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SPECIAL ISSUE—BETWEEN THE FARM AND THE CLINIC: AGRICULTURE AND REPRODUCTIVE TECHNOLOGY IN THE TWENTIETH CENTURY

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'Crook' pipettes: embryonic emigrations from agriculture to reproductive biomedicine[1]

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Abstract

While cloning, stem cells, and regenerative medicine are often imagined in a futurial idiom—as expectations, hype, hope and promises—this article approaches the remaking of genealogy in such contexts from a historical route. Through a series of somewhat disparate historical connections linking Australian sheep to the development of clinical IVF and the cloning of Dolly at the Roslin Institute in Scotland in 1996, this article explores the linkages through which agriculture, embryology, and reproductive biomedicine are thickly intertwined. Key to this examination is not only the history of experimental sheep breeding, and its somewhat unexpectedly genealogical connections to (Australian) national identity ('wool in the veins'), but also the re-emergence of a distinctive frontier ethos in the context of assisted conception, and later human embryonic stem cell derivation. I have set this scene of genealogical interconnection against the criss-crossing traffic between Britain and Australia, and the wool trade, to emphasise the importance of global, as well as local, connections in the bloodlines of animals such as Dolly. In sum, this article examines the idea of the 'biological frontier' by exploring its histories as a means to offset the assumption that this frequently encountered idiom describes a future that is, or must be, by definition, unknown and unknowable.

Keywords: Embryology; Cloning; Pastoralism; Frontier; Sheep breeding; Dolly; Genealogy

[1] This article is adapted from Franklin (2007).

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1. Introduction

Following its first successful practice in 1978, in vitro fertilization (IVF) has quickly become established as a routine component of fertility treatment, and more than five million children have been born worldwide through this technique—which is today considered a normal and routine component of reproductive biomedicine. The controversy concerning 'test-tube babies' that reached a peak shortly before Robert Edwards and Patrick Steptoe succeeded in their pioneering experiment in human reproduction has dimmed to a point that many are unaware IVF was ever controversial, still less how intensely it was opposed, even by otherwise sympathetic members of the medical and scientific communities (Edwards & Steptoe, 1980, pp. 106–107). In the early twenty-first century, it is cloning, preimplantation genetic diagnosis (PGD), and human embryonic stem cell derivation which have become the focus of international debate and sharp division between those for whom they are seen to represent the future promise of scientific improvement, and those who fear they are pushing humanity 'too far' into the realms of biological re-engineering (Fukuyama, 2002; Habermas, 2003; Henig, 2004).

Inevitably such debates are overly focused on the future, and on what is 'new' about high profile reproductive techniques such as somatic cell nuclear transfer. However, not only are many of the basic techniques of embryology and models of reproductive physiology used in procedures such as IVF more than a century old (Hans Spemann successfully performed nuclear transfer on sea urchin embryos in the 1920s), but these scientific models and techniques are also far more substantially intertwined in the development of reproductive biomedicine than may appear to be the case. As British mammalian developmental biologists such as Graham (2000) and McLaren (1998) have observed, and as Edwards (2001, 2004, 2005) has similarly emphasized, the postwar context of experimentation in the embryology of vertebrates was a uniquely productive period, especially in the UK, where many of the theories and techniques out of which human embryonic stem cells, somatic cell nuclear transfer, and human therapeutic cloning—such as embryo biopsy, and precise molecular analysis of the contents of a single blastomere—were derived.

This article attempts to explore yet another dimension of the development of the techniques that have come to define contemporary reproductive biomedicine, namely their connections to agriculture, sheep breeding, colonial pastoralism, and in particular the emergence of the Australian fine-wool trade. By tracking the somewhat unexpected connections between IVF, the Australian outback, and Dolly the sheep, this article follows a meandering path, perhaps suited to its ovine orientation, back in time to the international connections, material transfers, market networks, and symbolic exchanges in which, it argues, contemporary developments in reproductive biomedicine, stem cell science, and 'cloning' are usefully situated. These further involve what the article describes as a set of *genealogical connections* linking Australian sheep and wool to the mythology of the frontier—imagined as both a pastoral and heritable origin of shared substance—and later the emergence of the Australian nation, which still later celebrates its national identity on yet another frontier—that of reproductive biomedicine, where Australian clinicians and scientists have been both prominent and celebrated 'pioneers'.

This article thus begins by exploring the significance of selectively bred sheep to Australia's settler economy and the means by which its four-footed frontier came to be seen

as the birthplace of a national identity that was repeatedly described as if pastoralism *were itself a form of primitive national protoplasm*. The idea of 'wool in the blood' of contemporary Australians is not only a popular, and widely cited, idiom, but a 'living legacy' in the form of sheep stations where the land, people, and animals share the same name (Austin, 2004; Ward, 1978; Perry, 1963). This foundational ovine idiom, whereby a pastoral legacy of sheep-breeding becomes, in the words of Australian anthropologist Wolfe (1994a,b, 1998), something that is 'carried in the veins' of contemporary Australians, adds a useful historical dimension to the frequent depiction of biology itself as a 'frontier'.

The most challenging process to document, for which this article provides only a descriptive scaffold, is the way in which the Anglo-Australian legacy of shared sheep and wool bonds was 'transferred' into human IVF in the 1980s, when the standard protocols for IVF were adapted to include ovulation induction—a technique developed for sheep (Kannegiesser, 1988; Robinson, 1967).[2] The rationalization of sheep ovulation acquired human form under the close supervision of Alan Trounson and Carl Wood, widely celebrated as the fathers of Australian IVF. Trounson, who cloned a lamb as a doctoral student at the University of Sydney by splitting a six-day-old morulla in two, with pipettes he shaped to resemble crooks, could be seen to be as much a product of a distinctive Anglo-Australian scientific coupling based on sheep and wool as are Dolly, the Roslin Institute, IVF, or stem cells[3] see Fig. 1.

The fact that Trounson was supported by an Australian Wool Board Scholarship[4] to study at Cambridge, where his contemporaries included many of the scientists who later contributed to Dolly's creation (and together comprise one of the world's most powerful and accomplished scholarly lineages of reproductive biologists), cannot be considered purely coincidental, but rather forms part of a legacy this article tries to begin to unpack—as it does the celebration of Australian achievements in IVF as part of the nation's centenary (Kannegiesser, 1988).

