*Genetics and the Institutionalization of Plant Breeding Expertise, 1900-1930*

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*Introduction*

On one widely-held view, the history of genetics has been a history of scientific expertise replacing practical, everyday, expertise. As one early geneticist put it, the 'breeders' eye'; 'that happy gift some breeders have acquired of recognising the merits of one individual plant amongst thousands', was supplanted in the years after 1901, by the geneticists' eye, which would, 'eliminate chance and work definitely for the end in view'.[2] The geneticists' eye allowed the breeder to see into the plant's hereditary composition, without being led astray by its superficial characters. The genetic plant breeder, by tracking genes, would thus be able to summon new varieties into existence. Plant breeding could dispense with the skill-based processes of picking the right plant, as geneticists simply read the hereditary patterns. The claim was that the new genetic expertise rationalised a set of previously held 'precepts [of heredity] as fantastic in their way as mediaeval medical prescriptions,' and brought new precision to plant breeding that diminished the need for skill and luck; '[n]ow … the main principles of the subject are fairly clear'.[3]

The first geneticists promoted themselves on these rationalising claims. Over the course of their careers they were lauded by others as successful in producing important new agricultural plants. Such celebratory histories have been retold by successive generations of scientists and popular historians, who echo the first geneticists' claims. In the early twentieth century, Anglophone culture, we are told, waved goodbye to the heroic artisans of plant breeding, because, 'genetics allows you to make predictions so it takes a lot of the effort out of plant breeding'.[4] Mass-production of food, diminished hunger and increased life expectancy were brought about across the twentieth century by geneticists and the scientific expertise that rationalised plant breeding.

A counter-analysis to this triumphalism was mounted in the 1980s by rural sociologists, Marxian biologists and historians of science interested in plant breeding. In the American case, the move to the geneticists' eye, they argued, was driven not by any intrinsic superiority in this view but by a series of extrinsic factors. One was the desire on the part of nascent professional scientists to secure social status. For some scientists this meant a place in academia. Others made strong connections with industry in the form of professional plant breeding firms. On a Marxian analysis, as capital moved into these firms, bottom-up structures

of plant breeding that utilised the breeders' eye, an ability anyone could develop – the competition – were sidelined and then eliminated as an obstacle to profits.[5] At its strongest, the counter literature suggests that traditional breeding might have been just as productive as the new genetic plant breeding had it received the same funding and resources.[6] Another way of developing this thought has been to show how little genetic theory had to do with the supposed signal success of American genetic plant breeding; F1 hybrid maize.[7]

While there is much truth in these counter analyses, a bold story of privatisation is not the whole story. Despite the power of plant breeding firms, in America, the institutionalisation of expertise around plant breeding was ultimately facilitated by public institutions. The Land Grant Universities and their aligned experimental stations, at which genetics flourished, worked in concert with plant breeding firms. The Federal Department of Agriculture explicitly planned for the state to develop a plant breeding market which would then be populated by private firms.[8] This imperative explains in part why the US legislature capitulated to plant breeding firms' demands for intellectual property in plant varieties much earlier than many European countries.[9]

To sketch out a crude summary; genetic plant breeding expertise in America was initially developed in public Land Grant Universities, and then transferred to commercial plant breeding firms for various social and economic reasons. While traditional plant breeding expertise found some support at the public institutions initially, especially in publicly-oriented 'extension' work, the net effect has been a transfer of the business of plant breeding away from traditional breeders – in this case often farmers – towards genetics and private interests.[10]

Looking to Britain, a different picture of the sequestration of plant breeding expertise emerges. In Britain public agricultural institutions were slow to develop in comparison to the US. Initial support arrived in the form of 'The Whiskey Money', a rebate derived from shifts in licensing laws in the 1890s which provided almost accidental support for technical instruction.[11] A system of Government small grants was developed around the turn of the century but remained restricted in scale.[12] When government did begin to fund plant breeding, it did so under an ethos that presumed, as Winston Churchill put it in the first year of the 1905-1915 Liberal government, 'public ownership and control were better than private speculative ownership and control, other things being equal'.[13] Within this context, early British geneticists argued for the value of their work under an ethos of the public good. On many occasions they reminded the public that they had no financial stake in their work. From around 1910 and increasingly after the First World War, British geneticists were successful in securing public funding to develop a large technological system for plant breeding.[14] Several

institutions were established for breeding, producing, testing and distributing the seed that was to flow through the system. In its initial intention, the new seeds would inspire new forms of national and imperial agriculture.[15]

