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THE AUROCHS THROUGH TIME: A HISTORY OF INTEGRATING TIMESCALES AND DISCIPLINES IN THE STUDY OF THE ANCESTRAL COW

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Abstract

This thesis provides a biographical account of the aurochs, the wild and extinct ancestor to cattle, through the lens of time. It argues that the aurochs, as a scientific object that spans multiple time scales and has been studied through various disciplinary lenses, is best understood by foregrounding its temporality as a processual entity – one that is in a state of constant change and transformation. Since the nineteenth century, the aurochs has been seen as a representative of different times: a signifier of a past wilderness, of a prehuman world, of a world that saw the evolution of humanity, of a future of unpredictable climates. By providing a biographical account of the aurochs and tracing its study across different historical and cultural contexts, the thesis demonstrates how objects like the aurochs can bridge disciplinary boundaries and bring together different approaches to knowledge. As episodes in this dissertation demonstrate, pursuit of holistic inquiry into an object of cultural and scientific salience can provide a helpful foil for historical expectations of how the object might otherwise have been cleaved.

The scope of this thesis includes an informal network of aurochs interlocutors who pursued study of the aurochs from the nineteenth century to the present, and who integrated the different timescales of their fields of work to do so. It examines the aurochs through paleontology in nineteenth-century Europe, and in particular Britain and nineteenth-century Colonial India; turn-of-the-century British and American breeding and genetics institutions; Nazi Germany; and contemporary rewilding in the Netherlands. This thesis offers contributions to historical understanding of interdisciplinary research, and the challenges of studying systems with multiple time scales.

Introduction

> "The appearance and disappearance of successive groups of wild animals, the varying climate and geography, the successive invasions of tribes, the gradual development of civilisation, fall within my scope. The materials necessary for this task are perplexing in their abundance, and lie scattered over a wide field; the progress of discovery is very swift, and there are great blanks in the story yet to be filled in. Nevertheless, after a preparation of many years by researches in this country and on the continent, it seems to me to be better to attempt to perform the task, however imperfectly, rather than to wait for that perfection which perhaps might never come."[1]

> "Time dissipates to shining ether the solid angularity of facts."[2]

In 1998, a humerus bone was found inside a cave in Derbyshire, England. The bone was described as belonging to an aurochs, *Bos primigenius,* which was the wild progenitor to domesticated cattle, and is now extinct in the wild. It was radiocarbon dated to roughly 6,700 years old.[3] In 2011, the specimen underwent a complete genome sequence, using advancements in DNA sequencing to obtain 417 million DNA reads that could with high confidence be aligned to the reference genome for cattle. The genome provided a remarkable genetical picture for the aurochs, based upon the first complete nuclear genome sequence of the wild animal. The sequence would go on to inform the work of a Netherlands-based rewilding group, that seeks to breed back to something like the aurochs in order to drive ecological processes that establish wild spaces. What made this specimen's sequence so valuable to those aims was its radiocarbon dating, placing it comfortably before the "Neolithic" in Britain, the beginning of human

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[1] William Boyd Dawkins, *Early Man in Britain and His Place in the Tertiary Period* (London: MacMillan and Co., 1880), 5.

[2] Ralph Waldo Emerson, "History," in *The Essential Writings of Ralph Waldo Emerson* (New York: Modern Library, 2000), 116.

[3] Stephen D.E. Park et al., "Genome Sequencing of the Extinct Eurasian Wild Aurochs, Bos Primigenius, Illuminates the Phylogeography and Evolution of Cattle," *Genome Biology* 16, no. 1 (December 2015): 234, https://doi.org/10.1186/s13059-015-0790-2.

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settlements, and the appearance of domesticated cattle in Britain. To some genomics researchers, its date allows the specimen to be "confidently assumed to represent a 'pure sample,' free from possible genomic contamination through later cross-breeding with domestic cattle."[4]

The bone is from a single British individual, and consequently that individual has outsized impact, as the rewilding group uses it as a genetic guide for breeding its "aurochs 2.0." What pressure it might feel were it aware of its genomic weight today. The oddity of that genome and its current role as a representative of aurochs-kind is that it is frozen in time. The genome sequence is a static snapshot of not just one British individual, but also one individual at one moment in its life, and at one moment in the broader history of the aurochs in general. The genome is an accomplishment: it is informative for the first generation of phylogenetic trees that relate the aurochs to domesticated cattle today. Still, it is just one snapshot in time making it insufficient to characterize what the "aurochs" is because the genome abstracts the animal away from one of its most dynamic elements: its relation to time and how humans have studied that.

A quick rundown of the aurochs' dynamic timespan demonstrates the broad scope of its timely existence: it evolved roughly two million years ago in South Asia, was first domesticated around 10,000 years ago, and went extinct as a wild animal in 1627, according to Polish census records of the remaining populations. In the late nineteenth century, the fossils of the aurochs, *Bos primigenius* were reconciled as the same entity that had been described in records from the Classical era on as the "urus," bringing both prehistory – before written records – and history into its temporal fold. It is now informing rewilding work in Europe, looking towards the future and its shifting climate. The timescale of the aurochs, therefore, is pluralistic: it appears at

[4] Mikkel-Holger S. Sinding and M. Thomas P. Gilbert, "The Draft Genome of Extinct European Aurochs and Its Implications for De-Extinction," *Open Quaternary* 2 (September 27, 2016): 7, https://doi.org/10.5334/oq.25. For its placement as a pre-domesticated specimen, Park et al., "Genome Sequencing," 2.

several significant moments or periods in the past. The achievement of the full genome of the aurochs does not convey the species' multifaceted legacy. The animal has garnered scholarly and popular attention for centuries, from natural historians, classicists, and antiquarians, to ecologists, breeders, and archeologists. That legacy has bestowed it with many names: aurochs, Urus, *Bos primigenius*. It will most often be referred to as "aurochs" in this thesis, unless otherwise stated, for example when its scientific name is most suitable to differentiate it from other animals that had coopted the term "aurochs" in historical literature. Its representation has been found in cave paintings, such as Lascaux, and its countenance as a large and fierce animal was reportedly described by the likes of Caesar, and reflected upon by the poet Walter Scott.[5] In the 1920s and 30s it served as the back-breeding goal of two German brothers supported in their endeavors by the National Socialist state. Today, the aurochs is the functional target of rewilders in the Netherlands who seek to alter landscapes through wild grazers that resemble an "aurochs 2.0." It is certainly far from static.

The aurochs, therefore, can be understood as an organism that is dynamically attached to time – time's depth, its records, and its disciplines of study. It itself is also a dynamic entity, one that, like any biological entity, changes over time, undergoing processes related to its life, evolution, domestication, death, and unusually in this case, rebreeding. This is a biography of the aurochs that aims to assert the relevance of time to its existence, and the lessons that might impart for those who have sought to reconcile its sometimes-discordant timescales. The dissertation argues that the aurochs has been a charismatic scientific object from the nineteenth century to the present: the kind which rallies interdisciplinary interest and mixed methods of

[5] Julius Caesar, *Commentarii de Bello Gallico,* trans. Carolyn Hammond (Oxford: Oxford University Press, 1996), 132-133; Walter Scott, "The Ballad of Cadyow Castle," in *Minstrelsy of the Scottish border: consisting of historical and romantic ballads, collected in the southern counties of Scotland: with a few of modern date, founded upon local tradition* (Edinburgh: Longman and Rees, 1803), 386-396.

study.[6] From this biography, it makes the broader case that objects such as the aurochs, whose existence has spanned several timescales and their forms of study, are best considered as processual entities - objects in flux in which change and process are as real an element of the object as its fossilized horns.[7] These historical and contemporary stories of the aurochs in scientific and cultural thought suggest a lesson for when interdisciplinarity arises seemingly naturally, without institutional pressures for it to do so; objects that are foremost 'in-process' may lend themselves to being considered quite holistically, no matter the corners of specialty science or culture in which they are considered. They may also serve as an important reminder that change and process are challenging ontological properties to capture in both science and epistemological studies of science, yet nonetheless bring together some of the most interesting biological questions today, and some of the most pressing environmental ones, including how to study systems with multiple timescales.[8]

The historical contexts for this thesis are the development of correlative paleontology in nineteenth-century Europe, and in particular Britain and nineteenth-century Colonial India; turn-of-the-century British and American breeding and genetics institutions; Nazi Germany back-breeding; and contemporary rewilding in the Netherlands. It uses interviews, as well as archival and digitized material in the form of correspondence, pamphlets and popular publications, scientific papers, photographs, maps, and diagrams, from elite scientists, amateurs, and breeders to make sense of how the aurochs was understood at different times and in different places.

[6] For reflection on the role of "charisma" in drawing interest to nonhuman entities, see Jamie Lorimer, "Nonhuman Charisma," *Environment and Planning D: Society and Space* 25, no. 5 (October 2007): 911–32, https://doi.org/10.1068/d71j.
[7] Katherine Valde, "Philosophical Perspectives on Time in Biology" (PhD diss., Boston University, 2019), 4-5.
[8] *Ibid.,* 1-8 and 19-22, and Nicholson and Dupré, eds. *Everything Flows: Towards a Processual Philosophy of Biology,* 2018.

CONTRIBUTIONS OF A BIOGRAPHY OF THE AUROCHS

The narratives in this thesis owe much to the methodological style of historical biographies of scientific "objects," "entities," or "non-humans."[9] From the gene, to reconstructed fossil animals, to dreams, narrating the life of an entity that emerges within the context of scientific scrutiny, falls under the scope of science for a time, or tumbles out of scientific fashion has proven to be a fruitful approach to ordering the time of the entity and understanding its value. The history of an object's hold on scientific and cultural attentions can tell us much about scientific priorities over time at the same time that it can explore both the "realness" of the scientific objects and the cultural appraisal of their appeal.[10] The choice of the term biography to characterize these contributions in the history of science is meaningful: it denotes a narration through time that centers the object, while tracing how the world has also changed around it. The

[9] Lorraine Daston, ed *Biographies of Scientific Objects* (Chicago: University of Chicago Press, 2000), and Daston, ed., *Things that Talk: Object Lessons from Art and Science* (New York: Zone Books, 2004; Claudine Cohen, *The Fate of the Mammoth* (Chicago: University of Chicago Press, 2002); Lukas Rieppel*,* *Assembling the Dinosaur: Fossil Hunters, Tycoons, and the Making of a Spectacle* (Cambridge, Massachusetts: Harvard University Press, 2019); Harriet Ritvo, *The Animal Estate: The English and Other Creatures in the Victorian Age* (Cambridge, Massachusetts: Harvard University Press, 1987) and Ritvo, *Noble Cows and Hybrid Zebras: Essays on Animals and History* (Charlottesville: University of Chicago Press, 2010); Lorimer, "Nonhuman Charisma," 911–32.

[10] In his 2006 chapter, "A Textbook Case Revisited," Bruno Latour explores knowledge-making pathways and how our model for understanding them derives from well understood objects. His concern in this regard is drawn out with reference to the display at the American Museum of Natural History of horse evolution, and coincident exhibition of changing understandings of the horse lineages. As he notes, the displays demonstrating both evolutions as processes still unfolding is important. If, as he says, "you interrupt the chain, you remain undecided about the quality of the knowledge claims, exactly as if the lineage of one horse species were interrupted due to a lack of offspring. The key feature for our discussion here is not to ask from any statement, 'Does it correspond or not to a given state of affairs?' but rather, 'Does it lead to a continuous chain of experience where the former question can be settled retroactively?'" From Bruno Latour, "A Textbook Case Revisited – Knowledge as a Mode of Existence," in *The Handbook of Science and Technology Studies* 3rd Edition, ed. by E. Hackett, O. Amsterdamska, M. Lynch and J. Wacjman *(*Cambridge, Mass, MIT Press, 2006), 9. See also, *The Concept of the Gene in Development and Evolution: Historical and Epistemological Perspectives*. Cambridge Studies in Philosophy and Biology. Cambridge, UK: Cambridge University Press, 2000; Cohen, *Fate of the Mammoth*; Doris Kaufmann, "Dreams and self-consciousness: mapping the mind in the late eighteenth and early nineteenth centuries" in *Biographies of Scientific Objects,* ed. Lorraine Daston (Chicago: University of Chicago Press, 2000), 67-85.

essays by scholars in Lorraine Daston's edited compilation *Biographies of Scientific Objects* enable that balancing act of changes – those of the object, those of the world around it, and how the two alter each other.

For this thesis, the benefit of such biographies is that they allow us to hold the dynamic nature of the entity itself in center stage. In this narrative, the aurochs continually emerges through various approaches to its study. It was discovered and described in fossil form in the nineteenth century, but that is only the first episode in its dynamic development over the course of the thesis. Its fossil form was, after centuries of confusion, reconciled in the nineteenth century as the same entity described in historical documents. Following the development of the theory of evolution, early twentieth-century geneticists and breeders saw its specter lurking in domesticated cattle, as their offspring occasionally reverted to some past, wild form. Scientific knowledge of the aurochs has, in this way, developed over time. The aurochs itself, as a biological entity, changes too, at the scale of its evolution, domestication, and extinction, and in its individual life processes and between generations. Change is a dominant feature of its existence as an evolving entity, conceptually and biologically. We are justified, therefore, to consider the aurochs in this thesis first and foremost as a "processual entity," in which the processes of the aurochs, and its relationship to time, are understood as characterizing features.[11] As a processual entity, the aurochs has retained its productivity, generating interest over time, and as Daston has written, "to exhaust or freeze such objects is to reduce their scientific reality,

[11] Drawing from John Dupré's "process ontology," in which he advocates for characterizing entities through their processes in time, their emergence, maintenance, and stabilization. This is opposed to general mechanistic ontologies, that characterize entities as static essences. See Eric Bapteste and John Dupré, "Towards a Processual Microbial Ontology," *Biology & Philosophy* 28, no. 2 (March 2013): 379–404, https://doi.org/10.1007/s10539-012-9350-2. Also, Valde, "Time in Biology," 54, for more on the contemporary call to add process ontology into biologists' current toolkit.

though they persist as things."[12] To proceed with reasserting the pluralities of time in the story of the aurochs, and to characterize it beyond its abstracted genome, first necessitates a brief orientation to the ways that time are used in this thesis.

Biology is no stranger to time. While paleontologists and ecologists find unique methods to overcome the distance of time between them and their objects of interest, experimental molecular biologists forecast ways to manipulate biology's building blocks to the creation of something new in the future. As philosopher Katherine Valde has asserted, biologists and philosophers of biology could stand to think more about time because their work is so intimately related to it. She points out several means by which biologists manipulate, abstract from, or otherwise reckon with the presence of time in their systems of study.[13] Biologists freeze time, sometimes literally in the case of frozen specimens. Biologists model time, to wrestle a phenomenon whose timescale is too durational to readily observe in a studiable size. Biologists overcome time when it has eroded away the finer points of evidence they might look for in a fossil. Time is a relevant factor in dividing the pursuits of biologists into their disciplinary buckets. It is also a jargony language for describing biologists' philosophical commitments. Histories of evolutionary biology often directly or indirectly scrutinize the temporal priorities of the theorists they study: vitalists are processualists; teleologists are directionalists; anatomists are static substance ontologists; some developmentalists and embryologists are proxy-thinkers; and any evolutionist is a historian thanks to Darwin.

[12] Daston, "Introduction: The Coming into Being of Scientific Objects," in *Biographies of Scientific Objects,* ed. Lorraine Daston (Chicago: University of Chicago Press, 2000), 12.
[13] She unifies all of these under the umbrella of "abstraction," methods by which biologists abstract from the time that is inherent to their phenomena of study. She gives four primary ways: physically, for example freezing; procedurally, for example observing the system when it is static; mathematically, for example fluctuation analysis; and conceptually, by obscuring time all together. Valde, "Time in Biology," 25.

But the temporality inherent in biology is more than can be readily seen in disciplinary divides or schools of thought. It offers the connecting sinew between the entities and their processes, between the scales, and between the metaphysics. Temporality promisingly foregrounds the mess of interconnectivity between the scales of study, and reminds biologists that any piece of their natural puzzle is in fact, in flux, changing at the influence of another, and changing others in turn. For this thesis, biology and its disciplines offer two important forms of temporality by which the aurochs can reveal something about how humans study the natural world and different timescales. The thesis examines the historical and contemporary interactions of these forms of time through the aurochs. The first, is the concept of a hybrid "productive combination." The second, is the concept of relational timescales.

There have been calls to reintroduce the comparative framework of time in biology because of the reorientation it might provide to scientists who specialize, separate, and handle static substance ontologies in their methods.[14] While it is not accurate to call this a full resurgence of vitalism, the current "Extended Synthesis" in evolutionary theory is certainly emphasizing the more processual elements of its so-called Modern Synthesis predecessor, calling for movement away from treating entities as static, reduced, substances.[15] One way to do this is

[14] Valde, "Time in Biology," 1-2.

[15] The Extended Synthesis was almost immediately called for in the 1950s by Conrad Hal Waddington, and was more recently advocated for by Massimo Pigliucci, "Do We Need an Extended Evolutionary Synthesis?" *Evolution* 61:12 (2007): 2743-2749, https://doi.org/10.1111/j.1558-5646.2007.00246.x. For more on evolvability, see D.J. Futuyma, "Evolutionary Biology Today and the Call for an Extended Synthesis," *Royal Society Interface Focus* 7 (2017): 20160145. https://doi.org/10.1098/rsfs.2016.0145, and J.F.Y Brookfield, "Evolution: The Evolvability Enigma," *Current Biology* 11, no. 3, (2001): R106-R108, https://doi.org/10.1016/S0960-9822(01)00041-0. Paleontologists, such as George Gaylord Simpson, famously advocated for the integration of evolutionary perspectives through questions that centered time in evolution. See his 1944 Tempo and Mode in Evolution. George Gaylord Simpson, *Tempo and Mode in Evolution*, A Columbia Classic in Evolution (New York: Columbia University Press, 1984). In the German context, integration between disciplines was perhaps less of a momentous occasion, and more of a standard operation in biological disciplines. See Jonathan Harwood, *Styles of Scientific Thought,* for that argument in the context of genetics and evolution in early twentieth-century Germany.

productive engagement between fields such as developmental biology and paleontology, with entities that exist as both living and fossil forms generating value from what philosopher of biology Aja Watkins has called their "productive combination."[16] The broad scope of the aurochs' temporal record, I suggest, makes it one such productive combination, because it is accessible in – crudely stated – dead and living forms. The aurochs evolved millions of years ago, leaving fossils in Europe, India, and North Africa from as early as the Pleistocene (discussed in Chapters 1 and 3). It also left traces of its existence from historical periods, in the form of its hides, and depictions of it in paintings and written descriptions (discussed in Chapters 2, 4, and 5). Yet the extinct wild aurochs has been understood, since nascent evolutionary theory paved the way, as observable *in vivo,* as well. Its biological processes at the scale of individual and intergenerational life are accessible to biologists through its living descendants.

Its productive combination of "dead" and "living" knowledge is a temporal example of the kinds of entities whose dualisms make them cunning accomplices in scholarship that seeks to override existing divides in thought. Objects, entities, and materials have been the work-quadrupeds (because cows do just as much conceptual work as horses) of overcoming disciplinary divides, including dichotomies such as "real vs. constructed," "subject vs. object," and "nature vs. culture" in past scholarship. Vitalist philosophers are often cited in these

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Harwood, *Styles of Scientific Thought: The German Genetics Community, 1900-1933,* Science and its Conceptual Foundations series (Chicago: University of Chicago Press, 1993).
For more on the German paleontology context, see also Wolf-Ernst Reif, ''Evolutionary Theory in German Paleontology," in *Dimensions of Darwinism: Themes and Counterthemes in Twentieth Century Evolutionary Theory,* ed. Majorie Grene and Werner-Reimers-Stiftung (Cambridge, UK: Cambridge University Press, 1983), 173–203. And, Wolf-Ernst Reif, "The Search for a Macroevolutionary Theory in German Paleontology," *Journal of the History of Biology* 19, no. 1 (March 1986): 79–130.
[16] Aja Watkins makes the case that, similar to homology, living fossils provide a fruitful intersection for developmental biology and paleontology by virtue of their existence in fossil records and as living taxa. This makes them a "productive combination." Aja Watkins, "The Epistemic Value of the Living Fossils Concept," *Philosophy of Science* 88, no. 5 (December 2021): 1221-33, https://doi.org/10.1086/714875.

discussions, and Fernand Braudel, Gilles Deleuze, and Manuel De Landa have shown how process and materiality can reveal one another, often by turning a metaphysical dichotomy into a hybrid dualism, as Donna Haraway did with the figure of the cyborg.[17] Divides between nature/culture in the modern era have similarly been challenged; Bruno Latour for example has used "things" to cut right across it.[18] These threads of vitalist materialism have broadly been considered "hybrid ontologies."[19] They focus on entities that straddle divides in our thinking, and writing histories that center those things overcomes scholarly *a priori* commitments to either side of a divide. Through an exploration of the aurochs as both living and dead, this thesis leverages the litany of addendums that can be added to the aurochs' name ("hybrid ontology," "dual entity," "productive combination") to explore its temporality across the scientific disciplines that study both states of being.

As a "productive combination," the aurochs spans such a wide swath of time that it has left records along the way at various depths of the past, moments in the present, and now under rewilding, possible extrapolations into the future. It has, in other words, quite an expansive temporal record. Consequently, there are several means by which naturalists, breeders, geneticists, hobbyists, and ecologists have understood the aurochs. In this thesis, they are loosely characterized as deep time, prehistoric, historic, synchronic, and projected. For each record, those figures who studied it used specific material evidence of the aurochs and grappled with the difficulties of those records. Those records, in the hands of the actors in this thesis, were

[17] Donna Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in *Simians, Cyborgs and Women: The Reinvention of Nature* (New York: Routledge, 1991), 149-181.
[18] Bruno Latour, *We Have Never Been Modern,* trans. Catherine Porter (Cambridge, MA: Harvard University Press, 1993).
[19] Sarah Whatmore, *Hybrid Geographies: Natures, Cultures, Spaces* (London: SAGE, 2002). Donna Haraway, *The Companion Species Manifesto: Dogs, People, and Significant Otherness*, Paradigm 8 (Chicago: Prickly Paradigm Press, 2003). And, Haraway, "Cyborg Manifesto."

additive. Table 1, below, indicates the relationships between the records, their temporal orientation, the people who studied them, and the materials of the aurochs they used.

