: 36).

Here the optimistic liberal ideology that formed the backbone of De Vries' theorizing on science and society is developed to its fullest extent. It was the individual that held centre stage in De Vries' view of the social order, yet neither was it the aggressive and competitive individual of the right-wing *laissez-faire* extreme, nor was it the socialists' individual whose rights in society were determined by the power of his class. De Vries' individual would respond well to exactly those measures that the Dutch liberals deemed necessary to solve the crisis of society: division of labour, a reasonable share of prosperity for all, a better education, a civic spirit of mutual respect and cooperation, and a state that found its *raison d'être* in providing the means to these ends.

Clearly De Vries' mutation theory was not a 'merely scientific' theory about the mechanisms of heredity and evolution. It was at the same time a defence of science as one of the motors of social progress and a theory about the nature of the social order. It is clear that the theory incorporated both De Vries' scientific ideas and his social views and purported to present new insights into both heredity and society.

EPILOGUE

In the early decades of the twentieth century, De Vries enjoyed the status of a celebrity in The Netherlands. In 1916 the daily newspaper *De Nieuwe Amsterdammer* asked its readers to send in a list of the 10 most important Dutch people of the last 50 years. More than 60 000 readers responded, and De Vries came fourth on the final list, preceded only by national heroes such as the politician Johan Rudolf Thorbecke, the painter Josef Israël and the writer Multatuli (de Veer, 1969: 3). In Dutch botany De Vries remained a powerful figure until his death. It is a pity, however, that his difficult and headstrong personality prevented him from creating a Dutch school of genetics.

On an international scale, De Vries' fame reached its peak in the early 1900s. His rediscovery of Mendel's laws and his mutation theory provided an enormous stimulus for genetic research. Several American biologists picked up the study of heredity with the express purpose of discovering the mechanism of mutation, which they hoped would provide them with the means to produce new species and varieties at will (Kingsland 1991). Among them was Thomas Hunt Morgan. It was during his attempts to induce mutations experimentally in *Drosophila* that he discovered the mutants that were to become the experimental animals of his famous Mendelian research programme (Kohler 1994: 37–46). Other biologists, in England, America and elsewhere, were also stimulated by De Vries' publications to investigate the principles of Mendelian heredity. Finally, many biologists saw De Vries' mutation theory as a plausible alternative to Charles Darwin's gradualistic theory of evolution (Allen, 1969; Bowler 1983: 197–212). De Vries' international fame as the 'new Darwin' was relatively shortlived, however. In the 1910s his *Oenothera* research came under heavy attack, and a new generation of geneticists singled out his rediscovery of the Mendel laws as his most significant achievement.

At a much later date it was pointed out that De Vries did not 'rediscover' Mendelism independently and was not even a 'Mendelian' in the modern sense (Meijer 1985; Theunissen 1994a). His mutation theory was described as a mistake, an unfortunate stumbling block on the road to the New Synthesis (the integration of Darwinian evolution theory and genetics) of the 1930s and 1940s (Mayr & Provine 1980: 4–5, 20–21; Mayr 1982: 546–548). Of late, the tables have been turned again. De Vries is now hailed as one of the pioneers of biotechnology. Modern critics of the New Synthesis look more favourably on De Vries than its supporters. On the other hand, for those who have misgivings about biotechnology De Vries may rather represent its misguided *Urheber* than its heroic pioneer. Such evalutions are, of course, the product of hindsight. The historian should disengage him- or herself from such present-day perspectives and try to understand the past in its own terms. Nevertheless, I would not hesitate to call Hugo de Vries the most innovative and influential Dutch geneticist ever, and a major figure in the history of genetics.

REFERENCES

Allen, G.E. (1969): Hugo de Vries and the reception of the mutation theory. *J. Hist. Biol.* **2**: 55–87.

Bowler, P.J. (1983): *The Eclipse of Darwinism. Anti-Darwinian evolution theories in the decades around 1900.* Johns Hopkins University Press, Baltimore.

De Rooy. P. (1987): *Darwin en de strijd langs vaste lijnen.* Sun, Nijmegen.

De Veer, P.H.W.A.M. (1969): *Leven en werk van Hugo de Vries.* Wolters-Noordhoff, Groningen.

De Vries, H. (1876): *De voeding der planten.* Kruseman, Haarlem.

De Vries, H. (1880a): Ueber die Aufrichtung des gelagerten Getreides. In de Vries: *Opera e periodicis collata,* vol. 3: 523–588. Oosthoek, Utrecht.

De Vries, H. (1880b): Over de invloed der temperatuur op de kieming van zaden. In de Vries: *Opera e periodicis collata,* vol. 4: 251–263. Oosthoek, Utrecht.

De Vries, H. (1887): Beschouwingen over het verbeteren der rassen van onze cultuurplanten XI. *Maandblad Hollandsche Maatschappij van Landbouw* **9**: reprint.

De Vries, H. (1889): *Intracellulare pangenesis.* Fischer, Jena.

De Vries, H. (1893): Wetenschap in dienst der praktijk. *Landbouwkundig Tijdschr.* **9**: 217–230.

De Vries, H. (1895): De proefstations voor suikerriet op Java. *De Gids* **13**: 283–303.

De Vries, H. (1896): Proeftuinen voor selectieproeven. *Album der Natuur*: 65–74.

De Vries, H. (1898): Kapitaal en wetenschap. *Album der Natuur*: 353–366.

De Vries, H. (1899): Eenheid in veranderlijkheid. Rectorial Address, Amsterdam University, 1898. In: H. de Vries: *Zaaien en planten*: 3–25. Tjeenk Willink, Haarlem.