These genealogical aspects of frontier heritage and national identity, which are both literal and symbolic, and which in Australia have a distinctively sheepish cast, reveal suggestive dimensions of Australian 'in vitro' genealogies in the form of stem cells, genomics, and cloning. These explorations, as it turns out, also reveal a distinctively ovine descent pattern, as many of the components of IVF, embryo surgery, and ovulation induction, were perfected in sheep—often under funding from the Australian wool board, and, crucially, through a constant interchange of Australian and British agricultural animals, knowledges, techniques, and scientists. Thus, the bioeconomics of the wool trade can be seen to have laid many of the vital scientific, commercial, and agricultural foundations for contemporary partnerships between Britain and her commonwealth partners in the pursuit of future bio-innovation, while agriculture is also revealed as an

[2] As T. J. Robinson, editor of a volume of papers derived from a six-year study of sheep ovulation induction at the University of Sydney published in 1967, notes, the basic elements of control of sheep ovulation were already well established by 1960, and it was the 'solution' to quite precise 'problems', such as injection procedures, and a 'sharp end point' to progesterone treatment, that remained to be discovered in sheep (Robinson, 1967, p. xiii).

[3] The first UK stem cells developed at King's College, London in 2003 (by Sue Pickering, Peter Braude and Stephen Minger) were successfully characterised using a control specimen from Trounson's labs which had, in a sense, 'travelled back' to London in a curious post-colonial return to the Mother Country.

[4] Or 'Scholarsheep'.

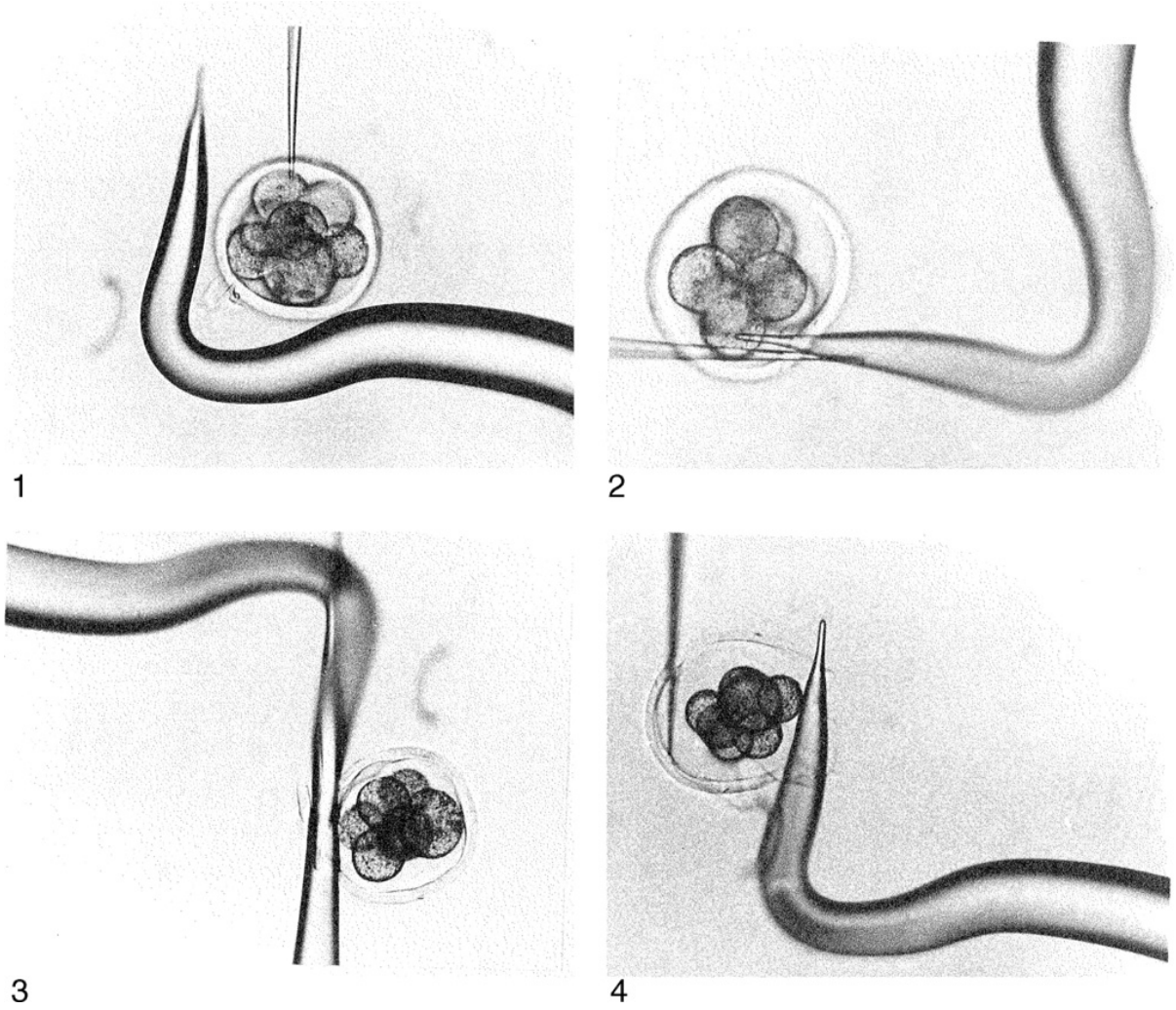

Fig. 1. Alan Trounson's 'crook' pipettes. The crook-shaped pipettes used by Alan Trounson to clone a lamb, shown in this image from his dissertation, neatly encapsulate the connections between pastoralism, agriculture, embryology and reproductive medicine.

important context for biomedical innovation. Together, these linkages offset the connotation of radical novelty that attaches to Dolly, cloning, and stem cells, while also revealing some intriguing historical linkages between pastoralism, the remaking of genealogy, the wool trade, assisted conception, cloning, sheep breeding, and the very idea of a 'biological frontier'.