Table 1. Records of the Aurochs in Relation to Time

Absolute	Newtonian					
Relative	Depth of Time				Present	
	Records	**Deep past**	**Prehistoric**	**Historic**	**Synchronic**	**Projected**
	Materials	Fossils	Fossils Cave art	Hides Paintings Descriptions Artifacts	Developmental characteristics (examples: horn development over maturation of cattle; intergenerational reversions)	Projected Models
	Actors (and associated disciplines)	Geologists, Paleontologists	Archeologists, Paleontologists, Geologists	Antiquarians, Historians, Ethologists	Livestock breeders, Geneticists, Ethologists	Ecologists

From within this framework of the aurochs as a temporal “productive combination”, we can refine our understanding of the aurochs’ temporality further by asking what exactly are the timescales of the aurochs and how have those who studied the aurochs brought them into relation? It straddles living and dead, making it a useful temporal combination, but how do those scales relate to one another? As Table 1 demonstrates, the timescales of the aurochs fit comfortably under a conception of time that describes time as a change of things, what is often called a relative view of time.[20] Counter to a Newtonian absolute view of time, in which time

[20] Ernst Mach, *Die Mechanik in ihrer Enwickelung: Historisch-Kritisch Dargestellt* (Leipzig: F.A. Brockhaus, 1883).

exists independently and reliably ticks away at a constant rate, relative views of time, developed in physics by Gottfried Wilhelm Leibniz and Ernst Mach, suggest that time is simply an ordering or measure of change, and is therefore relational between the things that are changing.[21] Relative time, therefore, considers how time emerges from sets of relations between things, and results in a dizzying flexibility in the measurement of time.[22] Historical study of the aurochs exists quite firmly within this relative concept of time, and a closer look at what exactly is relative to what in the case of the aurochs is warranted.

Katherine Valde, who has studied the philosophy of time in biology, has categorized the biological timescales used by biologists measuring some change over time as "external" and "internal" to the phenomena under scrutiny. Timescales may be most quotidian when they are external.[23] Clock time, for example, that is the hours, minutes, and seconds that we find along an x-axis in scientific graphs, are external to the biological functioning of the system charted along the graph.[24] Other timescales of which the phenomenon of interest is a function, such as

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[21] Relative time has been explored as a category of experience in certain moments of history, including in the collapsing of time that came with the technological advancements around World War One that led to a feeling of acceleration and loss of control. See, Stephen Kern, *The Culture of Time and Space, 1880-1918* (Cambridge, MA: Harvard University Press, 2003). Thomas Harrison beautifully summarized the myriad perceptual changes in time in Kern's book as this: "Simply expressed, between 1880 and 1918 time becomes understood in terms of simultaneity, heterogeneity, reversibility, relativity, and subjective fluidity…" From Thomas Harrison, "The Culture of Time and Space: 1880-1918 by S. Kern," *The Review of Metaphysics,* 39, no. 1 (September 1985): 162-163.
[22] For example, scaled-rates (when rates change as a function of time), as opposed to constant rates.
[23] Valde points to Shimon Marom's 2010 study "Neural Timescales or Lack Thereof," as a helpful example of a philosophy of biology work that scrutinizes issues relating to timescales in neuroscience. There, timescales are defined as the time in which the phenomenon of interest occurs. The issues he presents in the piece include assuming timescales are fundamental, even when they may not exist or reveal themselves readily. Shimon Marom, "Neural Timescales or Lack Thereof," *Progress in Neurobiology* 90, no. 1 (January 11, 2010): 16–28, https://doi.org/10.1016/j.pneurobio.2009.10.003.
[24] They are also often treated as "absolute" time, though even calendars and clocks, we need remind ourselves, are relative. Historicizing the calendar and the clock has been a fascinating way to underscore how far from absolute they may be. See, for example, Jacques Le Goff, *Time, Work and Culture in the Middle Ages,* trans. Arthur Goldhammer (Chicago: University of Chicago Press, 1980). Jimena Canales, *A Tenth of a Second: A History* (Chicago: University of Chicago Press, 2009). Vanessa Ogle, *The Global Transformation of Time, 1870-1950* (Cambridge, MA: Harvard University Press, 2015).

generations and biological cycles, however, can be said to be internal to the systems under study, and using them as a measure of time for a phenomenon foregrounds the temporality of the phenomenon, rather than abstracts from it.[25] The current field of chronobiology is, as Valde helpfully suggests, the most obvious form of considering the relation of external timescales, such as solar days, to internal timescales, such as circadian rhythms, in biological research, as it investigates how organisms keep time themselves.[26] In this thesis, I use Valde's categories of "external" and "internal" timescales to explore how the aurochs' temporality was measured.

The aurochs' "internal" timescales – that is, timescales emanating from its own biological processes – have been deeply manipulated by its interactions with humans. Chapters 4, 5 and 6 consider its domestication and its descendants' development into agricultural animals; its wild form extinction is a running thread in all of the chapters; its targeted de-extinction through intimate breeding interventions is discussed in Chapters 5 and 6. All contribute to altering the aurochs' internal timescales. Its "external" timescales – those that are used to situate its existence within other forms of charting time, such as radiocarbon dating, or historical periodizations – are deeply relative as well. For example, its emergence as an interesting scientific object in the nineteenth century, as Chapter 1 discusses, coincided with and played a role in the very projects of defining timescales in the recent geological past, then called the Tertiary. From the nineteenth century to the present the aurochs has held an unstable presence in time as it has appeared and disappeared from periodizing attempts, such as demarcations of the past based on humans and their writing ("prehistory" and "history"); based on climate, or geological stratigraphy ("glacial", "post-glacial", "Holocene," or "Anthropocene"); and based on economic and societal

[25] Historians, too, have considered cycles as phenomena worth scrutinizing. See Nick Hopwood, Staffan Müller-Wille, Janet Browne, et al. "Cycles and circulation: a theme in the history of biology and medicine," *HPLS* 43, no. 89 (2021), https://doi.org/10.1007/s40656-021-00425-3.
[26] Valde, "Time in Biology," 23.

development ("primitive", "civilized", or "pre-industrialized"). Attempts to periodize the geological past in the nineteenth century were deeply relative in their methods.[27] Correlating a geological clock across geographical space was even more relative, as Chapter 3 discusses in the context of Indian geology. And as the various depths of geological time and their proximity to human development turned out new specialties in the nineteenth century, such as "archeology" and "anthropology," relating such external timescales to one another became an expansive enterprise. Looking at time through the lens of the aurochs, then, this thesis traces how some nineteenth and early twentieth-century interlocuters sought to relate seemingly discordant timescales: archeological demarcations of "prehistory", geological periodizations, relative societal developments, and phenomena occurring within the timescale of a single generation of cattle. In temporal terms, this thesis in invested in how and why the relative external timescales in which the aurochs was featured were mediated with one other and connected to the internal timescales of the living animal.

Writing a narrative of the object in a way that includes its "internal" and "external" temporalities requires engagement with a wide range of historical and contemporary scholarly literature. External temporalities of the aurochs alone are informed by such widely different conditions as agricultural markets that drive their domestication and production, and elite exercises in periodizing the past into disciplinary domains through art, economics, writing,

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[27] Chapter 1 discusses this in more detail, but any account of the history of geological correlation cannot escape without reflecting on the relative nature of such pursuits. See, for example, Peter J. Bowler, *Fossils and Progress: Paleontology and the Idea of Progressive Evolution in the Nineteenth Century* (New York: Science History Publications, 1976). Martin J.S. Rudwick, *The Meaning of Fossils: Episodes in the History of Paleontology* (Chicago: University of Chicago Press, 1972). And Max Dresow, "Measuring Time with Fossils: A Start-Up Problem in Scientific Practice," *Philosophy of Science* 88, no. 5 (December 2021): 940–50, https://doi.org/10.1086/714855.

archeology and more.[28] Its internal temporalities are revealed through fields that chart the aurochs' past existence including paleontology and archeology, as well as genetics, and the multi-scalar evo-devo (evolutionary developmental biology).[29] The internal and external temporalities of this object therefore exist across vastly different literatures, let alone vastly different historical contexts. Still, this presents an opportunity. As the challenge of integrating multiple timescales is pressing in biology and under the banner of the Anthropocene, similar integrations are happening across even wider conceptual seas.[30] Placing distinct approaches to temporality alongside each other continues a conversation about our measures and use of time beyond biology, something suggested by the very methods of the historical figures who have made the aurochs part of their study. Bringing those literatures and contexts together within one

[28] Some of the literature on how markets shape the biology and temporality of living animals includes: Susan Schrepfer and Philip Scranton, eds., *Industrializing Organisms: Introducing Evolutionary History* (New York: Routledge, 2004). Chris Otter, *Diet for a Large Planet: Industrial Britain, Food Systems, and World Ecology* (Chicago: University of Chicago Press, 2020). Scholarship on national ideology shaping the biology of living animals includes Tiago Saraiva, *Fascist Pigs: Technoscientific Organisms and the History of Fascism* (Cambridge, MA: MIT Press, 2016). Those classic works in the history of science and anthropology that discuss the carving up of the geological past include: Peter J. Bowler, *The Invention of Progress: The Victorians and the Past* (Oxford: Basil Blackwell, 1989); Martin J.S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: University of Chicago Press, 2005); George Stocking, *Victorian Anthropology* (New York: Free Press, 1987). Foundational works on the formation of a societal historical conscious that demarcated the historical past include Reinhart Koselleck, *Futures Past: On the Semantics of Historical Time,* trans. Keith Tribe (New York: Columbia University Press, 2004); Hayden White, *Metahistory: The Historical Imagination in Nineteenth-Century Europe* (Baltimore: Johns Hopkins University Press, 2014); and, Constantin Fasolt, *The Limits of History* (Chicago: University of Chicago Press, 2004) on the formation of historical consciousness in the political context of state building.
[29] Integration of "eco-evo-devo" (evo-devo and ecology) into evolutionary theorizing has been a development of the "Extended Synthesis," but can operate on radically different scales of observation and intervention. Pigliucci, "Extended Evolutionary Synthesis."
[30] "Evolutionary History," a field articulated by historians Daniel Lord Smail and Edmund Russell advocates for an integration of evolutionary biology and history in methods and subjects, and is therefore a compelling site to further center temporality in a critical and interdisciplinary manner. See Edmund Russell, *Evolutionary History: Uniting History and Biology to Understand Life on Earth* (Cambridge, UK: Cambridge University Press, 2011) and Andrew Shyrock and Daniel Lord Smail, eds., *Deep History: The Architecture of Past and Present* (Berkeley, CA: University of California Press, 2011).

study, therefore, cannot be perfect, but this thesis advances the conversation further towards greater interdisciplinary integration.

The six entries presented in this biography depict the aurochs as a scientific object with a particularly dynamic relationship to time. The aurochs tended to draw scientific interest to the full range of its existence. The regional and scientific contexts in this dissertation are not entirely isolated from one another – scientists in one context cite scientists in another. Yet the deeper connecting thread of this "aurochs network" is the seeming commitment by actors in each to overcome the divides between different "times" of the aurochs and the usual methods that would study those. Its charisma drew in holistic study. Through the exploration of the aurochs, geneticists consulted paleontological writings; paleontologists factored in social evolutionists; and ecologists became historians. The aurochs appeared in many overt and implicit considerations of time including periodizing the geological periods of the Tertiary and Post-Tertiary; complicating the zoological dimension of the prehistory/history divide; piquing interest as a component of societal evolution in a colonial context; symbolizing nationalist visions of the past; and becoming a means by which to reinstate past wilds. Within science, the aurochs drew the attention of practitioners of science with both telescoped and protracted engagements with time, from deep-time paleontology to intimate breeder and geneticist engagement with short-term hereditary change. The thesis traces the writings of scientists and amateurs who drew on one another's work across disciplinary divides and levied arguments from one domain to access possibilities for their own. The resulting picture within this thesis is one of specialties leaning on one another, borrowing from one another, or reconciling each other through another. The aurochs, therefore, might be said to be a particularly "charismatic object," through its own inherent temporal properties that are compelling (its affordances), as well as the resonances of interest drawn out from those who interact with it (its affect).[31] Its charisma courted a holistic approach to studying it. Through its charism, the aurochs is useful to explore moments when interdisciplinary integration erupted in scientific practice without any directed institutional push; rather, squarely from the charisma of the object of interest.

Mediating between different timescales is a project not just for the biologist. Historians have long folded differing timescales and periodizations into their methodology, and sometimes have taken different perceptions of time as their historical subject.[32] Within the discipline of history, the context of contact between peoples, often under imperial impetus, has fostered comparison between their notions of time and differing forms of historical consciousness.[33] The setting of empire has, through this lens, become an important context in histories of science, at its most cutting, revealing the Western-dominant progressive narratives that have underpinned the very notion of "science."[34] Some scholars have applied this comparative analysis of time between places to the very rhythms of life and perceptions of time during modern globalization

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[31] Lorimer, "Nonhuman Charisma," 911–32. Tim Ingold, "Culture and Perception of the Environment," in *Bush Base: Forest Farm, Culture, Environment, and Development,* eds. Elisabeth Croll and David Parkin (New York: Routledge, 1992).

[32] Perrin Selcer's project, "The Holocene is History: Human Nature at the End of the Last Ice Age" examines what he calls the "liminal scale" between deeptime and historical chronicling.

[33] Scholarship on competing, consolidated, or conflated views of time between two cultures in historical imperial encounters include Thomas R. Trautmann, *Clash of Chronologies: Ancient India in the Modern World* (New Delhi: Yoda Press, 2009); Inga Clendinnen, *Ambivalent Conquests: Maya and Spaniard in Yucatan, 1517-1570* (Cambridge, UK: Cambridge University Press, 2003). Dipesh Chakrabarty takes on the linear historical conscious explored in Western historiography and scrutinizes what its overbearance means for "non-Europes" in Dipesh Chakrabarty, *Provincializing Europe: Postcolonial Thought and Historical Difference* (Princeton, NJ: Princeton University Press, 2000). A powerful example of differing cultural notions of time comes from anthropology: the terms "polychronic" and "monochronic," referring to how cultures conceptualize time by what happens within it. Within anthropology, polychronic cultures tend to engage in multiple activities at once, viewing time as more flexible. Monochronic cultures, by contrast, are characterized by their views of time as linear, and in which only one thing at a time can be done as time moves. Edward T. Hall, *The Dance of Life: The Other Dimension of Time* (Garden City, NY: Anchor/Doubleday, 1983).

[34] Latour, *We Have Never Been Modern*; Lorraine Daston, "The History of Science and the History of Knowledge," *KNOW* 1, no. 1 (March 2017): 131-54, https://doi.org/10.1086/691678.

and technological acceleration in the early twentieth century, while others have scrutinized the field of Western history itself and how it has sought to periodize the entire world.[35]

Such temporalities are inherently comparative, and the natural world is no exception.[36] The Anthropocene concept draws our current focus to human-created rhythms and temporalities and how those transform environmental time.[37] Since its modern use beginning in 2000 with P.J Crutzen and E.F. Stoermer's paper "The Anthropocene," the term has suggested the planetary impact of humans on the Earth system through myriad measures including climate change, energy use, deforestation, and air pollution.[38] While the term itself is formulated along the naming conventions of geological epochs (for example, Holocene, Pleistocene, etc), the Anthropocene as a time period, and as a provocation, is characterized by many possible signatures at different time and spatial scales, for example, a Geological Anthropocene, an Earth System Science Anthropocene, and a Historical Anthropocene.[39] Each "Anthropocene" concept has its associated evidence and disciplinary affiliations, with advocates suggesting either stratigraphic signatures, biodiversity and planetary thresholds, or historical capitalist milestones

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[35] Chakrabarty, *Provincializing Europe;* Diane Owen Hughes and Thomas R. Trautmann, eds., *Time: Histories and Ethnologies*. Comparative Studies in Society and History Book Series (Ann Arbor: University of Michigan Press, 1995); Ogle, *Global Transformation of Time*; Stephen Kern, *Culture of Time and Space*.

[36] Paul Huebener, *Nature's Broken Clocks: Reimagining Time in the Face of the Environmental Crisis* (Regina, Saskatchewan: University of Regina Press, 2020). Huebener has made the case for "ecocritical time studies," to understand these changes. He has argued for "critical time studies" more broadly, as "a process of inquiry that advances thoughtful re-evaluations of the social politics of time through the examination of temporal assumptions and the fostering of critical temporal literacy." Paul Huebener, *Timing Canada: The Shifting Politics of Time in Canadian Literary Culture* (Montreal: McGill-Queen's University Press, 2016), 14.

[37] Huebener, *Nature's Broken Clocks.* Barbara Adam has pointed out that it is a Western temporality that forms "a central part of the deep structure of environmental damage wrought by the industrial way of life," a common refrain in questions of environmental justice and culpability in Anthropocene discourse. Barbara Adam, *Timescapes of Modernity: The Environment and Invisible Hazards*, Global Environmental Change Series (New York: Routledge, 1998).

[38] P.J. Crutzen and E.F. Stoermer, "The Anthropocene," *Global Change Newsletter* 41 (2000): 17-18.

[39] Yadvinder Malhi, "The Concept of the Anthropocene," *Annual Review of Environment and Resources* 42 (2017):77-104.

as the significance, measures, and period markers of the Anthropocene. While these concepts may compete with each other in journals, taken together the Anthropocene concept is currently quite pluralist, and manages to sustain provocative and productive dialogue because of its integrative approach to seeking new ways of viewing nature and our relation to it. As a very lively current example of thinking about periodizing and marking time, the Anthropocene is demonstrative of a productive pluralist concept that integrates different temporalities. Humanist, justice-based, and philosophical discourse around the Anthropocene concept itself trades in notions of acceleration and 'golden spikes' that mark when parts of the world began accelerating.[40]

The aurochs story is similar to the temporal tensions within the Anthropocene literature. There is a tension within study of the aurochs between acknowledging the impulses and effects of humanity on the globe at large since the aurochs' evolution and wild extinction, and recognizing an acceleration of those effects in our modern times. In the conclusion of this dissertation the aurochs is considered as an embodied rewilding goal. Using cutting-edge genome analysis, ecologists are breeding cattle to become as aurochs-like as possible with a goal of bringing back wild spaces that match some conceived pre-industrial baseline for nature. While such genome-informed rewilding may be a modern phenomenon, this possible 'technofix' is mired in old debates. The genome results show a less linear relation between aurochs and its descendants, and the alleged purpose it will serve is often inconsistent and tied up in legalese about whether or not it will be treated as wild. In essence, this story is both post-modern, and also very nineteenth century. In this way, the aurochs mirrors some of the fundamental conceits

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[40] John Robert McNeill and Peter Engelke, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge, MA: The Belknap Press of Harvard University Press, 2014).
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of scholarship born out of the Anthropocene concept: it does not readily shed its nineteenth-century conceptual accruals.[41]

There is a payoff to the temporal dynamics of the aurochs, in that its history and scientific and cultural appraisal as a holistic, processual entity allows it to mirror contemporary problem spaces and provide new ways to conceive of them. These narratives are particularly salient to bolster the "productive combinations" and "hybrid ontologies" that are present in contemporary evolutionary biology in its so-called Extended Evolutionary Synthesis, as well as in broader critical time studies. They are also relevant to the Anthropocene, whose multi-scalar temporalities are reflected in projects created to meet the social, scientific, and economic challenges arising from it.[42] It demonstrates that even the organisms we use to represent our distant past, as well as our rewilded future, are as loaded conceptually with various historical ideals as they are biologically.

This dissertation tells a story that illuminates the ways in which scientific and cultural views engage each other in a temporal register. It suggests that foregrounding that register has made for fascinating scholarship in the past, and is being re-centered once again in current biological, humanist, and environmental thinking. History of science can be a provocative space that,

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[41] Deborah R Coen and Fredrik Albritton Jonsson have written on the significant afterlives of Victorian geology to contemporary Anthropocene conceptions. Deborah R. Coen and Fredrik Albritton Jonsson, "Between History and Earth System Science," *ISIS* 113, no. 2 (June 2022): 407-416, https://doi.org/10.1086/719648. In the final chapter of this thesis, the aurochs may be considered as a fleshy form of the Holocene nostalgia smuggled in from Victorian geology in our modern responses to the ecological crises of the Anthropocene.

[42] Julia Adeney Thomas, "History and Biology in the Anthropocene: Problems of Scale, Problems of Value," American Historical Review 119 (2014): 1587-1607. Dipesh Chakrabarty, "The Climate of History, Four Theses," Critical Inquiry 35 (2009): 197-222.

through the power of historicizing narratives, engages the “time” of its objects more radically and to interdisciplinary effect.[43]

Communicating such history of science stories of charismatic objects can have impact for a broader audience.[44] It is appropriate, honest, and perhaps in the long-run helpful, to share the dynamics of science in-process alongside the cut-and-dry stories. Scientific objects, like scientific ideas, can accrue layers of knowledge and meaning and can seem at times messy, or even ambiguous, in the face of their multi-faceted existence. Yet acknowledging that mess as part of the process of scientific work is an important reminder that when science is drawn to holistically pursue study of a charismatic entity, the entity itself is often a complicated whole. In other words, the dynamic temporalities of science and its history can be quite rational, as nature, including her hooved productions, are dynamic.

THEMES AND STRUCTURE

This thesis consists of six, generally chronological, moments in the development of different scientific ways of knowing the aurochs. The scope of each is limited to a discursive network of interlocuters on a specific epistemological problem to be solved about the existence and extinction of the aurochs. Consequently, there is some overlap in actors between the chapters, as many scientists and commentators who studied the aurochs had something to say on many different aspects of its existence. There are certainly additional historical contexts and materials related to the aurochs that are worthy of future investigation.

[43] The emphasis on constructed science has challenged the pure rationality behind progressive notions of the Enlightenment and has seen history of science come to terms with its largely western worldview.
[44] Latour makes this case clear in his appraisal of the museum exhibit on evolution. Latour, “Textbook Case,” 83-112.

Running through this narrative is also a thread of materiality. The history of science has a rich tradition of crafting narratives around things, and this thesis follows in that tradition. There is a productively destabilizing strain that recurs whenever the field reengages with the actual objects and materials that capture the interest of science at different moments.[45] Each chapter considers the aurochs not just from the perspective of its theoretical conception, but also the parts that best lent themselves to differing methods of knowing it (Table 1 demonstrates how those materialities are related to the temporal records of the aurochs). Chapter 1, in its focus on fossils, spends most time with the skulls of the aurochs. Chapter 2 introduces the hides. Chapter 3 turns again to the fossil form, and revisits the horns and the skulls. Chapter 4, in dealing with the aurochs' living descendants introduces coat color and even taste. Chapter 5 adds a comparative consideration of behavior and features such as udders and horns between domesticated and wild animals. Chapter 6 imagines the aurochs through its genome and its ecological function.

Over the course of the chapters, developments in biological thinking emerge and engage one another. The theory of evolution lurks in the background of some of the sources, until beginning in Chapter 3 it becomes more consequential for interpreting knowledge about the aurochs, its distribution, and its relation to its kin. The relationship between animal breeding in agriculture and in scientific inquiry into heredity is explored during the early twentieth-century development of genetics in Chapter 4. The normalization of integrated systems of ecology and evolution in biological thinking showcased in the global concern over wildlife depletion and the Anthropocene is considered in the final chapter.