The British case does not, however, simply present as a public or nationalised version of the American system. While it is true that early British geneticists in their public system-building activity absorbed, formalised, even supplanted, a great deal of traditional plant breeding expertise there are some interesting countertrends within the early part of this story.[16] In the years before 1930, farmers generally declined to instantiate several of the practices and farming systems that geneticists were recommending even as those same farmers utilised new genetic varieties.[17] Expertise around farming practice, what to farm and how, was resistant to geneticists' plans until at least the Second World War. Likewise, seed production and distribution, while attempted by geneticists within the system and in competition with private firms for much of the 1920s were abandoned in the 1930s. Just as there was no simple privatisation of plant breeding in the United States, the British story of nationalised plant breeding is more complicated than it might first appear.

This paper explores three further examples of counter trends to the assimilation of plant breeding expertise into a nationalised large technological system. First, the key proponents of British genetic plant breeding initially preached the accessibility of plant breeding with genetics. They presented genetics as though it were a method traditional breeders might adopt for themselves. Several popular texts praised the simplicity of the genetic insight for general audiences. Second, Rowland Biffen, the key genetic breeder in Britain and Chair of Agricultural Botany at the University of Cambridge, developed a public persona as a 'Wheat wizard, responsible for curing criminal plants' that spoke to the breeders' eye just as much as the power of genetic theory.[18] Third, the production of new genetic varieties by Biffen had less to do with the geneticist's insight, as he claimed, and was in fact based on his skills in developing and using the breeders' eye. This is obvious in Biffen's erratic use of genetic analyses in his scientific publications. He was, at best, an idiosyncratic geneticist. This paper argues that there was a complex and variegated relationship between early genetics and traditional plant breeding in Britain, in which the geneticists' talk of precision was often mismatched to practice and the promotion of genetic plant breeding often promised far more than geneticists were able to deliver. British genetic plant breeders owed more to, and attempted to court the favour of existing plant breeders to a far greater extent than triumphalist accounts of genetic revolution suggest.[19] To explore the case of British genetics and the institutionalisation of plant breeding expertise the rest of the paper is split into three parts. The first details the arrival and promotion of genetic theory as a

replacement for the breeders' eye arguing that it was, initially at least, presented as a popular theory of plant breeding, which could be used by anyone. The second part turns to Rowland Biffen's career and plant breeding work showing the extent to which his work was reliant on the breeders' eye, something that newspaper press coverage of the time recognised and emphasised. Finally, the third section analyses the ways in which one of Biffen's most successful students, Frank Leonard Engledow, characterised Biffen's work when he authored his former teacher's obituary.

*1. Popular Mendelism*

Geneticists, despite their claims to be revolutionising plant breeding, and creating new systems of production, were reliant on the societies, publications and structures of agriculture and horticulture. In the first two decades of the discipline's existence in Britain, two of the key genetic institutions were the University of Cambridge's School of Agriculture and the John Innes Horticultural Research Institution. These connections with agriculture and horticulture were essential for the institutional development of genetics. They also formed the framework in which geneticists argued for the value of their work and the reputations of their new varieties. They did so in a pre-existing moral economy of plant breeding. Genetic varieties flourished in the pages of the journals of the Royal Societies of Agriculture and Horticulture and at the public shows and medal-giving displays organised by these communities.

The connections between zoologist and first British geneticist, William Bateson and the Royal Horticultural Society have become the stuff of legend.[20] Beyond the apocryphal tale of Bateson first reading Mendel's work on the train to a Society meeting, historians of science have emphasised the importance of the Royal Horticultural Society in providing resources – plants and a place to publish – to Bateson and the first geneticists.[21] The Royal Horticultural Society stood within a wider network of connections, which have been characterised as aristocratic, and in contrast to laboratory science; domestic.[22] A similar analysis can be run for the Royal Agricultural Society, for which Rowland Biffen was consulting botanist, publishing the society's yearly botanical reports from 1910-1940. The early years of genetics were characterised by connections to horticulture and agriculture of a particular type: that created in societies denoted as 'Royal' and embedded in the higher levels of British class structures. On two significant occasions land providing space for genetic plant breeding experiments was gifted to the Mendelian movement by such wealthy benefactors. In several senses early genetics was reliant on the resource of the Edwardian British elite. This

remained true even after significant funding for genetic plant breeding arrived in the form of David Lloyd George's Development Commission from 1910.