United by shared interests of commerce, industry, and science, British and Australian scientists can be seen to share a lineage of vital innovation within the life sciences, bonding them, in Donna Haraway's terms (Haraway, 1997, p. 7), as kindred offspring of a specific mode of 'sociotechnical production' (or, in this case, *re*-production). If the genealogy (or even protoplasm) that links the sheep experiments of Ian Wilmut and Keith Campbell in Britain to those of Alan Trounson and Carl Wood, and back further still to the carefully tended flocks belonging Robert Bakewell and Joseph Banks is historically rooted in a shared commitment to agricultural improvement, livestock industrialization, medical and scientific progress, and the generation of new commercial markets, as this article suggests, so it may be both possible and necessary to consider the history of developments in contemporary reproductive bioscience, biomedicine, and biotechnology to be

at least equally important as their imagined futures in our discussions of where they may lead.[5]

2. Gaol to wool

Sheep are often considered to be synonymous with the founding of Britain's last, and largest Antipodean colonial possession, *Terra Australis*. However, the original colony of New South Wales was not originally imagined in a pastoral idiom. When the First Fleet touched ground at Cape Cove in 1787, the British ('Home') Government's intentions for its new possession were strictly 'import only': it was intended that the remote colony become a gaol in order to relieve Britain's overcrowded prisons of a significant portion of their convict population.[6] As historian G. J. Abbott claims in his account of early Australian settler–colonial history,

> Whatever ultimate reasons might have been implied in the British government's decision in 1786 to found a settlement on the east coast of Australia, the immediate explicit aim was to establish an economical prison . . . that by the end of the second year of its existence . . . would be self-sufficient. (Abbott, 1971, p. 17)

The first sheep to set hoof upon Australian soil, the ninety or so on board the First Fleet who survived the passage, were thus intended 'for subsistence only', and were so poorly cared for that within a year all but a few of their number had perished. In 1793, 110 additional sheep were unloaded in Sydney from the Indian ship *Shah Mormuzear*, bringing the total to 516 head in July 1794, when the first official livestock count was taken (ibid.).[7]

Sheep were useful in colonial Australia for many of the same reasons they have been a productive animal elsewhere. Requiring little to no maintenance from their keepers, and being highly mobile and tractable, they provided a reliable and efficient source of milk, wool, meat, lanolin, and other products including hide, manure, fleece, and tallow. Capable of living where other animals will perish, in part because they graze more efficiently than any other ruminant, and can do without water for prolonged periods, sheep were the ideal settler animal for colonial Australians, providing cheap subsistence on the hoof (Lydekker, 1913; Ryan, 1973; Ryder, 1983). Once the Blue Mountains had been crossed in

[5] This article is based on research into the 'pre-history' of Dolly the sheep, although its author is an anthropologist by training, and not a historian. Out of respect for the inevitable lapses of scholarly etiquette and omissions such an exercise entails, it is indeed a sheepish exercise, but with some hope the reader will also respect that its ovine tendency to wandering may be of benefit in spite of its undisciplined, and indeed semi-feral, character.

[6] In 1787 Great Britain was still in economic freefall following its army's expensive defeat at the hands of the defiant, and now constitutionally independent, former subjects in the 'failed' colonial project of New England.

[7] The sheep that were combined to produce Australia's first flocks came from many countries including Ireland, India, South Africa, and California. Later they were imported from Spain, Germany, Vermont, and France. The wool industry, which was not fully established until the 1860s, came eventually to rely on many different types of Merino sheep, among them the famous Peppin Merino, described by one sheep historian as: 'a triumph of cross-breeding with genes from many types of sheep, including the most primitive' (Garran & White, 1985, p. xiv).

1813, the spread of settlement rapidly followed the sheep runs out into the rich pasture-lands to the West. Indeed the settlement of New South Wales, often referred to as Australia's first frontier, was largely a settlement by sheep.[8]

3. Wool to wealth

Much dispute predictably surrounds the origins of the fine-wool trade in Australia, and the role of certain prominent Australian 'forefathers' within it, but most commentators identify a significant change in the early colonial economy in the period 1803–1804, under Governor King, when the colony began to reach self-sufficiency, and the real possibility of export, or 'staple', commodities arose in earnest. Prominent among such export opportunities was fine wool, a product that had already begun to be advanced through selective breeding programs employing imported Merino sheep by private pastoralists including the Macarthur, Marsden, and Riley families (Abbott, 1971, pp. 17–47). According to Jill Ker Conway,[9] one of the first Australian historians to research the early sheep and wool economy in detail, the fine wool industry of New South Wales developed unevenly from 1803 to 1835, beset by a number of compromising factors, and delayed from achieving significant expansion until 1820.[10] Abbott identified 1822 as 'when the accelerator was pushed to the floor,' leading to the 'wool boom' period of 1822–1851, widely described as Australia's 'Great Pastoral Age'.[11]

The beginning of the 'pastoral age', characterized by the celebrated Australian historian Sir Stephen Roberts, was 'the period 1835,' when 'the early history of Australia' and the 'real story of [her] progress' began 'suddenly to commence growth at practically a forced rate'

[8] New South Wales has been described as an ideal climate for the production of fine-woolled sheep, but sheep are known to thrive in a more diverse set of landscapes than almost any other animal. Indeed, few animals other than dogs exist in so varied and numerous a range of global habitats. Even Merino sheep, despite their African and Asiatic origins, and largely Mediterranean cultivation until the 1800s, have successfully been introduced to the harshest environments, such as Iceland, where they winter as happily as seals (Austin, 1950). They are equally robust in the face of drought, heat, dust, and the extremes of weather and disease imposed by a tropical, or desert, climate (Ryder, 1983; Youatt, 1894).

[9] Jill Ker, the young historian who grew up on a remote sheep station and wrote her honours dissertation on sheep breeding at the University of Sydney in the 1960s, was later to become the wife of Harvard historian John Conway, a leading academic and administrator at the University of Toronto, the first woman President of Smith College, and one of Australia's most internationally acclaimed authors, is today far better known by the name Jill Ker Conway, which is how I have cited her here, although her early works are listed in the bibliography under Ker (1960, 1961, 1962).

[10] These factors included the lack of proper breeding stock or knowledge of breeding, the small size of the labor force, the absence of established markets for wool, and the conspicuous lack of support from the British government for fine-wool production, evidenced by, among other restrictions, Governor Macquarie's failure to facilitate livestock pasturage in the rich valleys made available in 1813 by the successful crossing of the Blue Mountains, see Ker (1960, 1961, 1962). Other historians, including Abbott (1971), posit different factors, and disagree about the attribution of 'delay' to the wool trade, while concurring with Ker Conway that it only became fully viable after more than two decades of fits and starts.