The aurochs is introduced in Chapter 1 as a fossil, in the context of nineteenth-century efforts to periodize the deep past. Within this context, the chapter discusses the excavation of the

[45] Daston, *Things that Talk.*

aurochs and its genus, and its initial classification. Through the aurochs, two existing problems within nineteenth-century geology are explored: the limitations of taxonomic classification in the face of specific anatomical preservation patterns, and the possibility and promise of using different kinds of fossil organisms to periodize the geological past. The chapter argues that through the case of the aurochs, we are reminded that the very exercise of slicing geological time into named eras and periods requires a lot of heavy intellectual lifting, tradeoffs, and concessions, and that while some fossils may provide an excellent resolution to trace recent evolution, they do not provide natural cleavages for geological moments. The "internal" and "external" times of the aurochs are, in the historical context of this chapter, in a moment of precarious relativity: neither is yet absolute. That is, the timespan of the species itself was not yet known, and the geological periods which could be used to chart its appearance in time had not yet been devised. The aurochs was not ultimately the deciding factor in determining geological ages. Still, the aurochs' presence in these attempts to periodize geologic history was one of an agitator. And, like some of its co-agitators, such as the Irish Elk, part of the source of its agitation stemmed from the fact that it straddled the pressing periods of prehistory, taken to be before written records, and history, itself being institutionalized as a proper discipline into the nineteenth century. The historical is the focus of Chapter 2.

Chapter 2 introduces the aurochs as a historical relic using a fascinating episode in the history of the aurochs following its wild extinction in 1627. That episode is its supplanting by and confusion with its distant relative, the European bison. This chapter explores the discovery of the aurochs in the written record, referred to there most often as "urus." The chapter begins with the historical misunderstanding that the "urus" in written texts was a different animal than the fossil *Bos primigenius* depicted in Chapter 1. It then traces the eventual recognition by naturalists that the “urus” in texts was the same as the *Bos primigenius* fossils, and that the aurochs spanned prehistory and history. In this chapter, the aurochs gains a historical record and participates in the ordering of a prehistoric one.

This chapter takes as its sources nineteenth-century texts in German and English that sought to make sense of the sixteenth and seventeenth-century German, Polish, and Lithuanian accounts of the animals during their final centuries of existence before their wild extinction. Those sources continued to inform studies on the aurochs throughout the nineteenth, twentieth, and twenty-first centuries. It also introduces through those texts a layer of human fallibility in reports of the nature of the aurochs: could written accounts during the aurochs’ existence alongside humans be trusted as true eyewitnesses? Within these older sources the word “aurochs” often referred instead to the European bison. The confusion generated by the naming conventions, as well as the fallibility of these Early Modern “eyewitness” accounts became issues to resolve in the nineteenth century. The full promise of firsthand observation of the animals would become possible in the late nineteenth century, with a decisive turn recounted in Chapter 4 towards considering the living descendants of the aurochs as conveyors of information about their lost wild ancestor.

The third chapter takes the problems set out by Chapters 1 and 2 – namely how to order time, and how the aurochs in its prehistoric/historic timeline fit into and complicated that enterprise – and makes it global. Aurochs fossils were found in India and in North Africa in the nineteenth century, and it was within those British and French colonial projects, respectively, that it was interpreted. The geological clock being set across Europe starting in the early nineteenth century, described in Chapter 1, was being correlated across the colonies beginning in the mid-nineteenth century. The focus of this chapter is the Indian aurochs, which was determined to be the oldest variant unearthed, and therefore centered India as the earliest site of bovine evolution.

After its 1832 fossil discovery in alluvial plains, it would take several decades before the Indian aurochs variety, *Bos primigenius namadicus,* would be described by naturalist Hugh Falconer as an Indian form of the European aurochs, by then of interest in Europe. The chapter explores how the history of its evolution and domestication were concomitant with the history of relative human civilizational development being traced within British colonies. The chapter argues that the presence of the aurochs in historic and prehistoric records, and its cultural salience as an integral coevolved organism in human societal development added to its significance as a possible signifier of relative societal progress. Its presence in India conjured trans-continental imaginings of evolution and migration, and how those had been informed by climate. The aurochs was not simply placed into those theories of former worlds, but its very presence led to more refined correlated dating of India's geologic beds with Europe's, interpretations of an Asiatic origin of cattle, and a social picture of the role of wild and domestic cattle in societal evolution.

At the same time that cattle evolutionary history was gaining new dimensions in India, the stability of living cattle breeds was tested in the different climes of Britain's colonies. Chapter 4 shifts the dissertation towards a consideration of the living descendants of the aurochs and the role they played in interpreting its evolution. Set in opposition to the development of dairy and beef agricultural production in the nineteenth century, the chapter argues that the aurochs was increasingly perceived as both a relic and a synchronic ghost, haunting living breeds and asserting its presence through occasional reversions in domesticates or feral herds mythologized to be the direct descendants of the aurochs. Charles Darwin would eventually single out the diminutive white Chillingham cattle in Britain as examples *par excellence* of the aurochs, coalescing amateur and some scientific discourse about those Chillingham herds that had culturally propped them up as the purest inheritors of the aurochs' hereditary throne.

In this chapter, the living legacy of the aurochs also introduces new scientific possibilities for exploring the being and evolution of the lost wild ancestral bovine, along with their attendant temporalities. Hereditary science, Mendelian genetics, and agriculturally oriented statistical genetics became new additions to the epistemic landscape of "aurochs studies." Breeding experiments added new possibilities for accessing knowledge about the aurochs, and hinted at the possibilities for resurrection that such access would come to facilitate. This chapter contends with what historian Helen Kingstone has called "shallow time," what historians Hans-Jörg Rheinberger and Staffan Müller-Wille have called "horizontal relations," and what here is called "synchronic time."[46] The chapter considers the network of scientists operating between experimental farms and studies of fossils, as they grappled with their own very different timescales in their studies of the aurochs. While not true of every actor in the chapter, for some, time became an explicit component of their thinking about the study of the aurochs and the onset of new biological fields such as genetics.

Chapter 5 shifts from Britain to Germany to explore the ramifications of the culturally loaded interest in the aurochs, and the developments in thinking of its living descendants as smugglers of the aurochs' genetic material covered in Chapter 4. This chapter examines the

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[46] Helen Kingstone, "The Comparative Method in 'Shallow Time': Walter Scott, Thomas Carlyle, and Francis Galton," in *Historicizing Humans: Deep Time, Evolution, and race in Nineteenth-Century British Sciences,* eds. Efram Sera-Shriar and Theodore Koditschek (Pittsburgh, PA: University of Pittsburgh Press, 2018), 172-192. See also Hans-Jörg Rheinberger and Staffan Müller-Wille, "Heredity Before Genetics" in *Heredity Explored: Between Public Domain and Experimental Science, 1850-1930,* eds. Staffan Müller-Wille and Christina Brandt (Cambridge, MA: The MIT Press, 2016), 143-166.

extreme case of the Heck cattle – a breed of cattle created by Lutz and Heinz Heck, two zookeeper brothers in Nazi Germany – from the lens of global developments in evolutionary science during the interwar and World War II years, and as a practical application of a longer and diverse set of thinking about reversing evolution. The breed was intended to be a recreation of the aurochs, brought about through a selective breeding program that drew on the largest, most aggressive breeds found across Europe. Backing for this project came institutionally and personally from high-ranking party leader Hermann Göring, with the belief that the back-bred aurochs would populate the occupied forests of Białowieża in Poland for the storied Germanic *ur natur* (original nature) to be reinstated, and in which Göring and his cronies could exercise their inclination to hunt.

The chapter continues the thread of examining the scientific scape in which the aurochs was considered. In this context, the Heck cattle were born within an internationally isolated German zoology in the interwar and World War II periods, that expressed a holistic approach to evolutionary organisms, aligned itself with the state eugenics projects, and ultimately brought the mythical into alliance with the perceived possibilities of hereditary science to engineer organisms based upon discrete traits. The back-breeding projects of the Heck brothers took an expansive view of relevant information, including cave art, German myths, and prioritization of behavioral traits that would make for an exciting hunt. The strange episode of the Heck brothers' back-breeding scheme furthers the dissertation's argument that the stickiness of the aurochs as a cultural (in this case, nationalist) and scientific emblem is in large measure due to its existence at different temporal loci. The result is that, to some, it became worthy of breeding back from extinction.

The final chapter brings the biography to the present, to examine the fate of the aurochs in our moment of planetary crisis. In the Netherlands, the aurochs serves as a breeding goal for the rewilding ecology group, Stitching Taurus and its pan-European partner, Rewilding Europe. In this context, the aurochs is viewed as a keystone organism, which once fulfilled a critical role in maintaining a "natural" European landscape. Stitching Taurus is using the aurochs, from genome to horn shape, as a guide for their new Tauros breed, a wild cattle breed that will be, in their words, the "aurochs 2.0." The chapter argues that the multiple records and temporal existence of the aurochs renders it a match for the layered agendas of current rewilding work. Rewilding through back-breeding recapitulates many of the temporal dynamics which have stuck to scientific study of the aurochs since the nineteenth century. For example, current rewilders attempt to balance the expedited reproduction bred into contemporary agricultural cattle with the longer inter-generational evolution achieved through solely natural selection. At the same time, which past ecosystem serves as a target for such rewilding projects is shifting.

The concluding chapter demonstrates that the aurochs is a helpful "thing" with which scholars of the Anthropocene can think, given its embedded sticky temporalities explored in each chapter and their resonance with such temporal tensions within the Anthropocene. The conclusion suggests remaining threads, and suggests that the multi-scalar approaches to time and the environment in the Anthropocene are similar to those multi-scalar realities found in evolutionary biology, and that the dynamics of those entangled enterprises should not always be reduced. Reminding ourselves of the dynamic relation between times, parts, and processes can reinvigorate sciences, approximate a reality that centers process and change, and generate surprising interdisciplinary directions.

Chapter 1: The European Aurochs in Geological Time

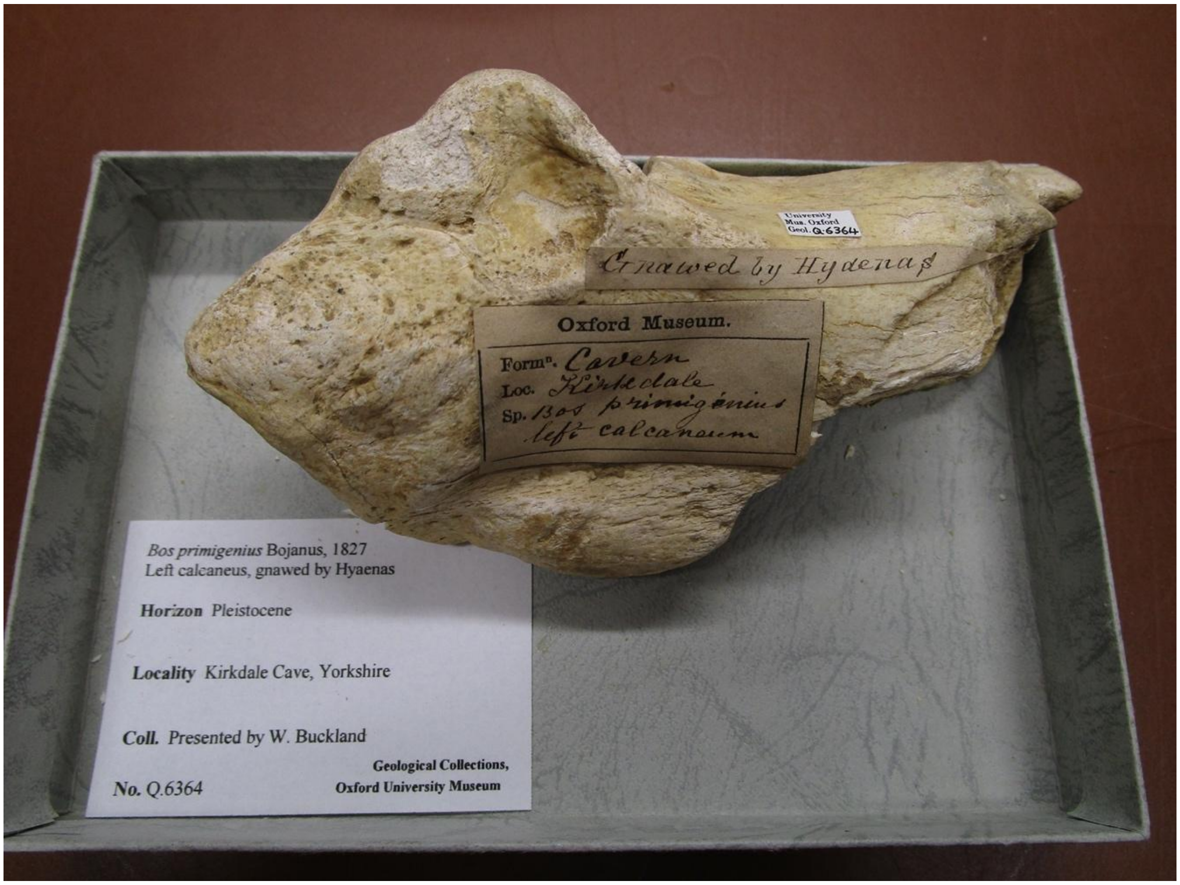

Figure 1. Aurochs calcaneum, found in Kirkdale Cave. Note on bone reads "Gnawed by Hyaenas."[1]

A pack of ancient hyenas dragged their prey into their cave den. The large ox would come to rest in an extensive cave system in a "pre-diluvial" valley, later to be named as part of the parish town of Kirkdale, Yorkshire. The wild bovine constituted part of the "ordinary prey" of the carnivores. The remains of the ox – teeth, some broken long-bones, and other bony limb fragments – would suffer gnawing by the hyenas, while the rest of the skeleton would be completely devoured. The ox teeth themselves indicated youth, or at least, not senescence, thus

[1] Photo by author. Specimen PAL Q.6364, Oxford University Museum of Natural History, Paleontology Collections, Oxford UK.

suggesting that the ox and his comrades had "perished by a violent death in the vigour of life."[2] The horns of the bovine would disappear – their spongy bony interior core likely eaten by the hyenas, while their outer keratinous shells "would not long have escaped total decomposition." The aurochs, and its fellow cave cohabitants, died, were digested, decomposed, and then, the remaining bits discovered in 1821.

When the fossils of aurochs, like those excavated in Kirkdale, were first described in 1827 as their own, extinct, species, they entered into a world in which the "deep history" of geology was being written, and the crude work of ordering that history was in a formative crucible. The nineteenth century brought a broader view of history into scientific and popular thinking, pushing the limits of the past further backwards during a time which was "dominated by a fascination with the past," as historian Peter Bowler has characterized it.[3] In literature and politics, European histories reflected on national and imperial heritage, at times written in Whiggish tones, emphasizing a progression from the past into a desired present or future; at others, historical and literary texts would embody Romantic views of the past, coveting the previously untamed.[4] Across both the European continent and its neighboring Isles, the past itself became more material into the nineteenth century as the remains of former worlds were discovered underfoot, interpreted, and used to make claims not only about those distant eras of time, but about the movement of time itself. The geological and paleontological discoveries of the nineteenth century caused what the Whig political historian Thomas Babington Macaulay

[2] William Buckland, *Reliquiae Diluvianae* (London: John Murray, 1823), 32-33.
[3] Bowler, *Invention of Progress,* 1.
[4] See, for example, Helen Kingstone's discussion of Walter Scott. Kingstone, "Comparative Method, 172-192. National distinctions in views of the past in the nineteenth century have been characterized by historians: the British are often shown to have characterized the teleological views of the past and future, while those in Scotland and Germany often stand in to characterize the Romantic view of the past.

called a "noiseless revolution."[5] Historians have since given noise to the revolution: most extensively, Martin Rudwick has traced the "bursting" limits of the past, while John W. Burrow among others has noted the true disruption caused by the expansion of the past into incomprehensible vast swaths of geological time.[6] The radical conceptualization of a deeper history for the earth and humanity challenged biblical views of time, and set in motion a revolution in how humans viewed themselves within nature and its history.[7] The sediment and its contents became the site of uncovering Earth's own history, and a font for literary metaphors of excavation, archaeology, and ossified pasts in popular literature, politics, and history writing.[8]

The problem spaces within this history have provided incredibly rich fodder for those curious about the cultural and scientific ways in which we have ordered our world. For one, geology in the nineteenth century has been depicted as a naturalizing challenge to biblical domination over historical thinking; it has been characterized as opening up a revolutionized way of viewing the world and our place in it; it has furnished arguments for and against evolution, informing Darwin's own thinking; and it has shared epistemic space with burgeoning disciplines that centered historicity in interpreting the world. It has also been theoretically rich in its varied approaches to seeking reliable and consistent ways to measure and periodize time in the past.

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[5] Thomas Babington Macaulay "The Romance of History," *Edinburgh Review* 47 (1828): 362.
[6] Rudwick, *Bursting;* and John W. Burrow, "Images of Time: From Carlylean Vulcanism to Sedimentary Gradualism," in *History, Religion and Culture: British Intellectual History, 1750-1950,* ed. Stefan Collini, Richard Whatmore, and Brian Young (Cambridge: Cambridge University Press, 2000).
[7] Rudwick, *Bursting.* This "deep time" revolution (a term coined by John McPhee in 1981), has been compared to the revolutions in thinking ushered in by Copernicus and Darwin. Toulmin and Goodfield have described it thus: "no transformation in men's attitude towards nature…has been more profound than the change in perspective brought about by the discovery of the past." Stephen Edelston Toulmin and June Goodfield, *The Discovery of Time* (Chicago: University of Chicago Press, 1982), 17.
[8] See for example, Burrow, "Images of Time," 215. Interestingly the prevalence of caves and subterranean settings in Gothic literature began with its earliest work, Horace Walpole's 1764 *Castle of Otranto.* But the subterranean would take on evolutionary dimensions in the nineteenth century, when cave-dwelling antagonists would represent degeneration and primitive states in works by Edgar Allan Poe and H.G. Wells, for example.

Nineteenth-century interest in prehistoric times and their vestiges has furnished much consternation about how humans in a Western tradition think about time, chart it, remember it, and imagine it.

The particular conceptual "revolution" into which the aurochs fossils strayed was that of measuring, correlating, and periodizing the geological past. Rock layers – called strata – rendered the terrain of Europe and across its colonies into representations of different long-ago times, with the vertical sections of strata read as a progression of time.[9] Creating what Stephen Jay Gould called a "yardstick of history" for those strata was a tricky feat in the nineteenth century: it was not always clear what the best method was for properly ordering the strata in time.[10] The temporalities extracted from those sections of rock were never "absolute," rather they were placed in time relative to one another through taxonomic classification of characteristic fossils (those that could characterize a particular rock layer, and therefore a particular slice of past time), or ratios of extinct to living organisms.[11] "Deep history" therefore was at once linear and non-linear, local and global. This chapter traces how the aurochs was discovered amidst debates about the unilinear ordering of time sought in the geological sections and the fossils contained therein, and the methods of achieving a periodization for relative geological time that were generated in the nineteenth century, specifically around the Tertiary Period, which today

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[9] See Daniel Rosenberg and Anthony Grafton, *Cartographies of Time*: *A History of the Timeline* (Princeton, NJ: Princeton Architectural Press, 2013), for an account of visual spatial representations of time in the forms of maps, and timelines. See also, David Sepkoski and Marco Tamborini, "'An Image of Science,'" *Historical Studies in the Natural Sciences* 48, no. 1 (February 1, 2018): 56–109, https://doi.org/10.1525/hsns.2018.48.1.56.

[10] Stephen Jay Gould, "The Power of Narrative," in *An Urchin in the Storm: Essays about Books and Ideas* (New York: W.W. Norton, 1987).

[11] David Sepkoski, "The Earth as Archive: Contingency, Narrative and the History of Life," in *Science in the Archives,* ed. Lorraine Daston, (Chicago: University of Chicago Press, 2017). Dresow, "Measuring Time with Fossils," reimagines the history of the use of fossils to correlate strata from a philosophical valance, demonstrating its lack of theoretical justification in the early nineteenth-century.

would coincide with the end of the Cretaceous Era (think dinosaurs) to the beginning of the Pleistocene glaciation (think mammoths).

The European aurochs fossils were found in ever higher numbers during the nineteenth century, and loomed in many of those discussions of the geological past. At the same time that it was being introduced as a fossil, undergoing taxonomic classification, and paleontological reconstruction, it was placed into uneasy geological periodizations, which were themselves being worked out in this period. The aurochs waded into the quite muddy waters of its external timescale: that of its placement within geological history. Discoveries of its remains, and the purported conditions of its life and death demonstrated geological time at its most complicated: the relationship of changing climate, external conditions, and fossil forms, and the intellectual struggle over which could truly order time and sort the others. Below, the external timescales of geological history into which the aurochs factored are first described, demonstrating the instability of "characteristic" or "index" fossils for reliably correlating strata, and the significance of the aurochs' discovery in proximity to Tertiary formations. The aurochs is introduced more fully into those attempts to periodize the geological period of the Tertiary, and its uneasy application as a characteristic fossil for the Tertiary is explored. The chapter considers several ways in which the aurochs contributed to and challenged the establishment of a neat chronology for the more recent geological periods, and how its pesky presence near evidence of human evolution and early human history would make its temporality even stickier into the rest of the nineteenth century.

THE PROMISING ORDER OF GEOLOGY

At the core of the stratigraphical ordering efforts in the nineteenth century were choices over which characteristics of that geological record should be used as the measure of time. Could fossils reliably display change over time, and therefore mark those temporal periods? If so, which fossils; and could they be correlated across distances? Or, were changes in fossil forms merely an inconsistent by-product of a different driving force, that itself was a reliable marker of the changes in former eras; perhaps climate or the nineteenth-century concept "conditions of life"?[12] Questions over how to best order the deep past were concurrent with its discovery underfoot. Indeed, rather than plugging fossil discoveries into a previously sorted chronological chart of the past, the reader ought to call to mind a scene in which fossils and geological ages constituted one another, often sloppily, and with much debate. While characterizing a chronological linearity of geological time, moving from oldest to more recent, was certainly the aim inherent in such projects, complications and disagreements abounded. In the midst of discussion over how to reliably trace a chronology of the deep past and periodize earlier ages, sometimes non-directional and non-linear methods were used by naturalists. Charles Lyell, for example, tried to eschew any progression at all early on in his theorizing, preferring instead a

[12] Attempts to order the past into a chronology, moving between successive events in an order from a 'beginning' to an 'end', often relied on non-chronological temporal tools. Peter Bowler, for example, has unpacked what a *progressive* read of the fossil record truly indicated about Victorian views of "time's arrow" (to borrow from Stephen Jay, Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*, The Jerusalem-Harvard Lectures (Cambridge, Mass: Harvard University Press, 1987). See Bowler, *Fossils and Progress.* According to Bowler, naturalists who underscored the evidence of the development of animal forms in the fossil record, including Lamarck and Darwin, were simply identifying some progression from simple to specialized forms as a by-product of other conditions. In fact, Bowler's *Fossils and Progress* is remarkable for its reduction of seemingly progressive nineteenth-century views of the history of life to simply being a coincidental effect of other driving forces in the history of the earth. Even Darwin, according to Bowler, only accepted a "progressive trend in evolution" to the extent that he viewed it as an "indirect and highly irregular by-product of natural selection, an equivalent only of the statistically inevitable progress through diversity postulated by Herbert Spencer's cosmic evolutionism." Bowler, *Fossils and Progress,* 12.

more cyclical view of the deep past.[13] The puzzle of how to create a chronology of the geological past did not always benefit from an assumed linear history.