The aim of this paper is not to further explore these connections between genetics, the land-owning aristocracy, and government; rich as they are. Instead, this section turns to the popular promotion of genetics in the early decades of the twentieth century through books such as Reginald Punnett's 'admirable little primer' *Mendelism.* Punnett's *Mendelism*, a key example of the early genetic best-seller, went through seven British editions, numerous reprints, American editions and translations into several languages.[23] Over the course of its life the initial 63 page volume swelled to 236 pages. From an initial 'short and popular essay' *Mendelism* grew to a lengthy and sometimes rambling account of the many theories that came to be part of genetic thinking. While genetics might have been an elite affair, books such as *Mendelism* openly courted a wider audience from a wider section of society.

*Mendelism* opens with the story of 'one of the most romantic chapters in the history of science'.[24] Punnett retreads (what was even then) the well-known story of Gregor Mendel, his work with peas, its loss and rediscovery. Readers of Bateson's earlier popular book, *Mendel's Principles: A defence,* (1902) or practically any early genetic writing would have been familiar with this story. They would also have expected the polemic that came next, about the importance of 'Mendel's Laws'; 'Economically their influence must be very great. Since the principles of heredity form the very basis of the breeder's operations, anything which throws new light on these hitherto obscure matters must largely influence an important industry.'[25] It was the breeders' eye that needed to be replaced, 'Till now [the breeder's] methods have been almost entirely empirical, and in great measure wasteful.'[26] Instead, and armed with the new genetic insight, 'the breeder may proceed to build up synthetically, character by character, the plant or animal which he requires'.[27] The invitation was an open one. The last three pages of Punnett's volume contain a note on how to breed plants, 'As some readers may possibly care to repeat Mendel's experiments for themselves'.[28] Against the other changes to the volume in its long-run of editions and reprints, these last three pages, instructing the reader of this 'book … intended to appeal to a wide audience,' how to self-fertilise plants, remained constant.[29]

For readers who wanted more detail, Punnett signalled in the third edition of *Mendelism*, that there was, 'Mr. Bateson's indispensable volume on *Mendel's Principles of Heredity* (Cambridge, 1909), where a full account of [genetic theory] is readily accessible.'[30] In the preface to his second genetic primer, Bateson was surprisingly frank as to what could be offered to traditional breeders, or fanciers, 'To prevent disappointment, however, it must be at once admitted that for fanciers Mendelism can as yet do comparatively little.'[31] Not only

was there little to offer as yet, but the fancier's work, Bateson admitted, had received unfair neglect:

> "Fancying" provides the chief interest in life for thousands of persons in this country. It is an occupation with which the scientific naturalist should have more sympathy than he has commonly evinced. If the scientific world had kept in touch with the operations of the "fancy" much nonsense which has passed into scientific orthodoxy would never have been written.[32]

Bateson, writing in this popular venue, proposes more of a collaboration than a revolution for traditional breeders. There were however two things that genetics could do for the fancier:

> First, in the study of the workings of the Mendelian system it will provide a most fascinating pursuit, which if followed with assiduous care may at any moment lead to some considerable advance in scientific knowledge. Secondly, the principles already ascertained will be found of practical assistance in the formation of new breeds and may save many mistakes and waste of time.[33]

Even as Bateson reiterates Punnett's standard genetic claims of rationalising away time and mistakes, there was undoubtedly an offer being made, that fanciers might use the genetic method themselves as a compliment to their own non-genetic skills.

*2. Rowland Biffen, Wheat Wizard: Curing Criminal Plants.*

Rowland Biffen was a genetic celebrity. Biffen's genetic work was featured in a wide range of publications including the *Times, Daily Mail* as well as more specialist popular publications. In the 1907 volume of *Science Progress* he claimed, 'In place of fantastic hypotheses the breeder now possesses well-grounded facts on which it is possible to base comprehensive plans for the betterment of the plants which are the objects of his experiments.'[34]In Biffen's rehearsal of the Mendel story he stressed that, 'Mendel saw the necessity of keeping the problems as simple as possible'. Indeed, his results were 'unusually simple'.[35] There was a sort of accessibility in the simplicity of Mendel's work that Biffen was keen to emphasise. While some institutionalisation of technical skill was necessary: 'it rests with those who desire to see their crops improved to provide those who are willing to acquire the technical knowledge necessary for such work with sufficient opportunities to carry it on.'[36] In other words if

Mendel's work was conceptually simple, the complex part was the technical aspect of how to breed - elucidated by Punnett in the last section of his book - but still, by Biffen's reckoning, an area over which traditional breeders ('those who desire to see their crops improved') retained control. Where Biffen's claims in *Science Progress* emphasised simplicity but retained a focus on the necessity of technical knowledge, in the *Daily Mail's* coverage of his work another story emerged.