[11] In 1815 the Australian Colonies provided 73,179 lbs of wool to Britain in comparison to the 6,927,934 lbs Britain imported from Spain. By 1849, this situation was more than reversed. While Spain's wool export to Britain had dropped to 127,559 lbs, Australia's had risen to 35,879,171. By 1888 Australia was home to 97,983,960 sheep, see Hawkesworth (1930).

(Roberts, 1964 [1935], p. 1).[12] Roberts's account, as Abbott points out, embellishes the earlier historian James Collier's (1911) argument in his classic account of *The pastoral age in Australasia* that the legalization of squatting (enacted in 1836) represented 'the true germinal protoplasm of the British colonies at the Antipodes' (Collier cited in Abbott, 1971, p. 4).

In an analogy that complements more recent sheep-breeder's successes in the arts of propagation, Collier suggested not only that Australian history is essentially pastoral, but that:

> the germinal protoplasm of pastoralism stretches from age to age and spreads from this country to that, but is always and everywhere self-identical. It is an undying chain, which began with the first domesticated herd of cattle or horses, the first tamed flock of goats or sheep, is still vital, indeed is more vigorous than ever, and will live on till mankind returns, at the end of its long parabola, to a condition resembling its primitive state. (Collier, 1911, p. 7)

In vivid language he depicts the crucial 'passage in Australian history' that quickened into life 'the true germinal protoplasm of the British colonies at the Antipodes, their substance and inner life . . . out of which all else has grown'. Significantly, the husbanding of proper native stock for the budding Australian nation required hard pruning to encourage proper growth:

> It had to be determined whether those immigrating pastoralists should be hunted like wild animals and turned into Bedouins of the desert, or should be encouraged to grow up like the patriarchs of old, nursing within themselves the germs of the future State . . . Two wise Governors endeavoured to regulate the inundation they could not dam, and by a series of ordinances they introduced law and order into the lawless doings of the adventurers. In these they saw the promise of opulence and of a mighty State. These sagacious men reported to that effect to the authorities in England, and succeeded in persuading them of the justice of their views. Squatting was legalized and regularized, and, giving an impetus to free colonization, it lifted the community to a higher plane, and started it on a new career. (Ibid. p. 4)

In this complex account of the 'impetus to free colonization', which directly precedes Collier's germinal pastoro-plasm analogy, a mixture of justifications are provided for the 'inundation' of illegal squatters into the Australian interior, driven by the 'sheep mania' of the 1830s. Collier's primordial pastoralists are thus the bridge between savagery (ugly, bold, and lawless), and civilization ('nursing within themselves the germs of the future State'). Importantly, they are seen not only to have *created* 'the real life of Australia', *but to embody this generative potential*, comprised in hybrid parts of their raw untamed vitality and the natural rightness of their pastoral urges. Performing the paradoxical semiotic cohesion typical of foundational narratives, it is a genealogy of pastoralism that establishes in these colonial outback patriots the 'rightness' of both nature and civilization.[13]

[12] Roberts held the Challis Professorship at the University of Sydney, and the first edition of *The squatting age in Australia*—long considered a 'classic' contribution to Australian historiography, and part of a tradition established by Collier in the early twentieth century of romanticising the early squatters and their outback adventures, was published on the centennial of his pivotal date, in 1935. I have used the updated and corrected edition published in 1964.

[13] As Collier later describes the legalization of squatting, it ended the 'abortive experiment' of its suppression by ensuring 'the ground was left clear for a right design that was of Nature's devising' (Collier, 1911, p. 5).

In turn, as 'the pastoral community was henceforth free to develop along its natural lines', Collier explains, 'all else' Australian grew from this 'root'. Out of the 'pastoral and central life of the Australian communities', he continues, rise up 'its nurslings, like the mechanical industries, or spring up out of it by natural growth, as agriculture and horticulture'. As he concludes, 'All this is the work of the Golden Fleece' (ibid., pp. 5–6).

A key transition in the history of the Australian frontier—and indeed what might be called the tipping point when a discernibly 'new' species is born out of its soil—is the point at which the pastoral outback legacy comes to be seen not only as shared and embodied as a bond uniting white settlers of otherwise disparate ancestry, but as having created something that is palpable *and heritable*. This 'germ' of national identity is widely depicted within the nostalgic literature celebrating the transformation of 'wild' outback culture into a 'civilized' fraternity which achieved its coming into being, or 'birth', in the midst of the 'sheep mania' accompanying the economic success of the early wool boom. As Roberts describes the birth of a new 'emotional patriotism' in the 1830s,

> Nobody minded being called a 'squatter' now . . . The mania was in full swing, and every able-bodied man thirsted for the bush and pined to ride in the dust behind masses of smelling sheep and live on an unchanging diet of mutton chops, unleavened damper, and post-and-rail tea. It was something in men's blood, like the emotional patriotism of a war period or the unnatural stimulus of a gold rush . . . The bush, the sheep, the clipper on the tide—the process almost ran like a refrain in men's minds, and the community sang their song of the western wagon and turned toward the interior. (Roberts, 1964 [1935], p. 9)

Almost like sheep themselves, this 'tide' of able-bodied men marched behind 'the western wagon' fueled by the 'emotional patriotism' that drove them 'like a refrain' towards the edge of the frontier.[14] The view that this historical process both emerged out of, and was created by, 'something in men's blood' has remained virtually unchanged, and remains a core narrative in textbook accounts such as that of Russel Braddock Ward (1978), whose postwar ode to the 'noble bushman' *The Australian legend*, first published in 1958, is still all but required reading for every Australian schoolchild today.[15]

In sum, it could be said that if the Australian economy was 'riding on the backs of sheep,' the Australian frontier was trodden in by them.[16] Sheep, who graze more thoroughly than cattle, consumed the indigenous fauna in its entirety, including tubers, shoots,

[14] Significantly, what might be called the 'frontier effect' described by Ward borrows not only from the earlier pastoral odes of Roberts and Collier, but from Frederick Jackson Turner, the American historian who first proposed his famous 'frontier thesis' (Turner, 1947, 1961) of American cultural independence from Europe in 1813 (the same year the Blue Mountains were crossed to find more grazing land for sheep in New South Wales)—a model which became an influential lens for understanding Australian history in the postwar period.