Still, the fossils of floras and faunas excavated by hammer or class-knife furnished a sense of time moving in the geological past, with changes between forms suggesting that the earth's history was indeed chronological; that is, built up with successive unique organisms changing over time. It is no surprise, then, that one of the most prolific modes of ordering the deep past in the nineteenth century was the use of so-called "characteristic fossils," or index fossils. In order to piece together a reconstruction of the earth's deeper past, nineteenth-century European naturalists sought to correlate their geological strata between regions and countries. Surveyor William Smith's survey of strata between England and Wales furnished an astonishing result for his efforts.[14] His survey made use of what he called "characteristic fossils," those he extracted, noting their localities, and then finding similar fossils in strata he could then determine were analogous.[15] Prior to Smith, geologists studying sections of the earth had utilized fossils only minimally to identify the different rock formations.[16] Lithography, or the study of sediment and rock compositions, was used as a method of correlation between different geologic formations, but was later joined, and then superseded in the nineteenth century, by the use of fossil fauna found in those formations. Through comparative anatomical observation, exemplified by the renowned French naturalist Georges Cuvier, fossils were used to relate the

[13] Bowler, *Fossils and Progress,* 69-79. Bowler describes Lyell's three-decade resistance to progression in the fossil record, and his theorizing about the subsidence and elevation of landmasses around the globe.
[14] Rudwick, *Bursting.*
[15] Sepkoski, "Earth as Archive," 62.
[16] Rudwick, *Bursting*, 97-98. Rudwick traces the development of geognosy, originally rooted in mining, from being purely descriptive in nature, to proposing causal explanations. As part of that progression, he notes the increasing recognition of the diagnostic potential of fossil fauna, though it was still only one of several measures used to describe a formation.

history of the earth.[17] In the early nineteenth century, the work of Cuvier, often hailed as the father of vertebrate paleontology, and Adolphe Brongniart, known for his work on fossil flora, helped develop a standard of stratigraphical mapping, which defined layered rock strata and provided a standard visual and descriptive language for discussions of the earth's geological past.[18] The stunning product of William Smith's survey, his 1815 Geological Map of England and Wales, demonstrated the utility of characteristic fossils for differentiating and correlating distinct formations across Britain.[19] Similarly, the Italian geologist Giovanni Battista Brocchi, working in the Subappenine beds of Italy, used fossil shells to correlate the so-called Secondary formations (today recognized as the Mesozoic Era, inclusive of the Triassic, Jurassic, and Cretaceous periods) with those of Paris and London. Through his work he coined a new term for an even more recent stratigraphic layer – the Tertiary.[20] Cuvier and Brongniart divided the Tertiary into smaller periods, which Lyell would later revise in his own "Tertiary" description, inclusive of what he would name the Eocene, Miocene, and Pliocene. Those early published

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[17] Cuvier, himself, however, did not place life's past organisms in a continuum of descent or linear hierarchy relation; rather he split the animal kingdom into four quite distinct grouping, between which there was no meaningful connection. That his *embranchments* would not be breached one to the next restricted how much progression could have occurred between the different forms of life on earth. See, Bowler, *Fossils and Progress,* 6.

[18] See Rudwick, *Meaning of Fossils*, Chapter 3 for a detailed discussion of the developments of fossil use in stratigraphic mapping.

[19] Rudwick, *Bursting,* 444. Smith's 1815 Geological Map took on new significance as examination of fossil fauna in Europe resulted in the discovery of progression of types. See Martin J.S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes: New Translations and Interpretations of the Primary Texts* (Chicago: University of Chicago Press, 1997)*,* 131. William Smith, "A Delineation of the Strata of England and Wales, with part of Scotland," (London: John Cary, 1815).

[20] Rudwick, *Bursting,* 525-529. The first deposits that were later labeled Tertiary were identified by Cuvier. He wrote about the Chalk Basin of Paris in his 1811 *Envrions de Paris.* Three years later, Brocchi first used the term 'Tertiary' in his *Conchiologia fossile subapennina con osservazioni geologiche sugli Apennini, e sul suolo adiacente* (Milan: 1814). See Charles Lyell, *Principles of Geology* II (Philadelphia: James Kay, Jum. & Brother, 1837) for contemporary discussions of the first uses of the term.

strata sequences for the Tertiary were largely built upon Brongniart's studies of invertebrate fossils.[21]

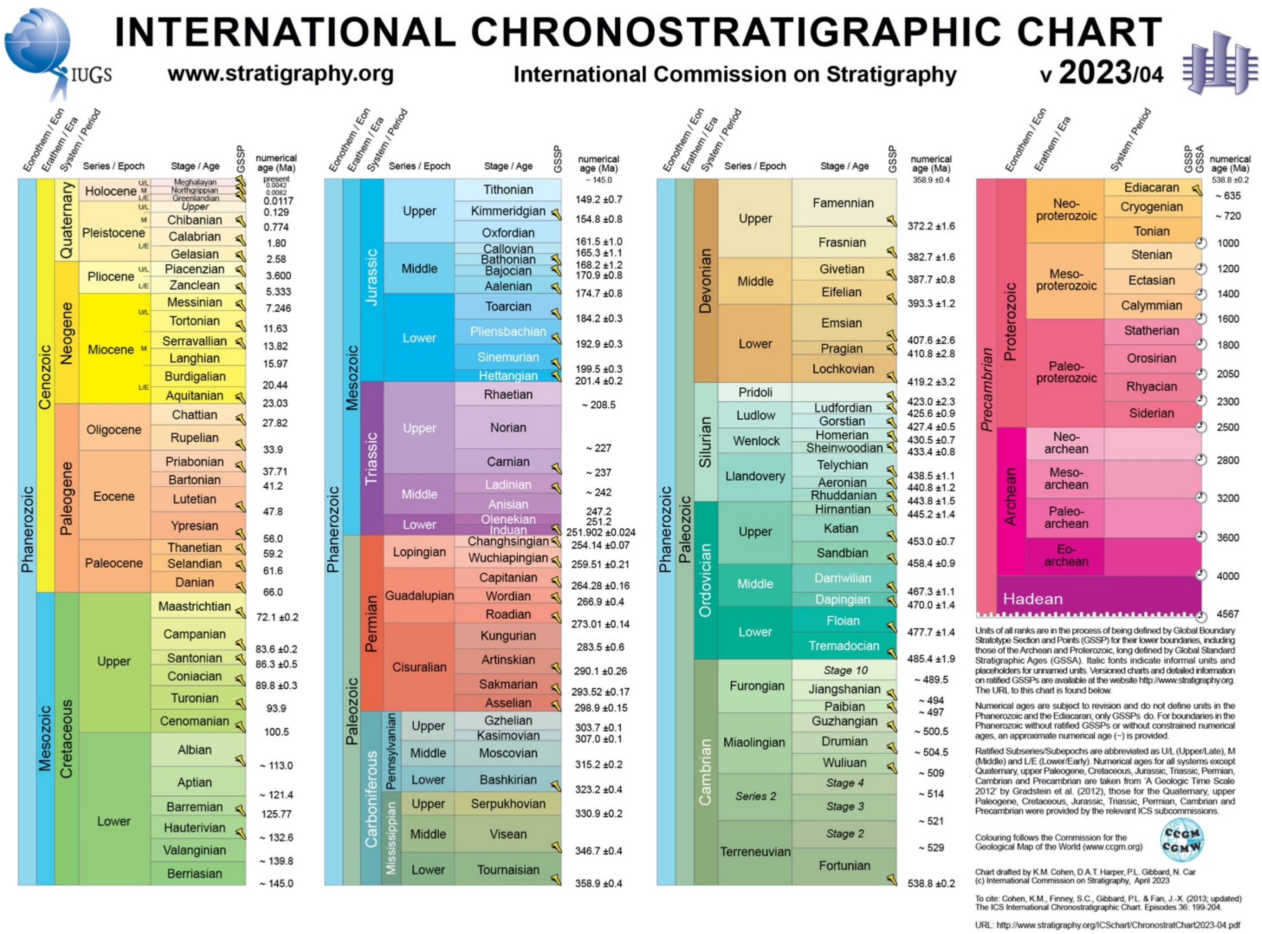

Figure 2. Modern stratigraphical chronology, with the eras of the Paleogene and Neogene on the far left corresponding to the "Tertiary" as it was most often used in the nineteenth century.[22]

[21] Bowler, *Fossils and Progress,* 17.

[22] Cohen, K.M., Harper, D.A.T., Gibbard, P.L. 2023. ICS International Chronostratigraphic Chart 2023/04. International Commission on Stratigraphy, IUGS. www.stratigraphy.org (visited: 2023/04/17).

		Great Britain and Ireland.
Post-tertiary or Quaternary.	*Recent* ...	Newer alluvial gravels. Peat mosses, &c.
	Pleisto-cene.	Cave deposits. Glacial drift.
Pliocene ...	*Newer* ...	Boulder clay and older glacial drift. Norwich crag.
	Older ...	Red crag. Coralline crag.
Miocene ...	*Upper* ...	*Wanting.*
	Lower ...	Hempstead beds.
Eocene ...	*Upper* ...	Bembridge, Osborne, and Headon beds. Barton beds.
	Middle ...	Bracklesham beds and Bagshot sands.
	Lower ...	London clay. Woolwich and Reading beds. Thanet sands.

Figure 3. Section of a "List of European Formations" based on Lyell's stratigraphical nomenclature, from 1877 *A Manual of the Geology of India.*[23]

The Tertiary gained traction as an important geologic period of study in Europe. It referred to the periods of the earth's history after the Cretaceous, but prior to the most recent period of geologic history frequently dubbed "Post-Tertiary." For most naturalists in the early-to-

[23] H.B. Medlicott and W.T Blanford, *A Manual of the Geology of India* (Calcutta: Geological Survey Office, 1877), lxxvi.

mid-nineteenth century, including Cuvier, Brocchi, and those in Britain such as William Buckland and Charles Lyell, the Tertiary/Post-Tertiary divide was particularly interesting because it seemed to correspond to important geologic, faunal, and historical phenomena – the potential Biblical deluge, an Ice Age, mass extinctions, and the emergence of humanity. The aurochs fossils would be found within proximity of that possible divide, as naturalists were determining which fossils might be used as characteristic signifiers of that time in the deep past. Before the aurochs even entered the efforts to periodize the Tertiary/Post-Tertiary divide, it was already a factious landscape, with disputes over whether characteristic fossils, and mammals at that, could be reliably used to identify that particularly loaded divide in the earth's history. Whereas William Smith had notably used characteristic fossils in his correlations of geologic strata, and relied on taxonomic identification for his purposes, Charles Lyell turned towards ratios of extinct to living organisms for methods of ordering geological time.

Before the 1833 publication of Lyell's third volume of his groundbreaking *Principles of Geology*, the Tertiary had been divided by geologists into Lower, Middle and Upper sections as follows: the oldest formations around Paris being the Lower, the Middle characterized by sections in Bordeaux and Touraine, and the Upper constituting anything that rested above the Middle Tertiary beds.[24] Lyell, however, had in mind another way of dividing the Tertiary. In 1828 he conceived of a classification of strata based on the fossil fauna found therein.[25] For Lyell, the strata could be ordered chronologically according to the proportion of fossil shell species in each stratum that were identical with living species.[26] To tackle the most recent

[24] Charles Lyell, *The Geological Evidence of the Antiquity of Man* (London: J.M. Dent & Sons, Ltd., 1914), 2. This version is a reprint of the 1863 first edition that contains an interesting foreword and asides that qualify Lyell's claims with additional knowledge accumulated after the original publication.
[25] *Ibid.,* 2.
[26] *Ibid.*, 3.

formations, Lyell divided the Post-Tertiary formations into "Recent" (closer to the present, and therefore younger) and "Pleistocene" according to the fossil shells and mammals found in the deposits.[27] The Pleistocene thus included any strata in which most of the fossil shells had living identical types, and a large portion of the fossil mammals were entirely extinct. The Recent strata referred to any in which all the shells and all the fossil mammals were still living.[28] Through a similar method he renamed the original three divisions of the *Tertiary* era: in chronological order, the Eocene, Miocene, and Pliocene. Some contemporaries objected to his nomenclature on the grounds that the most recent Tertiary division, the Pliocene, sometimes contained the remains of extinct mammals, though he excused this by claiming that the divisions were originally devised purely on fossil shell data.[29] Lyell later conceded that while the "bones of mammalia in the tertiary strata" gave insights of a "most interesting kind," they were too scarce in the fossil record to be solely relied upon in "characterizing the subdivisions of geological formations."[30]

For Lyell, the interesting mammals from recent European deposits could not be ignored, yet they presented difficulties. The presence of extinct mammals in seemingly recent strata and their overall dearth in the fossil record relative to the abundant fossil shells could pose problems for naturalists who relied solely on them. Clearly, the type of fossil fauna used could complicate the data derived and the conclusions drawn. Due to their abundance in the fossil record, invertebrates were largely prioritized by naturalists including Charles Lyell. Still, by the late nineteenth century, prominent geologists such as William Boyd Dawkins pushed for a periodization of the recent geological past based upon mammals, not invertebrates. Following

[27] Throughout this thesis, lower-case "recent" refers to a close proximity in time to the contemporary period, while upper-case "Recent" specifically refers to Lyell's subdivision of the Post-Tertiary.
[28] Lyell, *Antiquity of Man,* 4.
[29] *Ibid.*
[30] Lyell, *Principles of Geology* II, 217.

Darwin's 1859 *Origin,* the recent evolution and specialization of mammals in the fossil record suggested that they could, despite their difficulties noted by Lyell, offer a finer resolution of temporal tracking for recent geological strata. The aurochs, as a mammal and a fossil found in proximity to the Tertiary/Post-Tertiary geological divide, appeared in such discussions.

All of this made for a particularly vexing epistemological landscape in which the aurochs fossils were discovered, and to which they contributed. The cracks within the project of linear ordered chronology – the very aim of the naturalists – were revealed through efforts to fix the Tertiary and Post-Tertiary in time. Stabilizing fossil fauna in time, and deciding between conditions, climate, or changes in animal form as the measure of time in geology revealed early on that life's history might not itself be a useful indicator of the order of time. What might be seen as a direction, or progression, of forms was always complicated by groups that bucked expectations about when (or in strata terms, where) they might fit. Ordering time, therefore became a project that needed to explain trends and find associations between organisms and driving conditions if mammal fossils were to be used. The aurochs in particular found itself within many of these discussions. The discussions about the fossil animals and their geological past, for the Tertiary in particular, were circular: did the fossil fauna indicate something about the geological time of the beds in which they were found? Or did the beds reveal something about the slippery temporality of the animals? The aurochs' presence in these questions reveals a microcosm of the difficulties in a method of measuring and periodizing time in which the underlying relationship between the possible signals (fossils) and their own timescales were not yet established.[31] Which presented a reliable geological clock by which to order the rest? Enter a closer look at the aurochs and its emergence into this discourse.

[31] Dresow has described this as a "nomic measurement," borrowing from Hasok Chang (2004). In Dresow's words, "the problem of nomic measurement arises when researchers want to measure an

UNEARTHING THE AUROCHS

In 1821, the Reverend William Buckland discovered and described with imaginative flair the Kirkdale cave bone yard. His *Reliquiae diluvianae* detailed the discoveries in the cave system, once the site of a hyena den, according to his findings. The findings were one of many such discoveries over the nineteenth century; indeed, caves would prove to be prominent sites yielding well-preserved specimens of large, presumably extinct megafauna of Europe.[32] In addition to the fruits of caves and caverns, numerous railway and waterway construction sites, as well as peat bogs yielded fossils of cave bears, mammoths, deer, and ox in increasing numbers over the nineteenth century.[33]

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unobservable quantity *X* based on an observable quantity *Y,* but the relationship between *X* and *Y* is insufficiently characterized." He contends that X could be read as time (or the strata age), while Y is the faunal composition. Max Dresow, "Time, Life and Environment: Practices of Geohistory at the Intersection of the Earth and Life Sciences" (PhD diss., University of Minnesota, 2021), 58.

[32] For a compelling account of the relevance of caves and their fossilized contents in Germany see Patrick Anthony's "Making Historicity: Paleontology and the Proximity of the Past in Germany, 1770-1820," *Journal of the History of Ideas* 82, no. 2 (April 2021): 231-56.

[33] Chris Manias provides an account of many of these finds in Britain in his "Contemporaries of the Cave Bear and the Wooly Rhinoceros: Historicizing Prehistoric Humans and Extinct Beasts, 1959-1914," in *Historicizing Humans: Deep Time, Evolution, and Race in the Nineteenth-Century British Sciences,* eds. Efram Sera-Shriar and Theodore Koditschek (Pittsburgh, PA: University of Pittsburgh Press, 2018), 14-43.

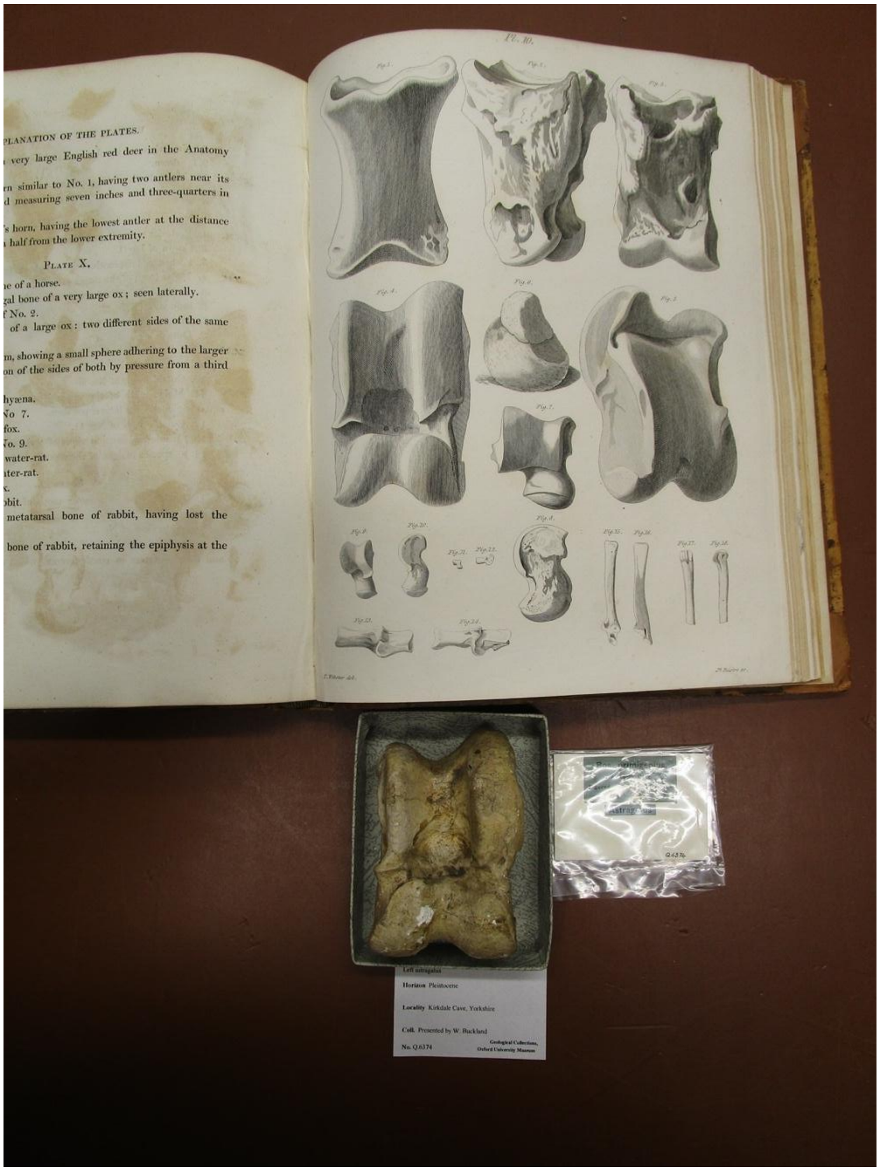

Figure 4. Astragalus of Bos primigenius from Kirkdale, depicted in Plate 10 of Buckland, 1823.[34]

The Kirkdale caves described by Buckland revealed bone fragments of animals including oxen, some with gnaw marks from the hyenas.[35] Of the teeth found in the cave, most were determined to be from a mammal group called ruminants, inclusive of bovines such as the

[34] Buckland, *Reliquia Diluvianae,* Plate 10 indicating in Figs 4 and 5 the "Astragalus of a large ox: two different sides of the same bone," next to original specimen. Photo by author, from Oxford University Museum, Geology Collections.
[35] Buckland, *Reliquia Diluvianae*.

aurochs. These specimens were transferred to Oxford University's Museum of Natural History by a Mr. Gell, where they now reside in the Geological Collections.[36] Aurochs fossils' taxonomic identity would, beginning in 1827, be classified as *Bos primigenius* by the German naturalist Ludwig Heinrich Bojanus, based on his description of an aurochs skeleton then mounted on display in Jena.[37] Carl Linnaeus had, almost a century prior, referred to wild aurochs and domesticated cattle under the same taxonomic name, *Bos taurus,* designating the domesticated cow and the earlier fossil ox as the same species. Bojanus untethered the two taxonomically, using a method of osteometry he developed for his work on the aurochs and the steppe bison.[38] Soon thereafter, specimens previously referred to as "fossil oxen" excavated in droves across Europe were often described or redescribed as *Bos primigenius*.[39]

In the late eighteenth and early nineteenth centuries, dedicated research into bone findings of the aurochs began.[40] After Bojanus described the aurochs as a separate species from

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[36] Buckland, *Reliquiae Diluvianae*, 63. A partial skeleton of *Bos primigenius* from Dream Cave near Wirksworth, Derbyshire*,* discussed by Boyd Dawkins in *Cave Hunting* is also housed in the Geological Collections of Oxford University Museum of Natural History; cited by William Boyd Dawkins, *Cave Hunting: Researches on the Evidence of Caves Respecting the Early Inhabitants of Europe* (London: MacMillan and Co., 1874), xxiv and 445.

[37] Ludwig Heinrich Bojanus, *De uro nostrate eiusque sceleto commentatio* Vol 13 (Bonn: Verhandlungen der Kaiserlichen Leopoldinisch-Carolinischen Akademie der Naturforscher, 1827.. The work is usually credited to 1827, the year of his death, and the aurochs' scientific citation is *Bos primigenius* (Bojanus, 1827). Piotr Daszkiewicz and Tomasz Samojlik, however, advocated for a change in the year of description to 1825 following a discovered copy of Bojanus' work in the Muséum National d'Histoire Naturelle in Paris, France which was published in 1825. Daszkiewicz and Samojlik, "Corrected date of the first description of aurochs *Bos primigenius* (Bojanus, 1827) and steppe bison *Bison priscus* (Bojanus, 1827)," *Mammal Research* 64 (2019), 299-300.