In 1908, the conservative journalist William Beach Thomas talked of, 'Bateson and Biffen, the Cambridge Mendelians' in an article published in the *Daily Mail,* 'Miracle Crops'.[37] In Beach Thomas's telling they were but one part of a four-pronged race. Also in the 'Hunt for the Prodigy' were Luther Burbank, a California-based breeder, who Beech Thomas felt was the subject of much 'picturesque hyperbole' on the part of American journalists, the 'ingenious M. Vilmorin, of Paris, who can … perennialise the strawberry at a wave of his wand,' and, 'John Garton, the agricultural James Watt.'[38] For Beach Thomas all of these different participants in the race of plant breeding were 'scientific'.[39] Beach Thomas did, however, have a favourite and it was John Garton's plant breeding nursery that he took the trouble to visit and it was form here that he reported back to his readers.

In 1909 an unnamed correspondent reported the release by Biffen of 'a wheat that should be worth as much as the best'. The writer thought, 'The coming farmers' season is likely to be famous for new grains', presumably Biffen's, but there were also reports from the 'French hybridisers' work, and mentions of Burbank and Garton. In ending the writer drew a distinction that was missing in Beach Thomas's view that these were all scientific methods. The author of the 1909 piece claimed, 'Mr Biffen has got his success by working on the strange law of Mendel, now exercising men of science all over the world.' In comparison, 'Mr John Garton, just as his counterpart, Mr Burbank, in America, plays for the sport and the great accident, and both promise great results'.[40] A second piece in 1909 - also from an unnamed correspondent - maintained the same distinction, contrasting Garton, the French hybridisers and Burbank ('called the Californian wizard') with Biffen, who, 'on the other hand, works wholly by system and has two triumphs to his credit.'[41] The triumphs to which the correspondent referred were a disease resistant variety released that year in Britian and a second high quality variety which had not yet been released.

After the First World War, the *Daily Mail* continued to run stories on Biffen and his plant breeding. By this time his competitors had fallen out of view. Biffen, instead of Burbank, was now the 'Wheat wizard. Curing criminal plants', he and his staff had 'quite surpassed all the "plant wizards" of the age in this or any other country.'[42] In his success the law of Mendel had become a sort of wizardry, 'Professor Biffen recently told a correspondent of the Daily

Mail that for his wizardry he "relied wholly on this law" in which Cambridge has a sort of corner'.[43] If Cambridge had cornered a particular type of plant breeding expertise, all this wizard talk suggested it was not a simple scientific expertise. While Biffen protested that his corner was 'wholly' due to genetic theory the *Daily Mail's* correspondent had actually tapped something of an uncomfortable contradiction in Biffen's work. While he talked up the scientific nature of his work, skill obviously remained an important element in his abilities.

*3. The art of plant breeding*

> Rediscovery of Mendel's principles gave a scientific foundation to the ancient art of breeding. Orderly synthesis displaced mysticism and guess-work. With Biffen more than with any other breeder lies the credit for the beginning of this transformation and within a dozen or so years of the Mendelian rediscovery his outlook had dominated plant breeding in all countries.[44]

These words come from Rowland Biffen's most successful pupil, Frank Engledow, also his successor as Chair of Agricultural Botany at the University of Cambridge. They are drawn from Biffen's obituary notice as a Fellow of the Royal Society. Printed in 1949, these thoughts exemplify precisely the triumphalist narrative of genetic revolution of plant breeding expertise with which this paper began. Yet, across the rest of the obituary Engledow admits precisely the same view of Biffen's skill celebrated by the *Daily Mail*. Biffen's 'contributions' were, Engledow clearly states, due 'to the art of breeding'.[45] Just like the traditional breeders' eye, 'Biffen's remarkable gift' was 'for detecting by eye the commercial merits' of plants.[46] Indeed, on Engledow's account of Biffen's work, 'empiricism was more to his taste than deep analysis', because Biffen had:

> The natural gift for plant breeding - still essential to success in the art - is commonly spoken of as an 'eye for plant breeding'. With Biffen it was the eye of the artist. ... The artistic instinct nearly always led him right in plant breeding though, on his own admission, sheer admiration of a beautiful ear led him to the costly error of using Swedish Iron wheat extensively as a parent. From years of work and tens of thousands of experimental plants he never got anything good.[47]