[15] Harking back to the germ theory of history once again, Ward's central claim was that it was not so much pastoralism itself, but *the struggle to establish a pastoral way of life* against the adverse 'conditions' in a 'strange environment' that made Australia. 'The germ of the distinctive 'outback' ethos was not simply the result of climatic or economic conditions . . . It sprang rather from their struggle to assimilate themselves and their mores to the strange environment' (Ward, 1978, p. 33).

[16] According to historian Charles Burfitt's figures (1913), more than 10,000 sheep had crossed over the Blue Mountains by 1820, establishing the inland sheep runs of New South Wales that almost immediately became the fledging colony's first viable export industry. In the same year the quantity of wool shipped from Australia to Britain rose from 99,415 lbs to 175,433 lbs, a figure that would double by 1825.

and seeds, as well as grass, terminating much of its subsistence capacity, and converting it into mutton and wool. As Roberts describes this process,

> From Bass Strait to the Pandora Pass, cattle and sheep were moving onwards; everywhere the lowing and bleating invaders were showing themselves a more relentless force of occupation than regiments of red-coated soldiers, and were passing over plain and mountain alike. (Roberts, 1964 [1935], p. 1)

Like the famed Cheviot sheep whose hardiness was essential to the enclosure of the Scottish Highlands—often regarded as Britain's first colonial frontier, whose breeding led to its praise by agriculturalists as 'almost man-made,' the selectively bred white tide of ovine settlement in Australia was *itself a genealogical frontier*, a product of the breeder's arts, and an animal that literally embodied the modern industrial principles Australian settlement was intended to serve, to uphold, and literally to propagate (Russell, 2004; Watson, 1984).

There are thus several complex and overlapping genealogical legacies condensed within Australia's distinctively ovine constitution, combining in distinctive ways the idioms and gene flows of human and animal bloodlines in the forging of a new national identity. Inextricable from this new identity were the transformations of the landscape, displacement of indigenous peoples, and the founding of a core national economy based on sheep and wool that continues to this day.

4. New breeds

One of the most striking legacies of Australia's national formation on its pastoral frontier, where wool, blood and soil remain so integrated with sheep that in many cases generations of families, their studs (or stations), and their breeds share the same name, is their reincarnation in the context of Australian reproductive biomedicine during the country's bicentennial celebrations in 1988. These developments not only extend our ability to consider the shaping influence of the frontier effect on the genealogies of nations, regions, farms, people and their domestic livestock, but to further explore the underlying principle of this connection, or transfer, which I would like to argue here is the means by which genealogy establishes *a direction*. In the arteries where blood and wool are mixed are also legacies of purpose, ambition, and toil toward particular ends, such as improved breeding methods, technological progress, and economic prosperity. The genealogical orientation of the transfer of sheep science into IVF was thus not only familial in the sense of creating new families, but also familiar in its alignment with scientific achievement as a source of national pride. As Anthony Fisher writes in his celebratory account of Australian IVF:

> Bicentennial Australia leads the world in many aspects of the reproductive technology 'race,' having produced many IVF 'firsts,' much of the early embryo experimentation, the first legislative regulation, and so forth. (Fisher, 1989, p. 6)

Referring to the birth of Australia's first test-tube baby, Candice Reid, the world's third IVF child, born on 22 June 1980,

> The success of the Australian teams was widely publicized and became a matter of national pride: of the first 16 test-tube babies, 3 were born in Britain, 1 in the U.S., and 12 in Melbourne. (Ibid., p. 12)

As well as a measure of scientific excellence, and world-leading technology, these achievements, as Fisher suggests, are evidence of enhanced national fertility—an accomplishment Fisher expresses in language evoking the nation as progenitor: 'Australia prides itself', he claims:

> *on having produced* over two thousand 'test-tube babies' and several world firsts: frozen embryo babies, donor egg babies, IVF twins, triplets, and quadruplets. (Fisher, 1989, p. 4, emphasis added)

The story of these achievements is narrated in considerable detail by philosopher and science studies scholar Harry Kannegiesser, in his celebratory bicentennial publication *Conception in the test-tube: The IVF story: How Australia leads the world* (1988). Once again, this story is very sheepishly Australian. As Professor Carl Wood notes in the opening sentence of his 'Preface' to Kannegiesser's book, the story of IVF is once again that of man and sheep united on an unknown frontier: 'The excitement of seeing a sheep embryo under the microscope triggered the development of in vitro fertilization in Melbourne' (Kannegiesser, 1988, p. x).

5. Wool to embryos

This excitement belonged to Alan Trounson, one of Australia's most eminent scientists and the Director of its newly established Stem Cell Bank at Monash. At the age of 16, Trounson accepted a scholarship from the Wool Board of New South Wales to become one of the 'wool technology students' pursuing 'wool technology subjects' at the New South Wales Institute of Technology in 1963. He went on to pursue a Masters degree at the Agricultural Research Station in Hay in western New South Wales, where he completed his dissertation on the promotion of multiple-births through selective cross-breeding, entitled 'Reproductive characteristics of Merino and Border–Leicester ewes' in 1968.[17]

On the basis of the strength of his experiments, and fueled by an increasing interest in embryology, Trounson was accepted by Professor Neil Moore of the University of Sydney Department of Animal Husbandry, an expert in large animal surgery, and 'Australia's leading scientist in agricultural reproductive biology' (Kannegiesser, 1988, p. 342). Neil Moore, who was trained at the Reproductive Biology Unit at Cambridge, and who is said to have been the first to suggest the idea of IVF to Carl Wood in 1969, supervised Trounson's Ph.D. on the development of fertilized sheep ova, completed in 1973. Following his doctorate, Trounson secured a Postdoctoral Fellowship to join the Agricultural Research Council Unit of Reproductive Physiology and Biochemistry at Cambridge, where he undertook a series of studies of control of oocyte maturation, embryo freezing, and embryo transfer, and worked with numerous prominent and soon to be prominent scientists including both Neil Moore's supervisor, Robert Moor, and fellow postgraduate Steen Willadsen, the first scientist successfully to clone sheep using somatic cell nuclear transfer.