[38] Cis van Vuure, *Retracing the Aurochs: History, Morphology and Ecology of an Extinct Wild Ox* (Sofia/Moscow: Pensoft, 2005), 31-32, and Daszkiewicz and Samojlik, "Corrected date," 2019.

[39] In 1993, a push to change the zoological nomenclature for the aurochs to *Bos taurus,* to keep with primacy conventions in zoological naming was granted, and then met with criticism. Gentry et al argued in 1998 that an exception to the convention could be made in the case of domesticated animals, and in 2003 *Bos primigenius* was reestablished as the scientific name for the aurochs, while *Bos taurus* is used for its domesticated descendants. Anthea Gentry, Juliet Clutton-Brock, and Colin P Groves, "The Naming of Wild Animal Species and Their Domestic Derivatives," *Journal of Archaeological Science* 31, no. 5 (May 2004): 645–51, https://doi.org/10.1016/j.jas.2003.10.006.

[40] van Vuure, *Retracing the Aurochs,* 28.

domesticated oxen in 1827, literature concerning the aurochs sorted any bone findings under the scientific classification of *Bos primigenius.* Most literature on the subject in the nineteenth century was published in English or German. Georg Gottlieb Pusch published several early works in German, such as his 1838 and 1840 essays on the aurochs bones. The aurochs bones themselves mostly derived from sites in Britain, Germany, and Denmark. Some of the most productive aurochs fossil sites included the Kitchen Middens and other archaeological prehistoric waste piles, as well as peat bogs, caves, and railway and waterway projects that cut through previously unknown fossil beds. In Denmark, the frontal plates and horn cores of a large bovine skull described by Pontoppidan in 1767 from Vendsyssel, North Jutland were later reinterpreted as *Bos primigenius.*[41] Brain cases were discovered in Rosenholm, Jutland, and Trotstrup, northwest of Odense, Funen and described as *Bos primigenius* by Johannes Christopher Hagemann Reinhardt, Senior in 1834.[42] An almost-complete skeleton of the aurochs was discovered in 1853 from Zealand, found "beneath a layer of peat, about 20 feet thick…lying in bluish clay."[43] The measurements of the nearly full specimen were compared with another complete skeleton of the aurochs from Scania in southern Sweden, which had been measured by renowned Swedish zoologist Sven Nilsson in 1847 (see figure 8). The aurochs fossil finds continued through the nineteenth century; Japetus Steenstrup of The Royal Danish Society described several finds, including that he excavated a complete aurochs skeleton from Store Damme, Moen. In his description of the find, Steenstrup noted its '"contemporaneity with the oldest pine woods in Denmark.'"[44] Aurochs specimens found in Switzerland were described by

[41] Magnus Degerbol and Bent Fredskild, "The urus (Bos primigenius Bojanus) and neolithic domesticated cattle (Bos taurus domesticus Linné) in Denmark. With a revision of Bos remains from the kitchen middens," *Det kongelige Danske Videnskabernes Selskab, Biologiske Skrifter* 17(1): 6.
[42] Degerbol and Fredskild, "The urus," 6.
[43] *Ibid.* Referring to Skandivanisk fauna, Däggdjuren (1847): 541-543.
[44] *Ibid.* Referring to OVSF (1870): 105-110.

Ludwig Rütimeyer, while a near-complete skeleton from Germany was described by Alfred Nehring in 1888.[45]

The public could participate in such finds, as well. While construction works yielded several specimens that would be donated to museums, activities such as peat cutting for fuel or cultivation could pose risk to the fossils. In 1861, Sven Nilsson wrote a letter to the editor of *Snällposten,* offering to purchase skeletons found during peat cutting at a rate of 50 rilksdaler for aurochs, bear, elk, reindeer, and boar skeletons.[46] He lamented, "I only regret that I did not announce this 20-30 years ago; a great deal would have been saved for science which has now been ground down into a simple fertilizer. But better late than never." In 1905, the Peat Bog Commission was formed by the Ethnological Association in Lund and made a plea to the public in the face of industrial bog working, asking to be informed by telegraph or phone when a find was made.[47] Posters were put up indicating the kinds of valuable relics that they sought.[48]

[45] The skeleton is now mounted and on display at Berlin Natural History Museum. For more on Nehring's descriptions, Alfred Nehring, "Über das Skelett eines weiblichen Bos Primigenius," *Sitzungsberichte der Gesselschaft Naturforschender Freunde zu Berlin* 4 (1888): 54-62.
[46] The Lund University Historical Museum *Zoological Hall* Exhibit, Lund, Sweden.
[47] The appeal was circulated in Swedish press, sent to schools, local governments, bog owners and parish offices.
[48] The Lund University Historical Museum *Zoological Hall* reports that between 1900 and 1929, as a result of those efforts, the Zoological Museum saw an increase in its donated finds.

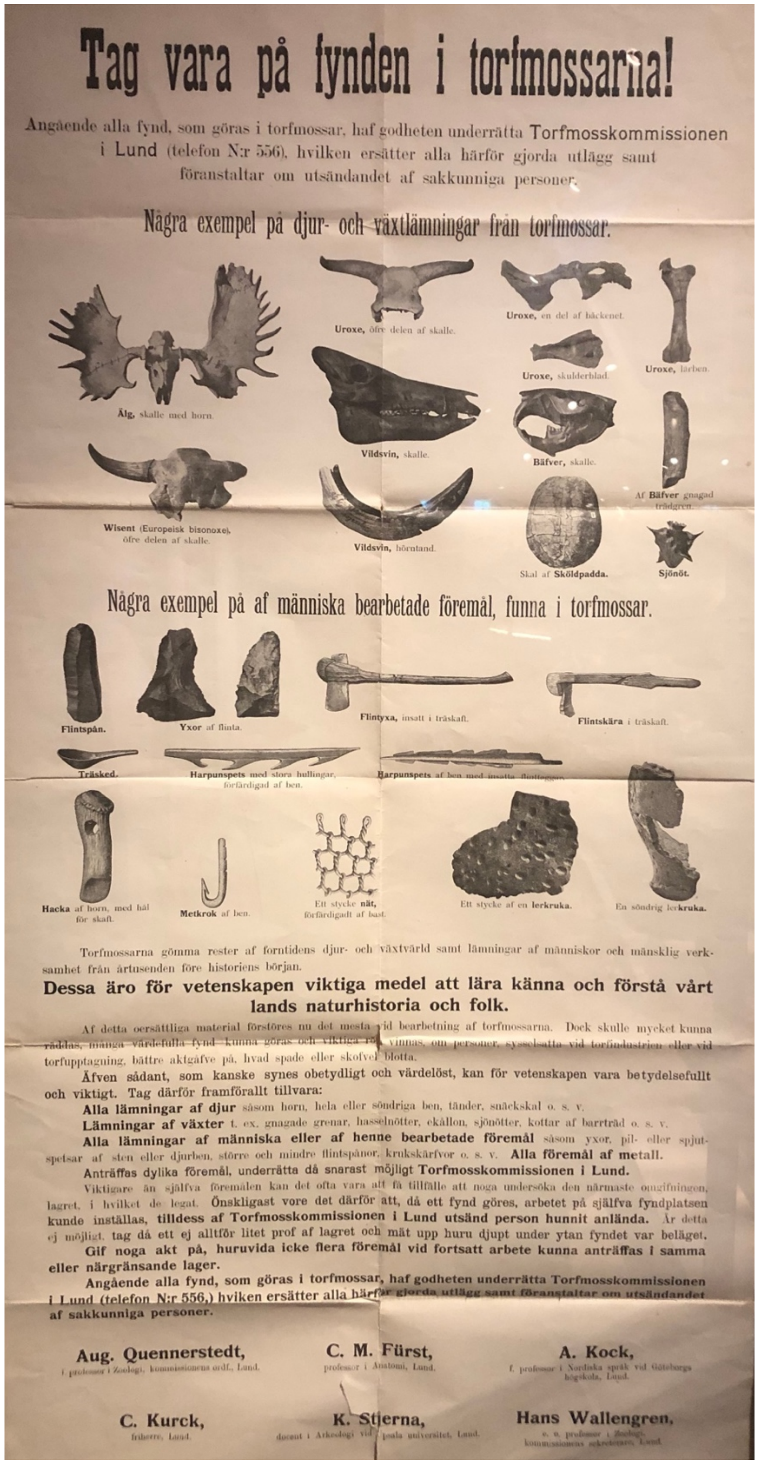

Figure 5. One public poster appeal on display at the Lund University Historical Museum. "Uroxe" skulls, long bones, and scapulae are noted in the poster, top right.[49]

[49] Photo by author. November 4, 2022, Lund University Historical Museum, *Zoological Hall* Exhibit, Lund, Sweden.

In Britain, the *Quarterly Journal of the Geological Society* published notices throughout the nineteenth century of fossil ox and *Bos primigenius* bones. Many were found during the laying down of railway tracks. For example, in 1893 the brick-clay near Pontac yielded a *Bos primigenius* bone during the construction of the Eastern railway.[50] Cumbria produced several specimens of *Bos primigenius,* found during excavations at the Silloth Dock in April 1883. The bones were presented to the chairman of the North British Rail Company, Sir Talshaw, and eventually donated to the National Museums of Scotland. John Alexander Smith, William Turner, and J Leitch referred to and described the humerus, horn core, mandibles, and metatarsal specimens derived from Silloth Dock in their works on the aurochs.[51]

[50] Andrew Dunlop, "On Raised Beaches and Rolled Stones at High Levels in Jersey," *Quarterly Journal of the Geological Society* 49 (1893): 530.

[51] Specimens from National Museums of Scotland, Collections Centre are Z.2018.20; 2018.20.6; 2018.20.2. References that correspond to those fossil specimens are: J. Leitch, "Notes on the geological formation and fossils of the Silloth New Dock," *Transactions of the Cumberland and Westmoreland Association for the Advancement of Science and Literature* 9 (1885): 169-174; W. Turner, "On fossil bones of mammals obtained during excavations at Silloth," *Proceedings of the Royal Physical Society of Edinburgh*, 8 (1885): 333-338; John Alexander Smith, "Notes on the ancient cattle of Scotland, *Proceedings of the Society of Antiquaries of Scotland* 9 (1873): 587-674; and W. Turner, *Proc. Roy. Phys. Soc*. 2 (1859): 70.

Figure 6. Clockwise from top left: left humerus Silloth Dock specimen; horn core, mandibles, and metatarsal specimens from Silloth Dock; two horns with partial skull from Silloth Dock; full skull of Bos primigenius, described in Turner, 1863.[52]

From the vantage point of the early twentieth century, prominent zoologist Richard Lydekker could reflect on the relative fossil yields of the counties of England over the nineteenth century. His survey, moving county by county highlighting the paleontological discoveries and publications about each, confirms the most productive sites for aurochs finds in England during the nineteenth century: railway construction sites, gravel pits, and peat.[53] Bedford county yielded some remains recorded by James Wyatt in the early 1860s, including of "the wild ox or aurochs"

[52]Photos by author of specimens Z.2018.20, 2018.20.6, 2018.20.4, 2018.20.2, National Museums of Scotland, Collections Center, Edinburgh, Scotland.

[53] Richard Lydekker, *Palaeontology of the Counties of England,* The Victoria History of the Counties of England (1909), in Geological Society of London Library.

and the “Pleistocene hippopotamus.”[54] E.B. Poulton reported mammal remains next to tree trunks in the Pleistocene sands near Reading, belonging to mammoth, the aurochs, a fossil group of horse, and a rhinoceros.[55] Gravel-pits near Reading turned up remains, as did the construction of a railway from Didcot to Newbury. Several of those were identified by Joseph Prestwich, and a skull exhumed from the peat of Ham Marsh was added to the museum collection of the Newsbury Institution.[56] After their unearthing, the fossils made their way into university anatomy and zoology departments, museum collections and displays, or private collections where they were placed on top of wardrobes or mounted on the wall if stable enough. Buckland’s specimens from Kirkdale rested in the collections at Oxford University’s Natural History Museum; other ruminant fossils and ox specimens were put on display in the vertebrate gallery (figure 7).

[54] Richard Lydekker, *Palaeontology of the Counties of England,* The Victoria History of the Counties of England (1909), in Geological Society of London Library, 33.
[55] Lydekker, *Counties of England*, 25.
[56] Lydekker, *Counties of England.*

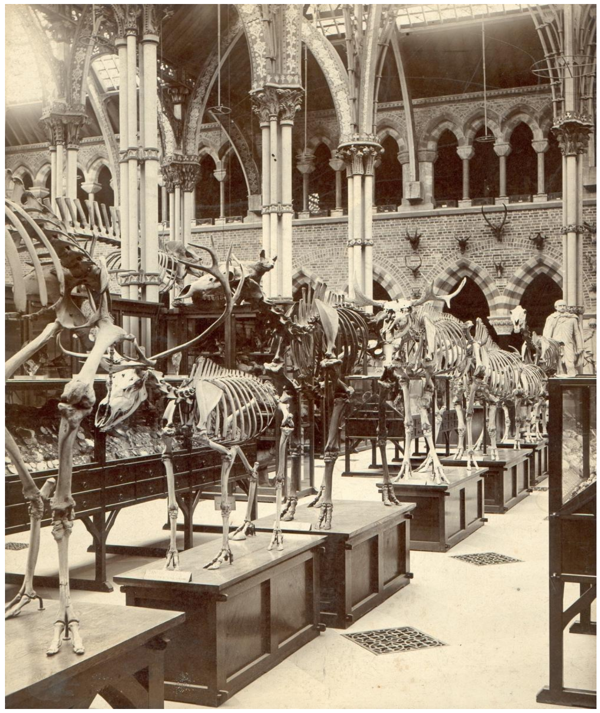

Figure 7. Central Court, looking east, Oxford University Museum, c. 1892 [57]

Figure 8. Sven Nilsson's aurochs skeleton, discovered in Önnarp, Sweden on display at the Lund University Historical Museum[58]

[57] "Court 5" print in archive room, box 4, folder 2, Oxford University Museum of Natural History.
[58] Photo by author. November 4, 2022, *Zoological Hall* Exhibit at Lund University Historical Museum, Lund, Sweden. For more on the exhibit at Lund University Historical Museum, see Dolly Jorgensen's

BEASTS OF BURDEN: BOS AS A (DIS)ORDERING INDEX

While Europe was dredging up and displaying its aurochs bones, the classification of the animal was undergoing revision. What made an aurochs an aurochs? Its taxonomic classification incidentally points to many of the difficulties incurred with determining its geological temporality. Initially, the aurochs was conflated with the domesticated cattle by Linnaeus; later, it would be confused with the European bison – a particularly interesting case of cultural memory loss following the aurochs' extinction in the seventeenth century, a topic which will be treated in Chapter 2. The fossils themselves, therefore, initially spoke in riddles to naturalists who were not sure whether they represented something alive or something extinct. Due to their broader evolutionary heritage as mammals, artiodactyls (a para-phyletic taxon classified by Richard Owen for its even-toed hoofs), and ruminants, the aurochs appeared in several debates over how best to chart geological time using fossils. Following Lyell's stratigraphical methods, geologists and paleontologists largely avoided classifying the periods of the past via mammals, preferring instead the ubiquitous presence of mollusks; the ruminants, and the genus *Bos* in particular had challenged attempts to periodize the past as early as Cuvier. Naturalists grappled with several issues that complicated the geological timeline of the aurochs, and thus problematized its use as a geologic marker. The first issue was the beast's own anatomy.

In order to conclusively identify *Bos primigenius* naturalists made use of the abundance of "detached teeth, vertebrae, ribs, and other bones of the skeleton – often mutilated and gnawed" that were distributed across Europe.[59] The genus *Bos* was recognized by the placement

research blog "The Return of Native Nordic Fauna," including video of the curators reconstructing the skeleton. https://dolly.jorgensenweb.net/nordicnature/.

[59] Richard Owen, *A History of British Fossil Mammals, and Birds* (London: J. Van Voorst, 1846), 496.

of its horn-cores (or the bony protrusions at the base of the keratin horns) and its “flat” forehead, “longer than broad.”[60] Indeed, “the various apparently trifling details” such as the construction of the teeth mattered greatly to not only classifying the animals, but also understanding the conditions of the animals’ life; a lesson that was passed down from Cuvier’s functional morphology.[61] With the skulls of an average-sized aurochs measuring a about a meter in length, and the span between their horn-cores measuring over one meter, skull measurements allowed for the best chance at a proper identification of some species within the genus, including of *Bos primigenius*.[62]

While the genus *Bos* and its species could sometimes be identified by the skull, discerning between the individual species often proved more difficult, as was lamented by Cuvier. In his paleontological studies he had established largely successful methods of comparative anatomical observation, and had found a dissimilarity in form within genera between the living and the fossilized species, which supported his broader idea of a catastrophic event that had expunged the extinct creatures in the recent past.[63] While he would leave the search for a cause of the catastrophic event to others, he no doubt viewed the sharp anatomical differences of living and fossil fauna as evidence of a boundary in the earth’s past. Yet one group, Cuvier observed, did not conform. The ruminants – mammals that digest via regurgitation – did not easily fall within the otherwise sharp anatomical divide between extinct and living. This became problematic as the faunal divide was increasingly used to identify a catastrophic

[60] Richard Lydekker, “Crania of Ruminants supplement” in *Memoirs of the geological Survey of India: Paleontologia Indica* I (Calcutta: Office of Superintendent of Government Printing, 1880), 95.
[61] Oscar Schmidt, *The Mammalia in their relation to Primeval Times* (New York: D. Appleton and Company, 1886), viii.
[62] Owen, *British Fossil Mammals*, 501-502.
[63] Rudwick, *Bursting,* 274. For more on the history of extinction thought, including catastrophism in Cuvier’s sense, see David Sepkoski, *Catastrophic Thinking: Extinction and the Value of Diversity from Darwin to the Anthropocene* (Chicago: University of Chicago Press, 2020).

boundary in the earth's past related to the undetermined Tertiary/Post-Tertiary divide. The problem posed by the ruminants deserved special consideration, and so Cuvier devoted an entire paper to it – his 1809 *Os fossils de ruminans* (*On the Fossil Bones of Ruminants Found in the Superficial Deposits*). The ruminants, including the genus *Bos,* were found fossilized in deposits alongside mammoths and other extinct animals, and yet while the latter exhibited striking anatomical differences as compared to their living analogues, the fossil ruminants bore an almost indistinguishable resemblance to living ruminants.[64]

Cuvier's solution to the ruminant puzzle was simple. He claimed that the naturalists identifying ruminants often relied on parts that would not preserve well in fossil form. Therefore ruminants, Cuvier claimed, truly did conform to his sharp extinct/extant divide, but suffered from a lack of clear evidence of the anatomical distinctions between the fossil and living forms simply because the evidence would not preserve.[65] Those problematic parts included the horns, from which only the bony interior horn-cores would fossilize, though the horns themselves would sometimes preserve under the right conditions, such as in peat bogs. Cuvier explained that ruminants, including *Bos,* "resemble each other so much that to characterize genera one has to use parts such as the horns, and these are not only altogether exterior, and consequently of little importance, but also vary – within the same species – in form and size, even to the point of being missing altogether in some circumstances, according to sex, age, and climate."[66] The horns being

[64] Rudwick, *Georges Cuvier,* 160.
[65] Georges Cuvier, *Os fossils de ruminans (On the Fossil Bones of Ruminant),* from Rudwick, trans., *Georges Cuvier,* 161.
[66] *Ibid.,* 161. In his 1796 work on the Megatheirum, which was translated into English, Spanish, and German, Cuvier outlined his idea of a natural hierarchy of animal functions, which in turn made specific anatomical parts more effective in determining animal relatedness and identification. He called this the "subordination of characters." Often the highest in the hierarchy were the anatomical structures associated with life-giving processes and not with the more superfluous or external characteristics of an animal. The horns and hoofs were therefore low on the hierarchy, as they were external traits and highly variable between individuals. Despite this, their rare preservation offered the best hope of demonstrating the

so morphologically plastic and not amenable to preservation made them far from the ideal way to identify species, yet with luck, preservation of skulls with horn-cores or even horns attached could afford positive identifications. The skull gave further insight to paleontologists such as Oscar Schmidt and Ludwig Rütimeyer, who classified sub-families of ox based on the form of the skull.[67] The skulls of oxen, according to Rütimeyer and Schmidt, were elongated, with an extreme rise at the back compared to their distant relatives, the Antelopes. The domesticated ox resembled the most extreme version of that skull. The development in individual cattle from the rounded Antelope-like skull of a calf into the adult elongated form was seen to corroborate "the most important proposition of our doctrine of descent: that the individual development is an abridged repetition of the historical development of the species."[68]

Towards the end of the nineteenth century, the methods for classifying *Bos* specimens were fully steeped in an evolutionary framing, grouping the animal forms in time in relation to their development from one another. As the refinement of the classification of various species of *Bos* was underway, so too was the placement of its fossil members in geological time. *Bos,* including the aurochs, was found amongst reindeer and mammoth remains within caves and strata that drew interest for their possible indication of a Tertiary/Post-Tertiary divide. Even as naturalists drifted from a biblical deluge interpretation of the perceived geological and faunal divide, those geologic periods retained their intrigue as evidence was increasingly found of human so-called "pre-historic" existence, pushing back the presence of humanity on the global

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differences between living and extinct ruminants, and therefore of supporting Cuvier's claims of a general faunal divide caused by a recent geologic catastrophe. See Rudwick, *Georges Cuvier,* 26, for a more detailed discussion on ruminants and subordination of characters.

[67] Schmidt, *Mammalia,* 176.

[68] *Ibid.,* 177. This being an example of recapitulation theory, or the biogenetic law, proposed by Ernst Haeckel in Germany in 1866 and summed by him as "ontogeny recapitulates phylogeny." For more, see Robert J. Richards, *The Tragic Sense of Life: Ernst Haeckel and the Struggle over Evolutionary Thought* (Chicago: University of Chicago Press, 2008).

stage to dizzyingly distant pasts. To those studying the aurochs, the question would be posed: what did the presence of *Bos,* and in particular *Bos primigenius* in deposits mean? Could animals like the aurochs be used to distinctly mark or help interpret the important Tertiary and Post-Tertiary history of the natural world and humanity?