De Vries, H. (1900a): Vooruitzichten in de plant- en dierkunde. *Album der Natuur*: 210–215.

De Vries, H. (1900b): Sur la fécondation hybride de l'endosperme chez le maïs. In H. de Vries: *Opera e periodicis collata,* vol. 6: 270–277. Oosthoek, Utrecht,

De Vries, H. (1901): Over het ontstaan van soorten door mutatie. *Album der Natuur*: 193–206.

De Vries, H. (1901–1903): *Die Mutationstheorie. Versuche und Beobachtungen über die Entstehung von Arten im Pflanzenreich,* 2 vols., Von Veit, Leipzig.

De Vries, H. (1904): The evidence of evolution. *Science* **20**: 395–401.

De Vries, H. (1905): Herleven. *Album der Natuur*: 367–342.

De Vries, H. (1906a): *Naar Californië. Reisherinneringen,* 2 vols., Tjeenk Willink, Haarlem.

De Vries, H. (1906b): Elementary species in agriculture. In: H de Vries: *Opera e periodicis collata,* vol. 6: 421–427. Oosthoek, Utrecht.

De Vries, H. (1907a): *Afstammings- en mutatieleer.* Hollandia, Baarn.

De Vries, H. (1907b): *Plant Breeding. Comments on the experiments of Nilsson and Burbank.* Kegan Paul, London.

De Vries, H. (1912): *Die Mutationen in der Erblichkeitslehre.* Borntraeger, Berlin.

De Vries, H. (1913): *Gruppenweise Artbildung.* Borntraeger, Berlin.

De Vries, H. (1916): Ueber die Abhängigkeit der Mutationskoeffizienten von äusseren Einflüssen. In: H. de Vries *Opera e periodicis collata,* vol. 7: 72–77. Oosthoek, Utrecht.

De Vries, H. (1918): *Van amoebe tot mensch*. Oosthoek, Utrecht.

De Vries, H. (1918–1927): *Opera e periodicis collata*, 7 vols. Oosthoek, Utrecht.

De Vries, H. (1925): Die latente Mutabilität von *Oenothera biennis* L. In: H. de Vries: *Opera e periodicis collata*, vol. 7: 633–681. Oosthoek, Utrecht.

Helsloot, P. (1984): De nutsbeweging. In: W.W. Mijnhardt & A.J. Wichers, (eds): *Om het algemeen volksgeluk. Twee eeuwen particulier initiatief 1784–1984. Gedenkboek ter gelegenheid van het tweehonderdjarig bestaan van de Maatschappij tot Nut van 't Algemeen*: 3–186. Edam.

Kingsland, S. (1991): The battling botanist: Daniel Trembley MacDougal, mutation theory, and the rise of evolutionary biology in America, 1900. *Isis* **82**: 479–509.

Kohler, R.E. (1994): *Lords of the Fly. Drosophila genetics and the experimental life*. University of Chicago Press, Chicago.

Mayr, E. (1982): *The Growth of Biological Thought. Diversity, evolution and inheritance*. Harvard University Press, Cambridge, MA.

Mayr, E. & Provine, W.B. (eds) (1980): *The Evolutionary Synthesis. Perspectives on the unification of biology*. Harvard University Press, Cambridge MA.

Meijer, O.G. (1985): Hugo de Vries no Mendelian? *Ann. Sci.* **37**: 189–232.

Pauly, P.J. (1987): *Controlling Life. Jacques Loeb and the engineering ideal in biology*. Oxford University Press, Oxford.

Pringsheim, E.G. (1932): *Julius Sachs, der Begründer der neueren Pflanzenphysiologie 1832–1897*. Fischer, Jena.

Stuurman, S. (1991): Het einde van de produktieve deugd. *Bijdragen en Mededelingen betreffende de Geschiedenis der Nederlanden* **106**: 610–624.

Stuurman, S. (1992): *Wacht op onze daden. Het liberalisme en de vernieuwing van de Nederlandse staat*. Bakker, Amsterdam.

Theunissen, B. (1992): De beheersing van mutaties. Hugo de Vries' werdegang van fysioloog tot geneticus. *Gewina, Tijdschrift voor de Geschiedenis der Geneeskunde, Natuurwetenschappen, Wiskunde en Techniek* **15**: 97–115.

Theunissen, B. (1994a): Closing the door on Hugo de Vries' Mendelism. *Ann. Sci.* **51**: 225–248.

Theunissen, B. (1994b): Knowledge is power: Hugo de Vries on science, heredity and social progress. *Br. J. Hist. Sci.* **27**: 291–311.

Theunissen, B. (1995): Een warm hart en een koel hoofd. Pieter Harting over wetenschap, de natie en de vooruitgang. *Bijdragen en Mededelingen betreffende de Geschiedenis der Nederlanden* **110**: 473–498.

Van Sas, N.C.F. (1991): *Fin-de-siècle* als nieuw begin. Nationalisme in Nederland rond 1900. *Bijdragen en Mededelingen betreffende de Geschiedenis der Nederlanden* **106**: 595–609.

Visser, R.P.W. (1992): Hugo de Vries (1848-1935). Het begin van de experimentele botanie in Nederland. In L. Kooijmans (ed.): *Een brandpunt van geleerdheid in de hoofdstad. De Universiteit van Amsterdam rond 1900 in vijftien portretten*: 159–178. Verloren, Hilversum.

Fig. 20. The audience hall of the society Diligentia in The Hague on 3 December 1910, ready to receive Hugo de Vries for one of his lectures. The mantelpiece is decorated to celebrate that De Vries had declined a professorship offered to him by Columbia University in New York. On the mirror is written: 'Retained for Holland' (Library of the Biological Centre, University of Amsterdam: Archive Hugo de Vries).