Having spent four years at Cambridge studying cryo-preservation of livestock embryos, the ova and embryos of cattle, horses, rabbits, rats, and pigs, the hormonal cycles of

[17] Central to his Master's dissertation, according to Kannegiesser, was the question of 'whether multiple births were caused by the ewe producing more eggs than normal or by her uterus accepting additional eggs for implantation' (Kannegiesser, 1988, p. 342)—a question that was in time to become key to Trounson's work in human IVF.

recipient and host ewes, and the chemical and molecular events of early pregnancy, Trounson was perhaps uniquely equipped as a scientist to return to Melbourne in 1977, at the request of Carl Wood, to assist him in the development of IVF.

From his extensive training with livestock embryos, ovulation induction, and ovine uteri, Trounson was able rapidly to introduce improvements to IVF, although not in time to 'win the race' against a neighboring Melbourne team, who delivered Australia's first IVF success in 1980. Nonetheless, Trounson's contributions to IVF were soon to gain worldwide recognition and acclaim, including his introduction of hormonal stimulation to induce super-ovulation, which has become standard practice in IVF. Trounson also pioneered techniques of embryo culture, embryo transfer, embryo biopsy, and embryo freezing, as well as sperm microinjection, oocyte and embryo donation, and oocyte maturation.

Continuing in a long line of Australian founding fathers born of sheep and wool, Trounson is Australia's most celebrated reproductive pioneer, working on the frontiers of biomedicine to improve methods of assisted reproduction, and more recently to direct Australia's efforts in stem cell propagation. His achievements extend the frontier ethic of improvement literally back in to genealogy, affirming the ongoing centrality of agricultural reproductive biology to the life sciences, and their commercialization. The importance of the sheep–human interface, historically so formative in Australian history, remains clearly evident in the ongoing technology transfer that intertwines sheep and human reproduction. The curious postcolonial return of stem cells made in Australia to London (see n. 3 above) retraces the path of a voyage that has become increasingly, not less, well described as a lifeline of both commerce and science.

6. British sheep

That these exchanges, or partner-sheeps, work in many directions is, of course, underlined by the world's most famous sheep, Dolly, born in 1996 to a distinctive lineage of experimental animal lines, whose connections are as intertwined as those of their scientific authors, or creators. As a final example in this depiction of sheep passages, exchanges, or transfers, in this brief account of what might be described as the history of ovination, it is worth pausing briefly to point out at least a few of Dolly's genealogical features that are relevant to a consideration of her not so much as a completely new kind of animal, but rather one that is in some respects quite traditional.

Like the Roslin Institute in Scotland where she was born, on yet another pastoral frontier of sorts, in July of 1996, Dolly is a direct descendant of the Imperial Bureau of Animal Breeding, established in 1929 to consolidate the vital agricultural connections, built up over more than a century to link Britain with her colonies and former colonies.[18] Dolly

[18] The Imperial Bureau of Animal Breeding was later renamed the Imperial Bureau of Animal Breeding and Genetics, and then the Commonwealth Bureau of Animal Breeding and Genetics. These were later merged with the National Animal Breeding and Genetics Research Organization (NABGRO) renamed in 1947 the Animal Breeding and Genetics Research Organization (ABGRO). Also in 1947, the University Department of Animal Genetics was constituted within the unit, which, in 1951 was renamed the Animal Breeding Research Organization (ABRO), while the Animal Genetics Section under Waddington became a separate ARC funded group within the University Department. It was eventually designated the ARC Unit of Animal Genetics in 1957 and later continued as the Institute for Animal Genetics at Edinburgh until 1990. The Roslin Institute shares this family history, as does Robert Edwards, who trained at Edinburgh in the 1960s under Conrad Hal Waddington, a leading embryologist and Professor of Animal Genetics.

continues these connections not only in terms of how her individual genealogy can be traced back through particular descent lines, and to her own frontier effect, in the form of the Highland Clearances which grew out of a similar 'sheep mania' in Scotland almost coincident with Australia's early colonization, but also through her scientific pedigree as the viable offspring of a team headed by Ian Wilmut, who trained alongside Alan Trounson and many of the other noted embryologists to emerge out of the vibrant climate of embryology in postwar Britain, in which sheep (and other mammals) have figured especially prominently. Like other carefully bred, semi-industrialised, agricultural animals, Dolly offers a demonstration of a *purposeful genealogy*, in the sense that she was the last in a series of experiments intended to achieve a more effective means of transgenesis. As Wilmut describes his initial interest in the experiments that led to Dolly's creation:

> I began to envisage how to advance the project that I had been thrust into, while also satisfying my own desire for original research in developmental biology. Answer: don't just add DNA to one cell embryos. Add it to plates of cultured cells, and then make embryos from the cells that had taken up the DNA most effectively. In other words, as the 1980s wore on I began to see that the future of genetic engineering in animals lay through cloning. (Wilmut, Campbell & Tudge, 2001, p. 161)

The aim, or purpose, of Dolly's genealogy was thus simultaneously economic and scientific, as Wilmut described his aims in terms of literally re-seeding sheep germplasm to 'grow' new animals, or, in his words:

> to grow animal cells in a dish, as if they were bacteria or cultured plant cells; and then transform these *en masse*; and then—as is already carried out with bacteria and plants—grow whole new animals from the cells that had taken up the genes most efficiently. (Ibid., p. 20)

In the same way that 'clone' derives from the Greek word 'klon' for twig, Dolly's viability is described through a mixture of idioms that, like 'culture', combine the botanical with the agricultural under the umbrella idiom of husbandry. In the same way that a strongly horticultural flavour attaches to the language of stem cell derivation, so that colonies of cells are propagated through reseeding them into successive beds of nurturing medium ('passaging'), so Dolly reminds us why blood, soil, and protoplasm can be interwoven so successfully as imagined, or actual, resources for the creation of genealogy.

Her birth was also the outcome of the very laborious and often unsuccessful process of manually inserting genes into sheep embryos—the method of creating transgenic offspring for which the Dolly-cloning technique was devised as an alternative to achieve a major step-gain in efficiency. Inspired by the work of Steen Willadsen (who in turn had been motivated by the work of John Gurdon, Karl Illmensee, and Hans Spemann, and who also took his degree from the British Agricultural Research Council's Reproductive Physiology Unit at Cambridge, more commonly known as 'the Animal Research Station', see Polge, 2007). Wilmut's thesis at Cambridge, on the freezing of boar semen, reflected the influence of his supervisor, Chris Polge, who combined excellent science with practical applications and later agricultural entrepreneurism (he founded Animal Biotechnology Cambridge in the 1980s). Like Trounson, Wilmut also found the embryo a fascinating research object, and later transformed his early agricultural work in reproductive physiology into human applications—in his case using molecular biology as a path to transgenesis (Wilmut, Campbell & Tudge, 2001, pp. 30–31).