Death, and more specifically, extinction, became potentially significant markers for different proposed ages of the geological past. Whether relative abundance of fossil genera was used, or the binary presence or absence of a specific fauna from a stratigraphic section, ages were defined by the dwindling numbers and ultimate extinctions of previously abundant fauna. In France, the use of fossil fauna to mark geological time was taken to the extreme. In 1861, Édouard Lartêt published his series of successive ages that corresponded to human prehistory, ending in an age dedicated to the presence of *Bos primigenius*: the Cave Bear age, the Mammoth age, the Reindeer age, and the Aurochs age.[69] The ages were predicated upon the dominance of those specific animals, found in the fossil records of Europe. His argument for the divisions, however, was not widely taken up across the Channel. As historian Chris Manias has shown, in Britain, Danish antiquarian Christian Jürgensen Thomsen's own 'Stone, Bronze, and Iron' material age demarcations were favored instead in discussions of prehistory.[70] In part, this was due to the unreliable chronological ordering of the animals. As geologist William Boyd Dawkins put it in his 1874 work, *Cave Hunting,* a cave might be relegated to the reindeer age, for example, because more of those animal fossils were found there, but one could not so easily set it apart from a purported mammoth age: "the division has been rendered worthless for

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[69] Manias, "Contemporaries of the Cavebear," 1; Édouard Lartêt, "Nouvelles Recherches sur la Coexistence de l'Homme avec des Grands Mammifères Fossiles Réputés Caractéristiques de la Dernière Période Géologique,*''Annales des Sciences Naturelles, Quatrième Série: Zoologie* 15 (1861): 176–253.
[70] Manias, "Contemporaries of the Cavebear," 21. Thomsen's 1836 work *Ledetraad til nordisk Oldkyndighed* would be translated to English for publication in 1848.

chronological purposes, by the fact that both these animals [reindeer and mammoth] inhabited the region north of the Alps and Pyrenees at the same time."[71] In the example of the reindeer-abundant cave, the fossils could be understood in light of the predator-prey interactions that resulted in the death of the animals: "[a reindeer] would be more easily captured by a savage hunter, than the mammoth, wooly rhinoceros, cave-bear, lion or hyaena."[72] Buckland had made similar considerations in his discussion of the Kirkdale hyena den find. Some of the larger animal remains, from hippos, for example, were likely not dragged in by the hyenas, he reasoned. The conditions of death and displacement of the remains resulted in a sampling bias of the fossil record: not everything alive, nor abundant even, would be preserved according to its living abundance. As a result, a cave described as part of the 'reindeer' age might instead be rich in reindeer due to the accessibility of the animals as transportable prey of early humans or hyenas. It was therefore more a measure of relative death than an absolute signifier of chronological time.

Still, Lartêt was not alone in his attempts to use mammals to order the recent geological past and its fossil contents. Even his critics sometimes sought better ways to utilize mammals to characterize geological divisions. The German-Russian naturalist Johann Friedrich von Brandt, for example, considered the faunal ages of Lartêt in his paper "On the Geographical and Geological Distribution of the Reindeer, the Bison, and the Aurochs," first communicated to the Imperial Academy of St Petersburg, and later circulated in the Proceedings of the Imperial Geological Institute of Vienna, and the *Quarterly Journal of the Geological Society of London* in 1867.[73] Brandt suggested that the limits between the "palaeontologico-chronological periods" of

[71] Boyd Dawkins, *Cave Hunting,* 352.
[72] Boyd Dawkins,*Cave Hunting*, 352.
[73] J.F Brandt, "On the Geographical and Geological Distribution of the Reindeer, the Bison, and the Aurochs" relayed by Count "M." in *Quarterly Journal of the Geological Society of London* 23 (1867).

Lartêt were not well-defined, and as such could not really be useful to geologists and paleontologists.[74] Instead, he suggested a five-period demarcation of the Tertiary faunas, in which the fourth period would be characterized by the extinction of the aurochs and *Cervus megaceros,* or the famed extinct Irish elk, in Central Europe. That period would end as late as the mid-sixteenth century.[75] The fifth period, "the present period," would be characterized by the impoverishment of wild mammal species driven by mankind.[76] For Brandt, then, relative mammalian abundance and extinction could be used to order chronological geological time, but to hang an entire age's definition on one species was impractical.

Could there be an 'Aurochs age' then? To make any kind of reliable judgments about the timespan of the aurochs and the relative age of fossil beds in which it may be found, naturalists took stock of the earliest recorded presence of *Bos primigenius* in geological deposits, and the latest appearance of the animal in the fossil record. Its extinction, however, was very clearly not a simultaneous global event. The different fossils constituting different sites across Europe in which the aurochs was found, suggested that it had been extirpated, or gone locally extinct, at different times in the past. In the Kitchen Middens of the Danish country the remains of "beaver, the seal, the red-deer, the roe, the wild swan, the penguin, and the urus [or aurochs] – the two last in very considerable quantities" were found. This admixture suggested familiar living species, as well as extinct. And yet, in other deposits that were generating interest because of their much older dates, the expected clearly extinct fauna such as the mammoth – those "gigantic mammalia of extinct species" – were not found in either the Swiss or Scandinavian deposits; the aurochs was, but it alone could not extend the date of those beds reliably backwards as it seemed to have

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[74] *Ibid.*
[75] *Ibid.*
[76] *Ibid.*

also existed at least as late as the time of Caesar.[77] Its presence just as well suggested that the sites were much younger than previously believed. The local extinctions of the aurochs across Europe were staggered in time, and therefore, defining an age by the presence or absence of the animal in fossil beds would make it impossible to correlate geological layers across Europe based on the binary presence of that animal.

In yet another attempt to rely upon mammalian fauna to order the geological past, William Boyd Dawkins created a characterization in 1880 similar to Brandt's, in which he relied upon mammals to classify the Tertiary beds.[78] His stated impetus was that the classification of the Tertiary based on the percentages of mollusk fossils and living forms in each division of the Tertiary no longer matched scientific knowledge on the subject. The Mollusca, further research since Lyell's writings had shown, had not changed "with sufficient swiftness to allow of their being used to classify the later Tertiary divisions." Nor, according to Boyd Dawkins, had the fossil invertebrates in general "changed fast enough to mark the later Tertiary divisions."[79] Those organisms had become evolutionary stable, in a sense, having "passed through their most important biological changes before the beginning of the Tertiary."[80] Mammals, therefore, taken widely in the nineteenth century to be the "highest of all" creatures on the hierarchy of forms, would have undergone their "specific changes" more recently and in a manner "sufficiently rapid for the purposes of classification."[81] Their recent and relatively rapid evolution promised a finer

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[77] "Review of *The Antiquity of Man,"* in *The Times,* April 9, 1863, in "Scientific Pamphlets," Library and Archives, Natural History Museum, London.
[78] William Boyd Dawkins, "On the Classification of the Tertiary Period by Means of the Mammalia," *Quarterly Journal of the Geological Society of London* 36 (1880).
[79] *Ibid.,* 380.
[80] *Ibid.*
[81] *Ibid.*

resolution of change in the geological record, and therefore, to Boyd Dawkins, a potentially valuable "yard stick" with which to demarcate the past.

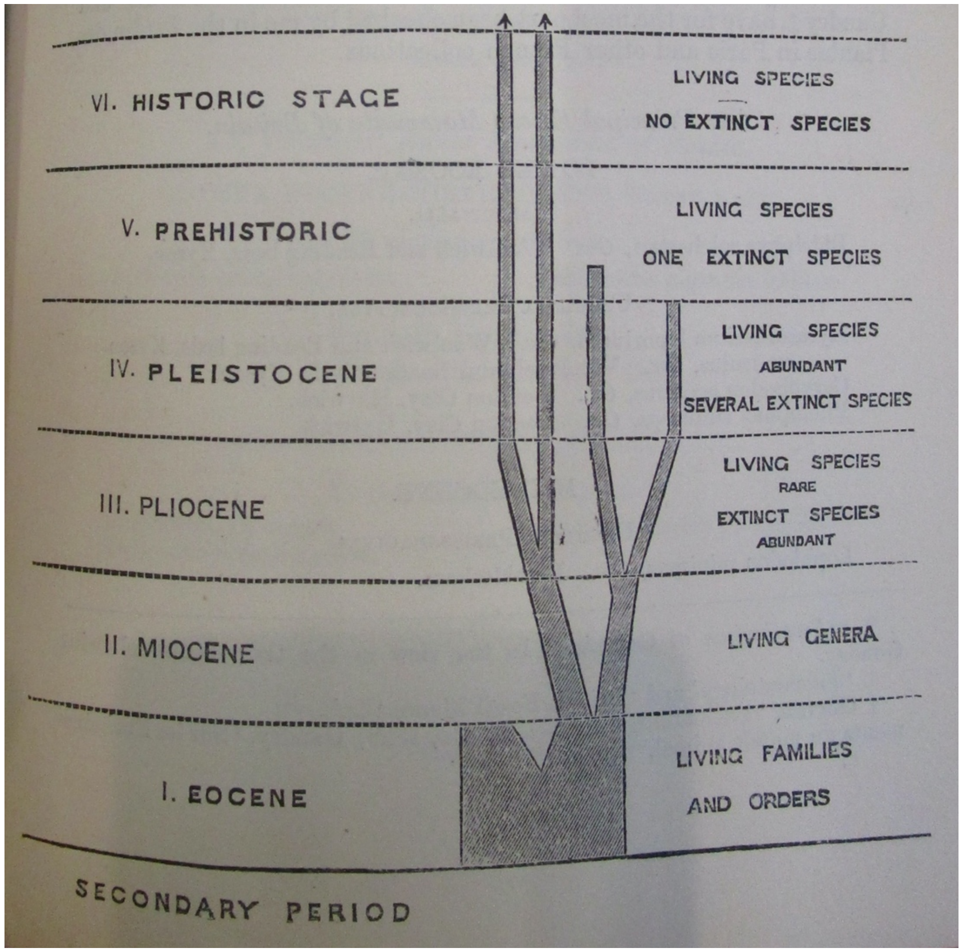

Figure 9. Diagram of the Tertiary Period in Boyd Dawkins, "On the Classification of the Tertiary Period by Means of the Mammalia"[82]

For his classification, Boyd Dawkins leaned on both relative abundance of living and extinct species, as Lyell had, but also pinned the presence or absence of certain taxonomic entities to his demarcated geological periods. Unlike Lyell, he constructed his classification around mammals. His research indicated that the genus *Bos* appeared first in the Pliocene, and the aurochs first appeared in the early Pleistocene, remaining abundant during what he classified

[82] Boyd Dawkins, "Classification of Tertiary," 381.

as the Mid-Pleistocene in Britain. The aurochs was "comparatively abundant in Prehistoric Britain, and it was hunted by the Neolithic men who excavated the chalk for the sake of the flint in Cissbury Camp."[83] Boyd Dawkins noted that it survived into at least the Bronze age, a demarcation of material culture used to periodize "Prehistory," borrowed from Christian Thomsen, but the aurochs was "probably exterminated" in Britain before the Prehistoric period ended.[84] Boyd Dawkins sought to update the classifications of the Tertiary beds that had largely been unchanged since Lyell, and yet his critics argued that his proposed classification via mammals did not actually change the temporal chronology or divisions that had been accomplished using mollusks. Some critics further argued that his system was not useful for charting the full geological past. The distinctions between, for example, the Historic and Prehistoric faunas in Boyd Dawkins' system were due not to climate-induced extinctions, but rather the destructive hand of mankind, they argued.[85] The difference in cause of extinction mattered to Boyd Dawkins' critic, as climate-driven extinctions could be an applicable indicator of faunal changes across the history of life, which could be expected elsewhere in the fossil record. Mankind could not, however, be found causing extinctions in the Jurassic. Mammals, it seemed, were only useful in so far as their recency afforded a granular view of change in the Tertiary fossil record; they were also, therefore, not able to be used to characterize earlier periods, as mollusks might be.

Richard Owen had previously focused on several particular issues related to mammalian fossils in Britain. He recalled in 1846 the "new and strange" mammalian fossil forms obtained by Cuvier from the Parisian chalk deposits, citing them as proof that the Eocene – classified then as

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[83] *Ibid.,* 402. Thomsen's demarcations of the Prehistoric period will be treated more in Chapter 2. The Bronze age was the middle of his three-age system.
[84] *Ibid.*
[85] *Ibid.* p 404.

the earliest layer of the Tertiary – had been a period of mammalian abundance. Because of their distinct forms, different, as Owen said, from "all known existing quadrupeds," they provided a potential characteristic of Eocene beds, from which the London clay was matched to the Paris basin in time.[86] Towards the end of the Eocene beds however, the British fossil record lost "every trace of the Mammalia of that remote period," only to "serve as the theatre of life to another race of warm-blooded quadrupeds" in the subsequent Miocene strata.[87] Fossils formed after the Miocene were found in the peat bogs and "the dark recesses of the caves" of Britain, which had once operated as "lurking-places for the predaceous species, and as charnel-houses to their prey."[88] While difference in fauna helped locate the Eocene/Miocene divide across regions in Europe, those post-Miocene mammalian fossils were not so easily used. Owen recognized that of all the mammal fossil remains of Britain, the genus *Bos,* and in particular the two giant oxen that were still living when the Romans "first penetrated the wilds and forests of uncivilized Europe," straddled any neat divide between the Tertiary and Post-Tertiary, making them essentially useless to indicate the geologic transition.[89]

As a mammal, then, and one that was often cited in debates about when to place the sub-divisions of the Tertiary, the aurochs seemed an unlikely candidate to serve as a reliable index fossil, indicating a particular slice of time wherever it should be found. Even more so, the extinction timeline of the aurochs made it all the more difficult to date the beds from which it was excavated. Its presence could suggest early Pleistocene, or well into the historic period depending on the location in Europe. In Britain, for example, the aurochs was seen to have gone extinct locally during "prehistoric" times, though it persisted for much longer in the forests of

[86] Owen, *British Fossil Mammals,* xvii.
[87] *Ibid.,* xxi.
[88] *Ibid.,* xxiii.
[89] *Ibid.,* 498.

central Germany. The aurochs, which had inspired poets and impressed Caesar, had also lived amongst extinct mammoths, rhinoceros, boars, and early horses according to the British fossil record, and then, as late as the seventeenth century, went extinct.[90] This late extinction, particularly when compared to its deposit cohabitants, including the mammoth, complicated what the presence of *Bos primigenius* in a deposit meant for its age. According to the fossil and historical record, *Bos priscus* – or the European bison – as well as the European aurochs, *Bos primigenius*, had outlived their Middle Tertiary cohabitants, such as the mammoth. Added to this, naturalists such as Owen and Boyd Dawkins considered a possible early extirpation of the aurochs in Britain, which might have prevented its local domestication and suggested its own timescale across Europe made it far too challenging to reliably use as a temporal signal in correlating strata across Europe.

Still, interest in the aurochs fossils persisted in attempts to periodize those divides of the Tertiary to the post-Tertiary, and the prehistory ages to the historic. Aurochs remains were also being found next to those of a quite familiar organism – that of the genus *Homo.* According to evidence from Britain and Germany, *Bos primigenius* had lived contemporaneously with early humans. A particularly tantalizing aurochs find from a German bog exhibited a wound on two of its vertebra, leaving a hole that was the perfect fit for an ancient stone javelin collected in Germany.[91] Richard Owen recognized that in "interpreting these evidences of primeval hostility" the "pointed weapons of the Ox and Deer-tribe," meaning their horns, and their "combative instincts" also needed to be considered as causes of the wounds.[92] Lartêt's own system that had boasted an "Aurochs age" was predicated in part upon early human hunting encounters with such

[90] *Ibid.,* 503-506.
[91] *Ibid.*, xxxiii.
[92] *Ibid.*

beasts. It was becoming clear that the age of the aurochs potentially coincided with humanity at a very ancient date. Additional startling discoveries of *Bos* amidst tools in 1859 in the Brixham Cave of Devonshire threatened to push back the timeline of humanity, making it coincide with the existence of now-extinct beasts. Charles Lyell synthesized the evidence for humanity's new timeline in his 1863 *Geological Evidences of the Antiquity of Man.* The Brixham Cave added to the "facts formerly adduced in favour of the co-existence in ancient times of Man with certain species of mammalia long since extinct."[93] Those facts had been generated by finds in other parts of Europe, where "the bones of Man or the works of his hands" had been found in the company of extinct "hyeana [*sic*], bear, elephant, or rhinoceros," and also oxen of a confused date.[94] The aurochs fossils were dredged up in the middle of a temporal mess: evidences of early humans, extinct mammoths, possible ice ages, if not deluges to those still holding on to a biblical account. Their fossils, therefore, were dredged up into a conceptual space of several competing schemes for measuring the past at different depths: relative geological measurements of time and the difficulties of correlating those between locations; the archeological and antiquarian divides of the prehistoric based upon material culture; and the most recent "historical" period of written record. These depths of past and their attendant recorded evidence were undergoing their own methodological reviews, and the aurochs fossils emerged at the boundary in which they all met. Its spillover between records of the past and attempts to demarcate saw it brought into attempts to order time, even as it was recognized as a poor means to do so.

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93 Lyell, *Antiquity of Man,* 2.
94 *Ibid.*, 1.

CONCLUSION

What then did the aurochs fossils reveal in nineteenth-century geology about time – its own or generally? To some, the aurochs was one of many now-extinct fauna that served as indicators of a post-glacial world. The relation of the aurochs and its deposit cohabitants to their conditions, climate, and environment became increasingly helpful for rendering a chronology of its deposits. In this view, the force that gave the earth's history its direction was not an ingrained teleology within living things; rather, it was changing physical conditions to which, in a post-Darwin world, organisms were seen to adapt.[95] In fact, even Brongniart's early classification of the Tertiary had relied on fossil flora, not fauna, as plants depended more on their external environments, and therefore would be a more reliable indicator of the climate changes over earth's history, to which plants, and subsequently animals were merely respondents.[96]

By 1874, Scottish geologist James Geikie synthesized prior discussions of the classification of the Tertiary and Post-Tertiary, as he examined the "post-glacial and recent deposits" of Europe to construct a history of Britain during the Tertiary and Post-Tertiary. In *The Great Ice Age and its Relation to the Antiquity of Man,* Geikie drew on the *Eiszeit,* or Ice Age, theory of Louis Agassiz and Karl Schimper, as well as on the evidence that proponents of the theory had amassed including traces of ancient glaciers.[97] In concert with the paleontological evidence of a catastrophic geological divide put forward by Cuvier, the hypothesized glacial theory suggested that a great glacial age at the close of the Tertiary had expunged the large quadrupeds that once roamed Europe. Evidence of that glacial catastrophe could be used to help

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[95] See Bowler, *Fossils and Progress,* 12 and Chapter 2 for further discussion on the relation of conditions and driving forces in the history of life.
[96] Bowler, *Fossils and Progress,* 25.
[97] Tobias Krüger, *Discovering the Ice Ages* (Leiden: Brill, 2013), 244-245. Krüger also discusses the reception of the *Eiszeit* theory in Britain.

set a geological clock across Europe. In presenting the evidence for the glacial epoch, Geikie referred to *Bos primigenius* in a manner that reflected the previous debates. He described the Scottish till – clay and boulder mixtures deposited by glaciers – as "remarkable from having yielded an imperfect skull of the great extinct ox (*Bos primigenius),* and remains of the Irish elk."[98] In the alluvial beds of Forfarshire *Bos primigenius* was also found, and, as Geikie noted, it was "now extinct."[99] His work was riddled with similar references to the aurochs that echoed earlier conclusions and debates.

The most significant appearance of *Bos primigenius* in Geikie's work, however, was its brief mention in a chart at the back of the book. The chart outlined the chronological progression of the Post-Tertiary period, from a great glacial epoch, to the post-glacial period, and finally to the Recent. From the post-glacial period, *Bos primigenius* was listed alongside the "relics of man," as one of the "recent and extinct or no longer indigenous mammalia" used as a characteristic marker of the post-glacial deposits.[100] Its presence in the list spoke to more than just its presence in the deposits. Its inclusion was a reflection of decades of discussion that showed *Bos* to be fraught with obfuscating temporalities. Yet, Geikie singled it out as one of four characteristic fossils of the Post-Tertiary, and post-glacial, fauna of Britain in his chronological classification of the geological past.

The aurochs indicated a faunal divide to some, or, as with Geikie, hinted at deeper ecological and climate-driven changes that themselves could be used to mark time. To others, though, the challenges imposed by the aurochs' successive extirpations and migrations that

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[98] James Geikie, *The Great Ice Age and its Relation to the Antiquity of Man* (London: W. Isbister, 1874), 161.
[99] *Ibid.*, 346.
[100] *Ibid.,* 516. Geikie refers to the Post-Tertiary in its entirety as the "Quaternary," as a rough equivalent to Lyell's "Pleistocene." He further divides the Quaternary into a Glacial Epoch, comprised of alternating glacial and interglacial warm periods, and a Recent, post-glacial period. See Note A in his appendix, 511.

resulted in an inconsistent appearance in fossil beds across Europe demanded that it be viewed processually: the aurochs itself challenged the possibility of creating well-defined limits between periods, despite Lartêt's attempts, as it spilled over the barriers between different geological and evolutionary characterizing events.

The European aurochs fossils suggested that the deep past, which was "bursting" at the seams through geological discovery after discovery, was not just deep; it was layered. It demanded and evoked many layered ways of knowing its temporalities, based upon human material culture records, fossil fauna, and climate evidence. To achieve an ordered linear chronology, sorting out the mess of characteristic indicators of time, and reconciling differing methods for periodizing that time was paramount.[101] It was in trying to accomplish that ordered time, that temporal units might noticeably spill out of their demarcated times. The aurochs was one possible unit.

The temporal layers seen in this chapter will not be readily resolved as the story develops in this thesis. In fact, they will grow. From here, the mess inherent in ordering ways of thinking about time in biology and society will be added to, and further intertwined. External timescales in which the aurochs did not quite fit, including measures of the geological and human past, would be correlated across continents and used to measure societal development. The animal's own internal timescale was similarly not fixed: it was, after all, a changing evolving organism, at times evolved or changed by human hands. In the next chapter, the relationship between the fossil records discussed here and the historic written record of the aurochs will be traced. That is,

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[101] This mess applies to non-linearity as well. As Peter Bowler has shown through his treatment of Lyell, Buckland, Cuvier, Darwin and others, geologists and paleontologists did not necessarily have a progressionist view of the history of life. Bowler, *Fossils and Progress,* 16. If the Whig historians of the nineteenth century can be comfortably charged with thinking about a directional temporality, according to Bowler, we should be cautious about applying the same unidirectional linearity to the temporality discussed by historians of the earth's life.

in Boyd Dawkins temporal scheme, the evidence of the aurochs that stems from the "historic" rather than "prehistoric" period. To Dawkins, the "prehistoric period" concerned "all the events which took place between the Pleistocene age on the one hand and the beginning of history on the other. To it belong most of the alluvia and the peat-bogs, as well as the contents of certain caverns characterised by the presence of the wild mammalia now living in Europe, and of the wild or half-wild animals which had escaped from their servitude to man."[102] The reconstructions of *Bos primigenius* derived from the fossils, such as those from Kirkdale, would speak to the prehistoric period. But the aurochs would come to be supplemented by a very different record – that of the historical: paintings, writings, and etymological research would all reveal how much historical overlap the living aurochs once had with humanity. The next chapter introduces the historical aurochs, and tells the story of how the historic and prehistoric aurochs and their different timescales were brought together under one name.

[102] Boyd Dawkins, *Early Man in Britain,* 247. He cites Lubbock, *Prehistoric Times,* and Evans, *Ancient Stone Implements,* for the demarcations of the prehistoric based on material tools used by the cultures of that time.