It seemed in fact that Biffen committed all of the sins of waste and inefficiency which he had promised to eradicate from the breeding process. Skill, on Engledow's account, and by

Biffen's own admission 'lucky accident' played no small part in the key British genetic plant breeding programme.[48]

*Concluding reflections*

What is the significance of these early counter-examples to the process of expertise institutionalisation that undoubtedly took place across the twentieth century? For one thing, they point to there being no smooth transition of expertise into the institution. This was a contested process, perhaps not quite a race, in which the resources of traditional plant breeding were required for genetic institutionalisation. Geneticists knew they had to court the favour of horticulturalists and agriculturalists and persuade them of the value of their work.

These counter-examples to the rationalising, expertise driven narratives of early twentieth-century scientific control and revolution should give us pause for thought about the latest claims around the latest techniques of DNA modification, including CRISPR. After the first genetic plant breeding program, detailed here, there have been a succession of supposedly new and revolutionary plant breeding methods, more or less associated with genetics: mutation breeding, radiation breeding, marker assisted breeding and of course genetic modification of the 21st Century.[49] In each case the new method was supposed to revolutionise plant breeding. Yet a new variety, still, in 2017, takes around ten years to breed; the same amount of time it took in Biffen's day. Wastage in the process, as much as skill and luck, still abound in the business of plant breeding.

# Endnotes

1. 'CONSCICOM: Constructing Scientific Communities: Citizen Science in the 19th and 21st Centuries' (http://www.conscicom.org) is an Arts and Humanities Research Council (AHRC) funded project.
2. Rowland Biffen, "Systematised Plant Breeding", in *Science and the Nation,* ed. A. C. Seward, pp. 146-175. (Cambridge: Cambridge University Press, 1917), p. 146-147.
3. Rowland Biffen and and F. L. Engledow, *Wheat-Breeding Investigations at the Plant Breeding Institute, Cambridge* (London: His Majesty's Stationery Office, 1926), p. 13.
4. Noel Kingsbury, 7 Feb 2010, 'The Food Programme: Seeds', *BBC Radio 4*, <accessed 26th Dec 2017> http://www.bbc.co.uk/programmes/b00qg0r4, quote at 14m. 53s.
5. See See Deborah Fitzgerald, *The Business of Breeding: Hybrid Corn in Illinois 1890-1940* (Ithaca: Cornell University Press, 1990); Jack Kloppenburg, *First the Seed: The Political Economy of Plant Biotechnology* (Cambridge: Cambridge University Press, 1988); Berris Charnley, 'Seeds Without Patents: Science and Morality in British Plant Breeding in the Long Nineteenth-Century', *Revue Economique* 64, (2013): 69-88.
6. Richard Lewontin, "The Maturing of Capitalist Agriculture: Farmers as Proletarian", *Monthly Review* 50 (1998): 72-85.
7. Jean-Pierre Berlan, "The Political Economy of Agricultural Genetics", in Rama S. Singh *et. al.* (eds.), *Thinking about Evolution: Historical, Philosophical, and Political Perspectives*, pp. 510-528 (Cambridge: Cambridge University Press, 2001).
8. Gar Allen, "Essay Review: History of Agriculture and the Study of Heredity – a New Horizon", *Journal of the History of Biology* 24 (1991): 529-536.
9. Daniel Kevles, "Patents, Protections, and Privileges: The Establishment of Intellectual Property in Animals and Plants", *Isis* 98 (2007): 323-331.
10. This is the general picture developed by Jonathan Harwood, *Technology's Dilemma: Agricultural Colleges between Science and Practice in Germany 1860-1934* (Bern: Peter Lang, 2005) and Jonathan Harwood, 'Did Mendelism Transform Plant Breeding? Genetic Theory and Breeding Practice, 1900–1945', in D. Phillips and S. Kingsland, eds. *New Perspectives on the History of Life Sciences and Agriculture* (Springer, Cham: Amsterdam, 2015).
11. For a general overview of this history see Paolo Palladino, *Plants, Patients and the Historian: (Re)Membering in the Age of Genetic Engineering* (Manchester: Manchester University Press, 2002).
12. Dominic Berry, 'Bruno to Brünn; or the Pasteurization of Mendelian genetics'. *Studies in History and Philosophy of Biological and Biomedical Sciences.* 48 (2014), pp. 280-286.
13. Winston Churchill, 'Consolidated Fund (Appropriations) Bill'. House of Commons Debate (02 August 1906) vol 162, cc1382-425.
14. Berris Charnley, "Agricultural Science, Plant Breeding and the Emergence of a Mendelian System in Britain, 1880-1930". (Unpublished PhD Thesis: University of Leeds, 2012).
15. Berris Charnley, 'Experiments in empire-building: Mendelian genetics as a national, imperial, and global agricultural enterprise', *Studies in the History and Philosophy of Science: Part A.* 44 (2013): 292–300.
16. Joseph Hodge, *Triumph of the Expert: Agrarian Doctrines of Development and the Legacies of British Colonialism* (Ohio University Press; Ohio, 2009).