The birth of Dolly—a sheep designed as part of an experiment to make human medicine—in an agricultural facility, then, is not so unusual. In the same way that Chris Polge's research on freezing livestock gametes laid a path to frozen human embryos—now a crucial component of IVF—so too did Wilmut's path to transgenesis eventually transform itself into human applications. Thus, both metaphorically and historically, and in ways that confirm the inseparability of her imagined and actual conception, Dolly is the viable offspring of a complex scientific lineage in which agriculture, medicine, embryology, and reproductive physiology have long been combined in the service of both extending basic science and producing new clinical applications. Often these practical innovations also have significant entrepreneurial dimensions, and are in some respects as market-driven as they are the result of scientific curiosity. The resemblance of Alan Trounson's pipettes to agricultural, or more specifically pastoral, tools is fitting, as are the propagational languages of stem cells and cloning—for it is in an explicitly agricultural idiom that many of the most innovative 'health and wealth deliverables' are being both created and imagined.[19]

7. Conclusion

Trounson's crook pipettes also serve as a fitting emblem for more than two centuries of continuous trade between Britain and Australia based on sheep experimentation, sheep-breeding, sheep products, and exchanges of actual sheep. Similarly, in spite of her ubiquitous association with either improved or dystopic futures, Dolly is a useful animal through which to consider how viable offspring embody hybrid lineages of science, industry, agriculture and medicine in ways that take their shape not only from national, but imperial and colonial, histories. As Joseph Banks's and Robert Bakewell's pure-bred 'experimental' flocks could be seen as scientific animals in sheep's clothing, so too were such rationalized and re-engineered animal bodies the conduits for the international exchange of specialist knowledge about breeding and improvement, which was consolidated through both commercial and scholarly ties. It is the intersection of these complex historical ties with particular lines of industry captured in the genealogical lineages of animals such as Dolly that this article has analysed as a set of vital economic, scientific, and biological relations. In contrast to the extent that reproductive biomedicine and stem cell science are routinely envisaged in a promissory temporality of future progress, I have tried to suggest here that it is useful to consider their historical connections to much earlier patterns of capital accumulation, selective breeding, and transnational partnerships in the creation of new products, markets, and trade. Like the voyages of Joseph Banks, the 'Father of Australia', whose efforts to nurture his 'favorite' colony were inseparable from his concerns with the improvement of sheep,[20] the sea-crossings of British and Australian scientists left in their wake a vast collection of 'findings', both material and theoretical, through which natural history might be put to work in the service of empire (Jardine, Secord & Spary, 1996;

[19] For more on 'imperial science' see Anker (2001), Crosby (2004), Drayton (2000), Fara (2003), Gascoigne (1998), and Jardine, Secord & Spary (1996). In addition several scholarly works on the life and sheep of Joseph Banks explore the close relationship between agricultural, imperial, entrepreneurial and scientific interests, including Carter (1964, 1979, 1988), Gascoigne (1994, 1998); Maiden (1909).

[20] Fittingly, Banks exchanged an Australian kangaroo, among other imperial trophies, for his first Merino sheep, illegally imported from France, and selectively crossbred them with Robert Bakewell's sheep.

Miller and Reill, 1996). The legacies of these contributions to what Patricia Fara has called 'imperial science' (Fara, 2003, p. 152), or Richard Drayton names even more precisely 'the agrarian view of empire' (Drayton, 2000, p. 103), are not only to be found in Kew Gardens (where Banks kept his famous flock of Merino sheep), but in the carefully tended gardens of wealthy North Sydney suburbanites, where English tea roses bloom and Jack Russells bask in the tropical heat. So too are they evident in more recent exchanges, such as the vials of stem cells 'born' in Trounson's Monash laboratories and sent traveling back to Britain, via Singapore, in kind of postcolonial biological handshake with the scientists at King's.

These legacies, while significant in and of themselves, can be seen also to have another, deeper, agricultural dimension when we consider the connections between land occupation, early subsistence agriculture or 'settlement', and the frontier. For it is here too that genealogy is, in a sense, *always already technologically assisted*. Only here, it is not 'nature' who is being given a 'helping hand', as in assisted conception discourse, but humans themselves who are imagined to be remade by their frontier abjection. Almost substitutable for the livestock on which they depended, the 'sheep manias' of both the early colonial period of New South Wales, and the occupation of the Scottish Highlands, provide a crucial background to the efforts to 'assist' genealogy, to propagate cellular vitality, and to redirect genomic functionality in today's high tech world of bio-innovation. That the process of nation-formation is itself couched in terms of germinal protoplasm, propagation, and the 'seeds of pastoralism' only underlines the range of connections yet to be mapped in the transition from farm to clinic, from clinic to farm, and back again. If two of the most important legacies of Australian pastoralism are the generic forms of its two primary idioms, those of genealogy and the frontier, which are united in the figure of the blood, or protoplasm, that connects the Australian character both to its sheep, and to its Mother Country, it is no surprise to find a powerful expression of this historical pattern in the context of contemporary bioscience and biomedicine. In the vital agricultural connections historically linking Australia to Britain, in part through sheep-breeding, is both a mutual commitment to a version of agricultural, commercial and industrial improvement, and a shared orientation towards the future that continues to find its form in genealogy.

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References

Abbott, G. J. (1971). *The pastoral age in Australia: A re-examination*. Melbourne: Macmillan Australia.

Anker, P. (2001). *Imperial ecology: Environmental order in the British Empire, 1895–1945*. Cambridge, MA: Harvard University Press.

Austin, H. B. (1950). *The Merino: Past, present and probable*. Sydney: Grahame Book Company.

Austin, P. (2004). 'Wool in the blood'. *Outback*, *35*, 46–48.

Burfitt, C. T. (1913). *History of the founding of the wool industry of Australia*. Sydney: Wiliam Applegate Gullick.

Carter, H. B. (1964). *His Majesty's Spanish flock: Sir Joseph Banks and the Merinos of George III of England*. Sydney & London: Angus & Robertson.