Chapter 2: Historicizing the Aurochs in Human Time

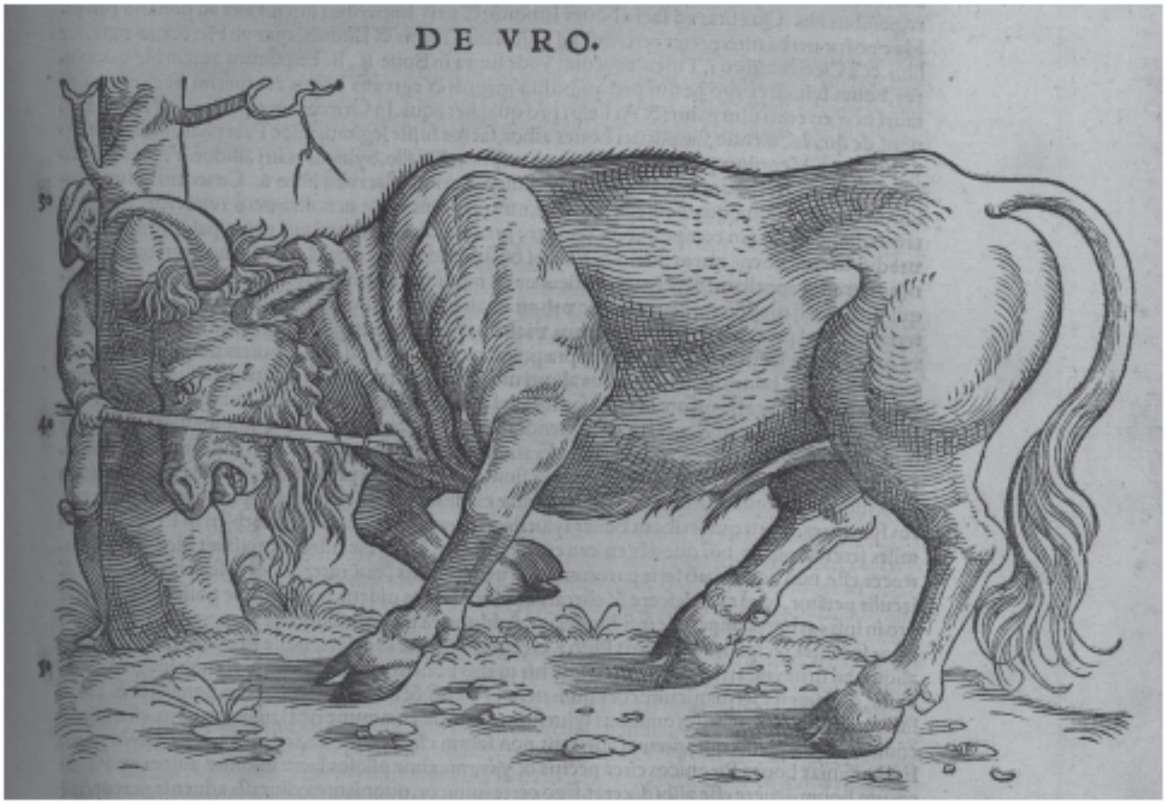

Figure 10. Aurochs woodcut in Gessner, *Historiae Animalum Liber I de Quadrupedibus viviparis* (Zurich: Christoph Froschauer, 1551), 157. [1]

In 1890, Richard Lydekker, esteemed British naturalist who wrote extensively on the natural history of present-day mammals and their fossil ancestors, penned a short review for *Nature* of William Temple Hornday's volume *The Extermination of the American Bison.* The volume was in part a memoir, reflecting on Hornday's experience as a member of the 1886 Smithsonian Institution Expedition to acquire bison specimens for the National Museum of Natural History "before," as Lydekker noted in his review, "it became too late."[2] By 1886, the

[1] Reprinted in Grażyna Jurkowlaniec and Magdalena Herman, eds., *The Reception of the Printed Image in the Fifteenth and Sixteenth Centuries: Multiplied and Modified*, Routledge Research in Art History (New York: Routledge, Taylor & Francis Group, 2021).
[2] Richard Lydekker, "The Extermination of the American Bison," *Nature* 42, no. 1070 (May 1, 1890), 11. Hornday was the Chief Taxidermist at the U.S. National Museum. See Mark V. Barrow, Jr., *Nature's*

American Bison's range had been drastically reduced, and its numbers were dwindling. While Lydekker's review charged the "crass stupidity" of the animals as a contributing cause of the herds' disappearances, the main culprit according to Hornday was two-fold: the completion of the major railway systems in the United States, and in particular the Union Pacific Railway in 1869 which split and reduced the range of the animals, and the hunting practices of the white settlers who sought to meet demand for "buffalo-robes" and other post-mortem bison keepsakes.[3] "Still-hunts" were particularly deadly; in these the hunting party would slowly approach a herd, lie down, and shoot the leader, and then at the herd's inspection of the dead bison, would proceed to shoot the rest one-by-one. The rather abrupt histories of the herds once separated by the railways created a fervor for preservation of the animals, inspiring the creation of wildlife protection measures such as committees to prevent extinction and protected parks, as well as the documentation of the animals for posterity.[4] The specimens collected by the 1886 Expedition were stuffed and displayed in the Smithsonian's Natural History Museum, while Hornday's book compiled a record of the human-driven near-extinction of the bison. Lydekker, in the conclusion to his book review, stressed the importance of such memory tokens: "we have to congratulate the author on having brought together such a number of facts in relation to the extermination of the bison, which, if they had not been recorded while they were fresh in men's memories, would probably have been entirely lost."[5]

Ghosts: Confronting Extinction from the Age of Jefferson to the Age of Ecology (Chicago: University of Chicago Press, 2009), 108-124, for more on Hornday's work on saving the American bison. For more on the exhibition that resulted, see Karen Rader and Victoria Cain, *Life on Display: Revolutionizing U.S. Museums of Science and Natural History in the Twentieth Century* (Chicago: University of Chicago Press, 2014).

[3] Lydekker, "Extermination of American Bison," 12.

[4] Barrow, Jr. *Nature's Ghosts,* recounts the history of animal preservation in the US. Chapter Four discusses the bison policies in particular.

[5] Lydekker, "Extermination of American Bison," 13.

The ability to document the nature of the animals, as well as the nature of their near extinction, was indeed fortuitous. Eye-witness records of lost species, or those created while "fresh in men's memories," still hold a captivation today.[6] While they do add a clear salience to something otherwise lost, historical records of animals that lived amongst humans are not without some errancy. Lydekker's review of Hornday's book exemplifies this promise and fallibility of those distant "eyewitness" historical accounts of organisms past. While lauding the direct account of the bison written by Hornday, Lydekker inadvertently waded into a centuries-long misunderstanding about the aurochs that occurred after its wild extinction, and was perpetuated to much confusion into the nineteenth century in written accounts of historical encounters with the animal.

Lydekker's brief review in *Nature* is a curious one. He lamented over several pages the process by which the bison's numbers were reduced, and lauded Hornday's attempts to keep the memory of those animals and events alive through stuffed specimen and written word. And yet, his brief mention of another animal by way of comparison to the American bison committed a mistake of forgotten memory that had been a source of confusion for centuries. Lydekker wrote about Hornday's book, "we have a full description of the general characters of the American bison, and the points by which it is distinguished from its European congener, the Lithuanian aurochs."[7] Lydekker's reference to the "Lithuanian aurochs" attracted the attention of Alfred Newton, Cambridge's first Professor of Zoology and Comparative Anatomy. Newton would go

[6] Errol Fuller's *Lost Animals: Extinction and the Photographic Record* (London: Bloomsbury Publishing, 2013) demonstrate the distinct emotional power that photographs of extinct animals can have. The images draw their unique power, as Fuller argues, more than a painting could have, from their eye-witness capture of something lost.
[7] Lydekker, "Extermination of American Bison," 12.

on to correct Lydekker in a letter to the editor of *Nature* just seven days later: the animal Lydekker referred to was actually a "Bison not Aurochs."[8]

Lydekker had used the name "Aurochs" in his review to refer to an animal that was actually a European Bison, also known as the *Wisent.* Perhaps he could be forgiven that misnomer, especially given its brief and unimportant appearance in a review focused on the more pressing issue of the American bison's plight. To Newton, however, the mistake was worth the trouble of correction. He clarified his critique as a correction of hypocrisy on Lydekker's part: Lydekker at one point in his review excused his own use of the term 'buffaloes' in reference to the bison, as "[Hornday] frequently employs this American misnomer for the bison."[9] Newton, however, turned the charge of misnaming around on Lydekker: "In his excellent article on the extermination of the American bison," wrote Newton in reply, "[Lydekker] remarks on the transatlantic practice of miscalling that animal a 'buffalo'; but on the next page he writes of 'its European congener the Lithuanian aurochs.' This is to perpetuate a common error at least as bad."[10] What was the "error" to which Newton referred, and why did he assert that its presence in Lydekker's short review was "common"? The name aurochs had, after the animal's extinction in the seventeenth century, been repurposed for the European bison, in what Cis Van Vuure has called a process in which "the memory of this wild bovine animal [the true aurochs] had become almost completely blurred by Linnaeus' time."[11] Lydekker's mistake, therefore, perpetuated the exact thing he praised Hornday for avoiding, when Hornday had retained cultural memory through his book on the extinction of the American bison.

[8] Alfred Newton, "Bison not aurochs," *Nature* 42 (May 8, 1890), 28.
[9] Lydekker, "Extermination of American Bison," 11.
[10] Newton, "Bison not aurochs" (May 8, 1890), 28.
[11] Van Vuure, *Retracing the Aurochs,* 31.

This chapter introduces the aurochs through its historical record, and where that record failed. The aurochs reportedly went extinct in the wild in the seventeenth century, a fate that the American bison narrowly escaped. In 1627 the last wild aurochs reportedly died in the Jaktorów forest in Poland. But even before its extinction, confusion over its existence abounded. In the historical record, as opposed to the fossil, the aurochs was described through its relation to humans, its ferocity and behavior, and its appearance in the flesh. In those records it was often called "Urus" in Latin, since at least Caesar's *Commentarii de Bello Gallicos* (his account of the Gallic Wars).[12] The story in this chapter is in part one of loss; the cultural forgetting of a species' existence and the subsequent confusing misnomers that had to be sorted in the wake of its wild extinction. While the aurochs was conflated with the European bison in written accounts, it was also not clear for much of the nineteenth century that the fossil *Bos primigenius* was the same as the "Urus" described in historical accounts. In this chapter, the names given to the aurochs and its kin are interrogated, so it is best to state at the outset which names will refer to which organisms in the chapter, to then highlight where the historical sources use them differently. The historical sources in this chapter use "Urus" to largely refer to the aurochs as it appeared in historical written records. They use "aurochs" less consistently: either to refer to the European bison, or to the aurochs that is the focus of this thesis. To differentiate between those uses of "aurochs," the scientific name *Bos primigenius* will be used to clarify when an author used "aurochs" to refer to the animal that is the focus of this thesis, or else a clarifying phrase such as "true aurochs" will be given. The chapter begins with an introduction of the "Urus" of historical accounts, and the uses of the word "aurochs" to refer to the European bison in Early Modern writings through the lens of the nineteenth century attempts to sort out the mess and draw out an

[12] Caesar is cited under "urus" in the Charlton T. Lewis and Charles Short, *A Latin Dictionary* (Oxford: Clarendon Press, 1879).

accurate description of the aurochs from the written record. It concludes by tracing how the *Bos primigenius* and the Urus were eventually brought together by William Boyd Dawkins, shown to be the same organism whose timespan stretched from Pleistocene fossil to recorded history, spanning the early days of human development to its Early Modern extinction.

The line between prehistory and history that was introduced in Chapter 1 can be understood as a line between different records from different depths of the past, and each had their own burdens to overcome. Despite the promise of the "eyewitness" records afforded by the aurochs' seventeenth-century wild extinction, fallibility within the record readily perpetuated itself. When the historical "Urus" was aligned with its fossil counterpart as an extinct animal distinct from the bison, the temporal records of the aurochs grew, and its study expanded to include new timespans.

Ultimately, Lydekker's mistake, as Newton pointed out, was not one author's misnomer; rather, it signaled a debate spanning centuries about the very existence of a wild ox unique from the European bison. Lydekker would be dragged into the debate by Newton, with several more back-and-forths in the Letter to the Editor section of *Nature.* Their short, published discourse would draw on Boyd Dawkins, as well as two nineteenth-century interlocutors who did much to sort out the historical mess of the aurochs and whose works continue to be authorities on the aurochs' appearance and demeanor, Georg Gottlieb Push, and August Wrześniowski. That mess of taxonomic naming, classical references, eye-witness accounts and specimens, Early Modern image recycling, and etymology would expand the room for confusion around the aurochs and its existence from the 1500s to the end of the nineteenth century.

URUS, AUROCHS, OR BISON?

The aurochs created quite a bit of confusion following its demise. Cis Van Vuure, in his thorough 2005 review of the aurochs, has compiled a rich outline of the historical confusion about the existence of the animal. But how that confusion was created, perpetuated itself, and was ultimately resolved benefits from more attention, especially as it relates to the different timescales of studying the aurochs and the risks of those records. How does an animal go from an intimate existence with humans, recorded and celebrated in classic texts and images, and then become forgotten during its life and following its extinction? The wild extinction of the aurochs was not just a paleontological problem, it became one that showed the frailties and misdirection inherent in early tracts on the animal. Those confusions were all in a name: what was the animal in fossil and written record? An aurochs, an urus, or a bison?

In the early nineteenth century, as aurochs fossils were dredged up, appearing in museums and natural history collections, the aurochs received its lasting binomial scientific name, *Bos primigenius*. The taxonomic naming of the aurochs signaled the questions that would drive debate until the end of the nineteenth century: had the aurochs skeletons truly belonged to a unique species, or were they remnants of only one wild bovine still living in Europe, the European bison? Linneaus himself, in his *Systema naturae,* had classified the "urus" under the name *Bos taurus,* denoted for European domesticated cattle, implying the aurochs and domesticated cattle were of the same species.[13] But in the nineteenth century, his nomenclature would fall by the wayside. The complete skeleton on display in Jena led naturalist Ludwig Heinrich Bojanus to classify the skeleton as belonging to a new species: *Bos primigenius*

[13] Carl von Linné, *Systema naturae: per regna tria naturae. I. Regnum animale. Editio decima* (Holmiae: Impensis Direct. Laurentii Salvii, 1758), 71. For further discussion see Van Vuure, *Retracing the Aurochs,* 31.

antediluvialis.[14] The 'andiluvian' (or, before the flood) added to the species name signaled Bojanus' belief that the animal had long been extinct, and was not the same as the "urus" described as existing alongside the European bison in historic records by the likes of Caesar. In fact, Bojanus discounted Linneaus' previous classification of the "urus" as *Bos taurus,* because he thought "urus" had referred to the European bison in Linnaeus' text.[15]

The taxonomic classification of the aurochs from the mid-eighteenth century on, therefore, reflected the state of knowledge about the very existence of the animal as a distinct species, as well as its timeline. For Linneaus, the aurochs, or "urus" referred to in classical texts, was simply a wilder form of the same species as domesticated cattle, *Bos taurus.* For Bojanus, the aurochs, *Bos primigenius,* was something else entirely that had nonetheless become extinct so long ago that any historical references to an "urus" or "aurochs" actually referred to the European bison and not his *Bos primigenius*. The historical record was therefore either tantamount to evidence of a separate species' existence, or rife with misnomers for the one wild bovine that had unquestionably lived amongst historic humans, the bison. In 1840, Georg Gottlieb Pusch entered the debate, characterizing the two camps that had been opposed at the end of the eighteenth and early nineteenth century.[16]

[14] Ludwig Heinrich Bojanus, *De uro,* 411-478.
[15] Van Vuure, *Retracing the Aurochs,* 31-32. More naming changes would come later: Gentry et al, "Naming of Wild Animal Species." In the 1990s the scientific name was changed back to *Bos taurus* to abide by naming priority conventions. In 2003, however, it was turned back to *Bos primigenius* after criticism.
[16] Van Vuure, *Retracing the Aurochs,* 31.

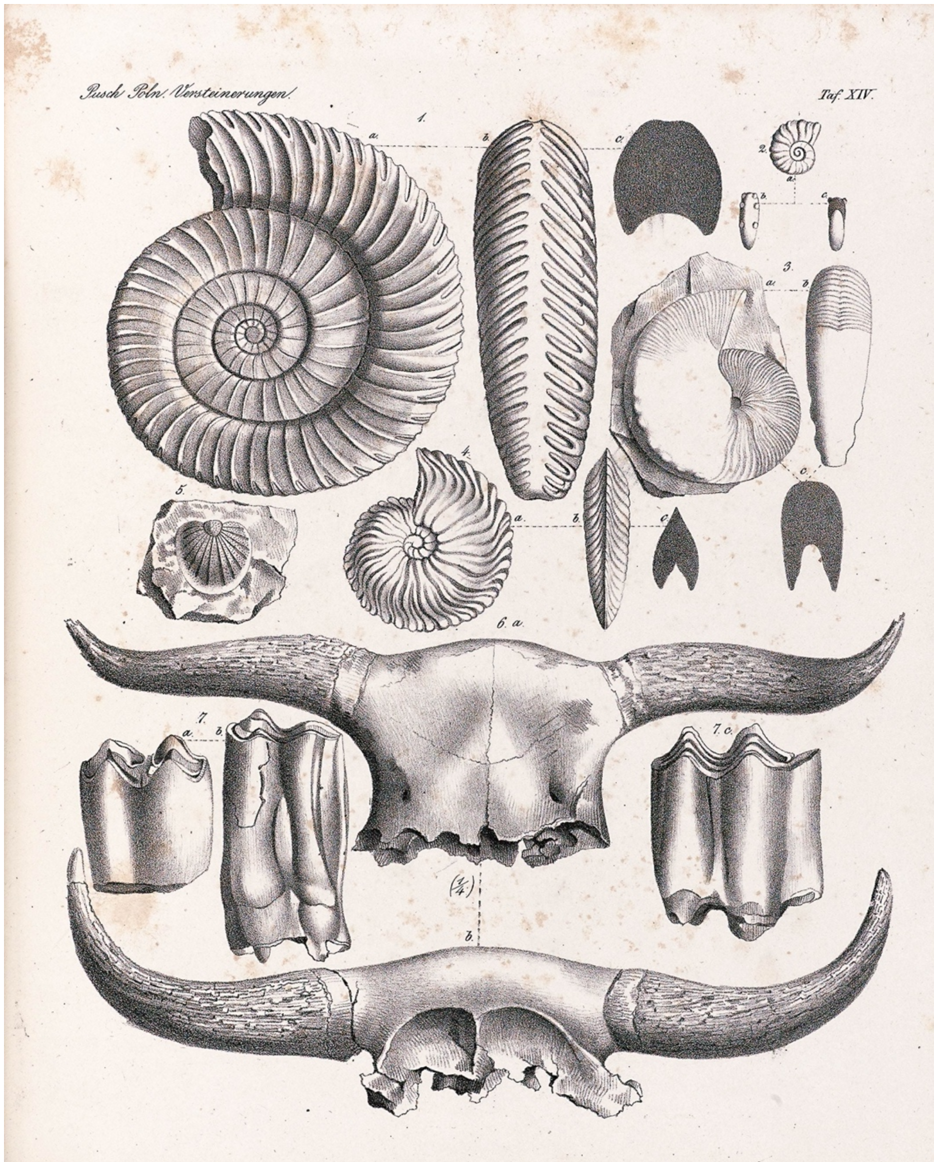

Figure 11. Plate 14 of Pusch's 1837 *Polens Paläontologie* (Poland's Paleontology) showing two views (6a and 6b, on bottom) of a partial *Bos primigenius* skull.[17]

Had more than one wild cattle species existed in Europe? Geologist Georg Gottlieb Pusch firmly argued that only one wild bovine had existed in Europe in historic times, and that was the European bison. As evidence, he cited Pallas (1777) and Bojanus, as well as Caesar, Pliny, and

[17] Georg Gottlieb Pusch, *Polens Paläontologie; oder, Abbildung und Beschreibung der vorzüglichsten und der noch unbeschriebenen Petrefakten aus den Gebirgsformationen in Polen, Volhynien und den Karpathen* (Stuttgart: Schweizerbart, 1837).

Tacitus. Not until 1878 when August Wrześniowski, a Polish zoologist and popularizer of Darwin's theory of evolution, wrote to explore the "question of whether or not in Europe, and in particular Poland, two different wild species of cattle lived at the same time as humans" was the matter widely considered settled, although Lydekker's slip-up suggests that the engrained misnomer continued.[18] Wrześniowski 's *Studien zur Geschichte des polnischen Tur* examined travel and inspection reports, descriptions, and woodcuts and poems that had been produced since the early 1500s, tracing the last two centuries of the aurochs' existence. His work was a major compilation for its attention to detail and meticulous scrutiny of the seeming contradictions in his historical sources, things which Pusch had used decades prior to challenge those historical sources and surmise that the aurochs was not its own species. In this way, Wrześniowski set up his intellectual heritage: he followed the likes of Cuvier, Ludwig Rütimeyer, Richard Owen, and Victor Carus, in favor of the view that two wild bovines had existed in Europe alongside humans, with the aurochs being one. Pusch, on the other hand, was placed by Wrześniowski in an intellectual lineage which included Prussian zoologist Peter Simon Pallas, and Bojanus.[19]

No matter their stance on the question of how many wild bovines had existed in Europe, naturalists cited the classical texts of Caesar, Tacitus, and Pliny as evidence of their position. The references were seen as authorities on the subjects, written, as they were, during the living existence of the "Urus" to which they referred. Their descriptions, however, were often vague and opened the door to competing interpretations. Caesar, for example, described in

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[18] August Wrześniowski, "Studien zur Geschichte des polnischen Tur," *Zeitschrift für wissenschalftliche Zoologie* 30 (1878): 494.
[19] *Ibid.,* 495-496. Wrześniowski notes that in a Polish translation of Cuvier's *History of Natural Sciences,* a "Prof Adamowicz" gave a note disagreeing that two wild bovines had existed in historic times in Europe.

Commentarii de Bello Gallico the “wild ox,” which were “slightly smaller than elephants, and in appearance, colour, and shape they resemble bulls.” The animals were noted as “extremely fierce and swift-footed, and attack people and animals on sight,” and the Germans would trap them in pits and kill them, a task which would “make the young German men tough,” and earn them status, as “those who kill[ed] the most wild oxen display[ed] the horns in public as a proof, which wins them considerable acclaim.”[20]

An animal with a similar description to that referenced by Caesar made appearances in medieval texts as well – in particular those celebrating moments of heroism on the part of the lauded. In Boyd Dawkins’ 1866 work “On the Fossil British Oxen,” for example, an excerpt from Book II of Notker Balbulus’s ca 883 work on the life of Charlemagne was given, the same hunting vignette which opened this chapter. In the scene, Charlemagne’s encounter with Bison or “Uri” (that is, urus) is told, with only a reference to the animal’s size and horns as a descriptive indicator of its identity:

> On the next day Charles, very tired of the quiet and leisure, prepares to go into the forest to hunt (Bisontium vel Urorum) Bisons or Uri, and to take the Persian ambassadors along with him, who, when they saw these gigantic animals, struck with very great terror, took to their heels; but the hero Charles, unmoved, mounted on a very swift horse, coming up close, drew his sword and attempted to cut off the head of one of them. But when he missed his stroke, the most fierce beast, rending his sandals and gaiters, and grazing his thigh with just the tip of its horn, made him a little more cautious, and then, enraged by the slight wound, took refuge in a most safe retreat, bristling with thickets and stones…And Isambardus, the son of Warinus, the persecutor of your patron Otmarus, having followed up the beast when he dared not approach nearer, thrust his lance between its shoulder and throat, pierced its heart, and presented it, still quivering, to the king..[21]

[20] Caesar, *Commentarii,* 132.
[21] Excerpt from the ‘Wars of Charlemagne,’ written by Notker Balbulus, Monk of St. Gall, quoted in William Boyd Dawkins, “On the Fossil British Oxen. Part I. *Bos Urus,* Caesar,” *Quarterly Journal of the Geological Society* 22 (1866), 400.