17. Berris Charnley, 'Geneticists on the Farm: agriculture and the all-English loaf', in *Scientific Governance in Britain, 1914-1979,* eds. Charlotte Sleigh and Don Leggett, pp. 181-198. (Manchester: Manchester University Press, 2016).
18. [Anon] 'Wheat Wizard', *Daily Mail,* October 28 1921, p.6.
19. This argument is related to and expands on the thesis developed in Paolo Palladino, "Between Craft and Science: Plant Breeding, Mendelian Genetics and British Universities, 1900-1920", *Technology and Culture* 34 (1993): 300-323 and Paolo Palladino, "Wizards and Devotees: On the Mendelian Theory of Inheritance and the Professionalization of Agricultural Science in Great Britain and the United States, 1880-1930", *History of Science* 32 (1994): 409-444.
20. Especially in popular accounts such as Robin Marantz Henig, *A Monk and Two Peas: the story of Gregor Mendel and the discovery of genetics* (London: Weidenfeld & Nicolson, 2000).
21. On the connections between genetics and horticulture see Robert Olby, 'Horticulture: The Font for the Baptism of Genetics', *Nature Reviews Genetics* 1 (2000): 65-69 and Gregory Radick, 'The professor and the pea: Lives and afterlives of William Bateson's campaign for the utility of Mendelism', *Studies in History and Philosophy of Science Part A* 44 (2013): 280-291.
22. Marsha Richmond, 'The 'Domestication' of Heredity: The Familial Organization of Geneticists at Cambridge University, 1895-1910', *Journal of the History of Biology* 39 (2006): 565-605 and Donald L. Opitz, Staffan Bergwik, Brigitte Van Tiggelen eds. *Domesticity in the Making of Modern Science* (Basingstoke: Palgrave Macmillan, 2016).
23. Reginald Punnett, *Mendelism* (Cambridge: Cambridge University Press, 1905).
24. *Ibid*, p. 1-2.
25. *Ibid*, p. 56.
26. *Ibid*, p. 56.
27. *Ibid*, p. 58.
28. *Ibid*, p. 69.
29. Reginald Punnett, *Mendelism* 3rd edition (Cambridge: Cambridge University Press, 1911), p. v.
30. *Ibid*, p. v-vi.
31. William Bateson, *Mendel's Principles of Heredity* (Cambridge: Cambridge University Press, 1909), p. vii
32. *Ibid.*
33. *Ibid.*
34. Rowland Biffen, 'Modern Plant Breeding Methods: With Special Reference to the Improvement of Wheat and Barley', *Science Progress* 1 (1907): 702-722, p. 704.
35. *Ibid.* p.704-705.
36. *Ibid.* p.722.
37. W. Beach Thomas, 'Miracle Crops' *Daily Mail* (13 August 1908), p. 4.
38. *Ibid.*
39. *Ibid.*
40. [Anon] 'Farmers' Larger Profits', *Daily Mail* (10 February 1909), p.5.
41. [Anon] 'Perfect Wheat', *Daily Mail* (27 July 1909) [n.p.].
42. [Anon] 'Wheat Wizard', *Daily Mail* (28 October 1921), p.6.
43. *Ibid.*
44. Frank Engledow, 'Rowland Harry Biffen. 1874-1949', *Obituary Notices of Fellows of the Royal Society* 7 (1950): 9-25, p.10.

45. *Ibid.* p. 15.
46. *Ibid.* p. 18.
47. *Ibid.* p. 19.
48. Rowland Biffen, 'Systematised Plant Breeding' (*op. cit. 1)*, p. 167.
49. See Helen Curry, *Evolution Made to Order: Plant Breeding and Technological Innovation in Twentieth Century America* (Chicago: University of Chicago Press, 2016).