Carter, H. B. (Ed.). (1979). *The sheep and wool correspondence of Sir Joseph Banks 1781–1820*. Norwich: Fletcher and Son.

Carter, H. B. (1988). *Sir Joseph Banks 1743–1820*. London: British Museum (Natural History).
Collier, J. (1911). *The pastoral age in Australasia*. London & Melbourne: Whitcombe and Tombs, Ltd.
Crosby, A. W. (2004). *Ecological imperialism: The biological expansion of Europe, 900–1900* (2nd ed.). Cambridge: Cambridge University Press.
Drayton, R. (2000). *Nature's government: Science, imperial Britain, and the 'improvement of the world'*. New Haven & London: Yale University Press.
Edwards, R. G. (2001). The bumpy road to human in vitro fertilization. *Nature Medicine*, *7*(10), 1091–1094.
Edwards, R. G. (2004). Stem cells today, A. Origin and potential of embryo stem cells. *Reproductive BioMedicine Online*, *8*(3), 275–306.
Edwards, R. G. (2005). Introduction: The beginnings of in-vitro fertilization and its derivatives. In R. G. Edwards, & F. Risquez (Eds.), *Modern assisted conception* (pp. 1–7). Cambridge: Reproductive Healthcare.
Edwards, R. G., & Steptoe, P. (1980). *A matter of life: The story of a medical breakthrough*. London: Hutchinson.
Fara, P. (2003). *Sex, botany, and empire: The story of Carl Linnaeus and Joseph Banks*. Cambridge: Icon.
Fisher, A. (1989). *IVF: The critical issues*. Melbourne: Collins Dove.
Franklin, S. (2007). *Dolly mixtures: The remaking of genealogy*. Durham, NC: Duke University Press.
Fukuyama, F. (2002). *Our posthuman future: Consequences of the biotechnology revolution*. New York: Farrar, Straus and Giroux.
Garran, J. C., & White, L. (1985). *Merinos, myths and Macarthurs: Australian graziers and their sheep, 1788–1900*. Rushcutters Bay, NSW: Australian National University Press.
Gascoigne, J. (1994). *Joseph Banks and the English Enlightenment*. Cambridge: Cambridge University Press.
Gascoigne, J. (1998). *Science in the service of empire*. Cambridge: Cambridge University Press.
Graham, C. (2000). Mammalian development in the UK (1950–1995). *International Journal of Developmental Biology*, *44*, 51–55.
Habermas, J. (2003). *The future of human nature*. Cambridge: Polity.
Haraway, D. (1997). *Modest_Witness@Second_Millennium. FemaleMan©_Meets_OncoMouse™: Feminism and technoscience*. London: Routledge.
Hawkesworth, A. (1930). *Australasian sheep and wool: A practical and theoretical treatise* (6th ed.). Sydney: W. Brooks.
Henig, R. M. (2004). *Pandora's baby: How the first test tube babies sparked the reproductive revolution*. New York: Houghton Mifflin.
Jardine, N., Secord, J., & Spary, E. (Eds.). (1996). *Cultures of natural history*. Cambridge: Cambridge University Press.
Kannegiesser, H. (1988). *Conception in the test-tube: How Australia leads the world*. Melbourne: Macmillan.
Ker, J. (1960). Merchants and Merinos. *Journal of the Royal Australian Historical Society*, *46*(4), 206–223.
Ker, J. (1961). The wool industry in New South Wales 1803–1830. *Bulletin*, *1*(3), 28–49.
Ker, J. (1962). The wool industry in New South Wales 1803–30, Pt. 2. *Business Archives and History*, *11*(1), 18–54.
Lydekker, R. (1913). *The sheep and its cousins*. New York: E. P. Dutton & Company.
McLaren, A. (1998). *Inter view one, part one*. Royal College of Physicians and Oxford Brookes University Medical Sciences Video Archive, MSVA 187. 3 July.
Maiden, J. H. (1909). *Sir Joseph Banks: The 'Father of Australia'*. Sydney: William Applegate Gullick.
Miller, D. P., & Reill, P. H. (Eds.). (1996). *Visions of empire: Voyages, botany, and representations of empire*. Cambridge: Cambridge University Press.
Perry, T. M. (1963). *Australia's first frontier: The spread of settlement in New South Wales 1788–1829*. Melbourne: Melbourne University Press.
Polge, C. (2007). The work of the Animal Research Station, Cambridge. *Studies in History and Philosophy of Biological and Biomedical Sciences*, *38C*, this issue.
Roberts, S. H. (1964). *The squatting age in Australia 1835–1847*. London & New York: Melbourne University Press. (First published 1935)
Robinson, T. J. R. (Ed.). (1967). *The control of the ovarian cycle in the sheep*. Sydney: Sydney University Press.
Russell, L. (Ed.). (2004). *Colonial frontiers: Indigenous–European encounters in settler societies*. Manchester: Manchester University Press.
Ryan, L. D. (1973). *Sheep in Australia*. Sydney & London: Angus and Robertson.
Ryder, M. L. (1983). *Sheep and man*. London: Duckworth.
Turner, F. J. (1947). *The frontier in American history*. New York: Henry Holt & Company.
Turner, F. J. (1961). *Frontier and section: Selected essays of Frederick Jackson Turner* (R. A. Billington, Introd.). Englewood Cliffs, NJ: Prentice-Hall, Inc.

Ward, R. (1978). *The Australian legend*. Melbourne: Oxford University Press.
Watson, D. (1984). *Caledonia Australis: Scottish Highlanders on the frontier of Australia*. Sydney: Collins.
Wilmut, I., Campbell, K., & Tudge, C. (2001). *The second creation: Dolly and the age of biological control*. London: Headline.
Wolfe, P. (1994a). Nation and miscegenation: Discursive continuity in the post-Mabo era. *Social Analysis*, *36*, 93–152.
Wolfe, P. (1994b). 'White man's flour': Doctrines of virgin birth in evolutionist ethnogenetics and Australian state-formation. *History and Anthropology*, *8*(1–4), 165–205.
Wolfe, P. (1998). *Settler colonialism and the transformation of anthropology: The politics and poetics of an ethnographic event*. London & New York: Cassell.
Youatt, W. (1894). *Sheep, their breeds, management, and disease*. London: Simpkin, Marshall, Hamilton, Kent & Co. Ltd.