Dawkins took that description as proof that at the beginning of the ninth century both "Bison" and "Uri" were still found in forests near Aix-la-Chapelle.[22] Even more, he found the brief description on the animal's horns sufficient enough to determine which – bison or "Uri" – the animal in the hunting scene was: "The description of the horns proves that the animal was one of the latter species [Uri, or true aurochs], as the size of the horns of the former is not such as to warrant the use of the term "immanissima."[23] From such a small inclusion, Boyd Dawkins suggested that the instance referred to the true aurochs, therefore situating it in a place, a time, and a particular relational behavior with humans. While the classical texts and medieval works were deployed and interpreted as allusions to the aurochs or bison, still more recent historical records had been kept and were cited by the nineteenth-century authors for their hints about the geographic distribution and distinct existence of the aurochs. Those records would be mined for their accuracy and inconsistencies, rather than assumed to be correct and interpreted as reliable descriptors.

Hunting the animals and displaying or gifting their remains was a long-held practice that left eyewitnesses and artifacts of the animals in its wake. While naturalists of the nineteenth century, such as Boyd Dawkins, worked to interpret the stories and accounts of violent encounters with bison and aurochs, the extant European bison continued to be sent as living diplomatic gifts for zoological gardens, or as preserved specimens. To those European bison, the name "aurochs" would sometimes be given. Those who lived near European bison, or visited them in zoological gardens, would therefore see the living animal associated with the name

[22] Boyd Dawkins, "On Fossil British Oxen. Part I," 400. Notker Balbulus's work was cited by Dawkins as Monachi Sangallensis Lib. ii. De Rebus Bellicis Caroli Magni. Folio. (Du Chesne.) Chap. xi.
[23] Boyd Dawkins, "On Fossil British Oxen. Part I," 400.

"aurochs," adding to the confusion of identifying the true aurochs as the same or different from the bison.

Richard Owen was one prominent naturalist who used the word "aurochs" in reference to the European bison. In 1848, Owen had the opportunity to dissect a European Bison, what he termed a "Male Aurochs," which had died in the ownership of the Zoological Society's Zoological Gardens of an "active inflammation and congestion" of the animal's right lung.[24] The animal, one of a pair, had been gifted to the society by Nicholas I of Russia via Roderick Impey Murchison, a geologist who had been knighted following his work to extend and classify older geologic systems of the Silurian, Devonian, and Permian. Owen surmised that the animal, labeled by him as "*Bison europeus"* in his paper read before the Zoological Society, succumbed to "the raw cold and heavy fogs, consequent on the undrained extent of clayground in which the menagerie of the Society is placed."[25] The bison was not the first to succumb to such conditions, according to Owen. People inhabiting Regent's Park, as well as other exotic animals had borne marks of the effects of "an atmosphere so loaded on the mucous tract of the respiratory organs to which it is applied."[26] The male "Aurochs", as Owen called it, was just shy of two-and-a-half years old, and following its death, was dissected, and finally presented as a mounted specimen. Murchison was asked to view the "forlorn relict" of the animal, for whose preservation "neither cost nor pains [had] been spared", in order to appreciate that its newly mounted condition might be worthy of the Imperial present before writing to Nicholas I in Russia of the animal's demise.[27]

[24] Richard Owen, "Notes on the Anatomy of the Male Aurochs (*Bison europeaus)," Proceedings of the Zoological Society of London,* 16 (1848): 126.
[25] *Ibid.*
[26] *Ibid.*
[27] Letter from William John Broderip to Impey Murchison, 29 September 1848, LDGSL/838/B/28/24 Geological Society of London Archives.

The stuffed specimen, gifted by Nicholas I when it was a little more lively was not the first time that an aurochs, or in this case, a bison, was presented as a signifier of diplomatic relations between Russia and Western polities. In the mid-1500s Sigismund von Herberstein, a diplomatic representative of the Holy Roman Empire, served missions in Russia and wrote extensively on Russian language and culture.[28] His ethnographic reflections informed centuries of writing on the aurochs, quoted lengthily by Wrześniowski in 1878, and by Pusch, as well as by Newton and Lydekker in their 1890 *Nature* argument. Herberstein's 1557 *Moscovia der Hauptstat in Reissen,* and his *Rerum Moscoviticarum commentarii* included reference to the "Tur," supposedly referring in Polish to the wild ox, as well as its life, hunting, and social relevance to the people in Russia and Lithuania. Herberstein himself was gifted bison, or "Zubr", skins by the King of Poland Sigismund I, as well as a dead "Tur" by Sigismund II Augustus in 1548.[29] In one of several glorifying poems about Herberstein, Caspar Pecius referred to the placement of stuffed specimens of both the aurochs and bison by Herberstein in front of his family portraits.[30] Art historian Polona Vidmar has made a compelling argument for which paintings were likely the images that hung in relation to the stuffed animals. Those were the most famous depictions of Herberstein, two portraits made from woodcuts by Donat Hübschmann, a painter and block cutter in Vienna. The two 1559 portraits were made to celebrate Herberstein's diplomatic service, and in particular, his mission to Sultan Suleiman's Ottoman Court.[31] One portrait depicted the dress in which the ambassadors were sent to the "Emperor of the Turks," and the other the clothes which had been given to them by Suleiman. Beneath the two

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[28] August Wrześniowski, "Studien zur Geschichte," 501-503.
[29] *Ibid.,* 503.
[30] Polona Vidmar, "Cæsari in Mis Omni Hora Fidelis Servivi: The Portraits of Sigismund Herberstein and Walter Leslie in Diplomatic Robes," *Radovi Instituta Za Povijest Umjetnosti*, no. 43 (February 2, 2020): 79, https://doi.org/10.31664/ripu.2019.43.06.
[31] Vidmar, "Portraits of Sigismund Herberstein," 75, 79.

Herbersteins in their differing dress, were reportedly two stuffed specimens, one of the 'Tur' and one of the 'Bison,' set on display to compare the differences in their own coats and form.[32]

Herberstein's account of the "Tur" in the Russian, Polish, and Lithuanian countryside was cited extensively by Pusch and Wrześniowski, and his reliability as a witness to the aurochs question became a focal point of the disagreement between the two authors. After resolving the "first and most important question" according to Wrześniowski, that of the "simultaneous existence of Tur or *Bos primigenius* and of man," (something to which the second part of the chapter returns), Wrześniowski went on to consider how long the bovine preserved itself in Europe, and especially in Poland.[33] To do so, he leaned extensively on Herberstein, quoting his work in its original Latin. Herberstein had described the "Uros" bordering Lithuania, noting "natives call them Thur, Germans Urox."[34] Those animals, according to Herberstein, were "really wild oxen, nothing but a distant domestic oxen," aside from their coloring. Descriptions of hunts and customs making use of the skins of the animals were also provided, along with two illustrations, whose captions warned against confusing the names "Tur" and "Zubr."[35]

[32] Recounted in Wrześniowski. See Vidmar, "Portraits of Sigismund Herberstein," for a historical account of the portraits and their display.
[33] August Wrześniowski, "Studien zur Geschichte," 498. Original: "Die erste und wichtigste Frage nach der gleichzeitigen Existenz des Tur oder Bos primigenius und des Menschen, its demnach endgültig gelöst: es bleibt aber noch zu erörtern, wie lange dieses Rind in Europa und insbesondere in Polen sich erhalten hat."
[34] *Ibid*., 499. Wrześniowski quotes Herberstein in Latin: "Uros sola Masovia Lithuaniae conterminal habet: quos ibi patrio nominee Thur vocant, nos Germani propie Urox, dicimus."
[35] *Ibid.,* 500.

Figure 12. Herberstein images of "urus" and "bison".[36]

The first, an image of the aurochs, noted in Latin: "I am Urus, to the Poles Tur, to the Germans Aurox, ignorant people gave the name Bison." The image of the bison was similarly

[36] From Sigismund von Herberstein, *Rerum Moscovitarum Commentarii* (in aedibus Joann Steelsii, 1556), and reproduced in Jurkowlaniec and Herman, *Reception of the Printed Image.*

labeled “I am Bison, to the Poles Suber, to the Germans Bisont, ignorant people gave the name Uri.” The distinctions between the animals in the images were clear: the form of the head and snout, the placement of the horns, the shape of the back, and length and placement of the coat. The images in Herberstein’s account were purportedly provided to him by informants in Poland, and eventually published in the 1556 third edition of his *Rerum Moscovitarum Commentarii.*[37] Before their publication in Herberstein’s work, however, the woodcuts’ designs were used to create images for Gesner’s 1554 *Icones animalium quadrupedum.* Once decontextualized, the same woodblocks or the designs from them circulated in texts that treated aurochs, European bison, and American bison, in what art historians Grazyna Jurkowlaniec and Magdalena Herman have called a “zoological and linguistic puzzle in the print era, when multiplied images contributed to both near solutions and ultimate global confusion.”[38]

Part of this confusion stemmed from Conrad Gessner’s 1551 *History of Animals (Historiae Animalium Liber I de Quadrupedibus vivaparis),* which described the aurochs and European bison as two species. He indicated that he had seen neither himself, and included an illustration only for the aurochs chapter “*De Uro,”* which was a woodcut based on Anton Wied’s map of Muscovy.[39] The map contained a small aurochs hunting scene, and Jurkowlaniec and Herman have suggested that Gessner must have had access to an early version of the map that included the scene: a man hiding behind a tree and using his spear to pierce the aurochs in the

[37] Herberstein, 1556, *Rerum Moscovitarum Commentarii.* The work was translated into English and German soon after its publication, and offered the West an eyewitness glimpse into Russia. See Samuel H. Baron, "Herberstein and the English "Discovery" of Muscovy," *Terrae Incognitae, XVIII* (1987): 43-54.
[38] Jurkowlaniec and Herman, “People Between Multiplied Things and Modified Images,” in *The Reception of The Printed Image in the Fifteenth and Sixteenth Centuries: Multiplied and Modified,* eds. Jurkowlaniec and Herman (New York: Routledge, 2021), 17.
[39] Gessner, *Historiae Animalum*. An account of the production of the Gessner image is given in Jurkowlaniec and Herman, *Reception of the Printed Image,* 13.

chest. That illustration, the one which heads this chapter, would appear again in Jan Jonston's c. 1652 *Description of the Nature of Four-Footed Beasts,* but for the chapter on the European bison, "Bison-Wilder Ochs-Wisent."[40] Jurkowlaniec and Herman identified in a later 1560 edition of Gessner's *Icones* a handwritten margin in Gessner's own copy, which noted that in fact the animal in the hunting scene should actually be referred to as the "Wisent," based on Gessner's reading of a copy of Mikolaj Hussowski's *Carmen de Bisonte,* a poem sent to him in October of 1559 which contained a description of the bison, or Wisent.[41] Still, into the seventeenth century, repurposed designs and circulated woodblocks, as well as the novel style of full-sheet engravings with associated captions, easily detached from their source manuscripts, would leave room for ambiguities in the associations between image and label. Skepticism also grew around the validity of the images themselves and the reliability of those who claimed to have originally designed them *ad vivum.*

Herberstein's account and the associated images were a deep well from which Pusch and Wrześniowski, among others, sought support for their opposing stances. Whether or not Herberstein was considered a reliable witness regarding the Tur and Zubr in part came down to the accuracy of his reported mission itineraries. According to Wrześniowski's research, and Herberstein's self-reporting, Herberstein made trips to Poland on Imperial missions beginning in 1516, passing through Krakow, then Wilno, Nowogrod, and on to Moscow, and returning via Smolensk.[42] He was sent again by Emperor Maximilian I in 1529, and then accompanied Archduchess Elisabeth of Vienna in 1543 to Krakow. These trips formed the conditions for his observation of the people and wildlife of the country of Russia, but also raised questions as to the

[40] Reproduced in Jurkowlaniec and Herman, *Reception of the Printed Image*, 14.
[41] *Ibid.,* 16.
[42] August Wrześniowski, "Studien zur Geschichte," 501.

validity of some of his claims. Pusch, for example emphasized that during Herberstein's two trips to Moscow, Mazovia was not directly traversed, and he likely did "not pay direct visit to this real fatherland of the Tur."[43] This suggested a contradiction in Herberstein's reporting, as he had stated that the "Tur" occurred exclusively in Mazovia – something he would not himself have witnessed – but also stated that the "Tur" occurred in Lithuania as well.[44] What to Pusch was a conclusive contradiction, Wrześniowski instead considered as a minor lapse, given that Herberstein had "so often visited Poland and has devoted much attention to the geography of the countries visited," and therefore that "all of these objections [by Pusch] do not prove that what Herberstein says about the Tur is incorrect, as more weighty reasons seem to speak in favor of his statements."[45]

The weight given to those statements stemmed from additional eye-witness accounts of the animals, often through the intimate interactions of hunting or even breeding. Gesner cited reports on the "Polish Tur": "they live in the Hercynian forest... in the thickest parts of the forest."[46] Their relation to humans in the reports ranged from tame to violent when provoked. Reports cited by Gessner, Anton von Schneeberger, who possibly visited the last aurochs population at Jaktorów, and Wrześniowski described that hunters would commonly use split pieces of wood to throw at and around the animal, blocking and holding the animal in place, and while still alive "they [would] pull off the skin which covers its forehead between the horns, and

[43] *Ibid.,* 503. Original: "…dass er diesem eigentlichen Vaterlande des Tur keinen unmittelbaren Besuch abgestattet habe."
[44] *Ibid.*
[45] *Ibid.* Original: "Alle diese Einwendungen beweisen aber nicht, dass das, was Herberstein über den Tur mittheilt, unrichtig sei, um so mehr, als zu Gunsten seiner Angaben gewichtige Gründe zu sprechen scheinen."
[46] *Ibid.,* 505. Wrześniowski quotes Gessner: "Agunt in sylvae Hercyniae parte a Warschavia principatus Masoviae primaria civitate quinque miliaribus distante, prope Sochaezowam et Koszkami pagos. Plaerunque in denissimis sylvae partibus versantur..."

which by its curly hair makes the animal horrible to behold."[47] Those parts would then be torn into belts and gifted by the Polish king, including to Herberstein who received two belts from the Queen Bona, according to Schneeberger.[48] Schneeberger's authenticity as an observer of the animals was disputed by Pusch, though Wrześniowski defended his credibility as he was highly published in botany and medical treatises, and so "was highly educated" and "well versed in natural knowledge" while traveling through the region.[49]

Wrześniowski did not stop with Herberstein, or his brief inclusion and discussion of the images of the aurochs and bison included in Herberstein's work. Wrześniowski meticulously considered the historical record of accounts of the living aurochs and bison, and from there was satisfied with his conclusion that both had existed as separate species, and both had lived in the historic period. The most important tool in his endeavor was his access to Polish texts. Wrześniowski expressed early on that a "large part of the relevant data is contained in Polish writings, accessible only to a narrow circle of readers," and thus his translations were key to giving non-Polish speaking naturalists access to the wealth of texts on the aurochs beyond Herberstein and Gessner.[50] In fact, language proved to be a natural cleavage in the debates over whether or not one or two wild bovines had existed in Europe: "of Polish scholars, only Brincken, Stronczynski and Sapalski have spoken out in favor of Cuvier's opinion [that two wild bovines had existed], while in the opposite camp, with the exception of von Pallas, only Polish or

[47] *Ibid.,* 506-507. Translation from Van Vuure *Retracing the Aurochs,* 92.
[48] August Wrześniowski, "Studien zur Geschichte," 506-507. Translation from Van Vuure, *Retracing the Aurochs,* 92.
[49] August Wrześniowski, "Studien zur Geschichte," 510. Original: "Das Migetheilte beweist gewiss nicht, das salles, was Schneeberger über den Tur mittheilt, unbedingt richtig sei, zeigt aber augenscheinlich, dass er hochgebildet und, für jene Zeit, in den Naturwissenschaften wohl bewandert war."
[50] August Wrześniowski, "Studien zur Geschichte," 494. Original: "ein grosser Theil der bezüglichen Daten in polnishcen Schriften enthalten ist, die einem verhältnissmässig nur Engen Kreise von Lesern zugänglich sind."

Polish-speaking scholars are to be found."[51] No doubt, access to the Polish-language records generated confusion about the description of the aurochs and the bison, rebuking the notion that those who lived amongst the animal had an engrained knowledge of their distinctness.

What the specimens, illustrations, and eye-witness accounts from Classical, Medieval, and Early Modern texts all denote are the ways in which the aurochs was not easily remembered or retained despite its coexistence with humans during centuries of history. Rather, history did what it often does: it obfuscated. The most obvious vestige of this growing space of confusion and conflation was in the names. To know an aurochs by its name was not an easy feat for those nineteenth-century interlocutors who had inherited the problems of the historical record of the animal. *Bos taurus* and *Bos primigenius antediluvialus* competed in the scientific binomial naming of the animal, while Wisent, Zubr, Tur, Aurochs, Urus, and more appeared in reference to animals that were bison, aurochs, or, in the case of the Gessner woodcuts, some unholy combination of the two. Dictionaries in German and English became sources in which the differences between the names could be parsed, though regionally specific terms for animals defied easy interpretation.

In their 1890 back-and-forth in *Nature,* for example, Newton and Lydekker pointed to a few sources that had devoted much attention to the etymology and proper usage of the terms "aurochs" and "wisunt" or "wisent." Newton directed Lydekker to Dr James Murray's edited dictionary, *A New English Dictionary on Historical Principles: founded mainly on the materials collected by the Philological Society,* whose 1888 version included a lengthy entry for "Bison"

[51] *Ibid.,* 496. Original: "Daneben muss hier auch noch hervorgehoben werden, dass von polnischen Gelehrten nur v. Brincken, Stronczynski und Sapalski zu Gunsten der Cuvier'schen Meinung sich ausgesprochen haben, während im entgegengesetzten Lager, mit Ausnahme von Pallas, nur polnische oder der polnischen Sprache mächtige Gelehrte angetroffen werden."

as well as for "Aurochs."[52] Newton could, by 1890, confidently write that the "'aurochs' (=ox of yore), Latinized by Caesar in the form *urus,* is or was the *Bos primigenius* or *B. urus* of scientific nomenclature."[53] According to Newton, "it is wholly by mistake that in its extinction as a wild animal its ancient name was transferred to the bison, or *Zubr,"* though as discussed above, this transference was already underway long before its extinction. Newton pointed also to Oskar Schade, who had written in 1882 an extensive article entry under "Wisunt" in his *Altdeutsches Wörterbuch,* which brought together many of the preceding references about the European bison and its etymologically vexing history.[54] The article was cited in Murray's dictionary, along with Caesar, Buffon, and Gray's Guide to the British Museum.

Murray's entry for "aurochs" claimed that the Latin *urus* and Greek *ovpos* were adopted from an Old Teutonic word, with uncertain derivation.[55] According to the entry, "aurochs" was:

> historically and properly the name of an extinct species of Wild Ox (*Bos Urus* Owen, *B. primigenius* Boj.), described by Caesar as *Urus,* which formerly inhabited Europe, including the British Isles, and survived until comparatively recent times in Prussia, Poland, and Lithuania. Since this became extinct, the name has often been erroneously applied to another species, the European Bison (*Bos Bison* Gesn., *B. bonasus* Linn.), still extant in the forests of Lithuania, in which sense it is used by some English naturalists. In early mod. G. [early modern German] *aurox, aurochs,* was still applied to the *Urus,* only since its disappearance (in 17th c.) has been popularly misapplied to the Bison, in which sense it was unfortunately adopted by some naturalists, before the facts were known.[56]

Previous attempts had been made to resolve the naming difficulties. In 1866, Boyd Dawkins proposed the exclusive use of "Urox" for what had been called in the written record "Urus," and "Aurochs" for Bison.[57] Boyd Dawkins had described the *Bos Urus* of Caesar as the "*Bos*

[52] Murray, ed, *A New English Dictionary on historical principles: founded mainly on the materials collected by the Philological Society* (Oxford: Clarendon Press, 1888).
[53] Newton, "Bison not aurochs" (May 8, 1890).
[54] Oskar Schade, *Altdeutsches Wörterbuch* Vol. 2 (Halle a.S.: Buchhandlung des Waisenhauses, 1882).
[55] Murray, *New English Dictionary,* 567.
[56] *Ibid.*
[57] Boyd Dawkins, "On Fossil British Oxen. Part I," 394.

primigenius of Bojanus." He cited Johann Baptist Fischer's *Synopsis Mammalium* of 1829 and its detailed treatment of the confusion of the terms "Urox" and "Aurochs" to support his case. Murray's dictionary entry for "Aurochs" critiqued Dawkins' suggestion: "but as *Urox* and *Aurochs* are only the earlier and later form of the same name, this is historically indefensible, and the only accurate nomenclature is to distinguish the two animals as *Uros* (or *Urox*) and *Bison* (improperly called *Aurochs)."*[58] Still, a major contribution by Boyd Dawkins was his conclusion in "On Fossil British Oxen" that the "large fossil ox of the Pleistocene period, termed *Bos primigenius* by Bojanus and Professor Owen, differs in no respect from the *Bos urus* of the Prehistoric and Historical period."[59] Though attempting to unite them under a name other than "aurochs", Boyd Dawkins convincingly argued that the aurochs of the written record (urus) and the aurochs known in fossil form (*Bos primigenius*) were one and the same.

Lydekker aligned himself with "a few authorities" as he referred to them, including Buffon, Cuvier, and Owen by whom "the term *Aurochs* has been restricted to the European bison," while "*Urox* or *Bos urus* [referred] to the species under consideration [the extinct wild ox of Europe] by Julius Caesar, Pliny…also by Cuvier, Nilsson, and our great naturalist, Prof Owen."[60] Like Wrześniowski, he had noted a divide in which countries used which terms, noting in his 1880 defensive reply to Newton in *Nature* that in "restricting the name aurochs to the European bison, I have merely followed the general custom of English zoologists…I find, however, that modern German zoologists… consider it proved that the name *Aurochs* belongs properly to the extinct *Bos primigenius*; and they term the bison, as Prof. Newton states, the

[58] Murray, *New English Dictionary,* 567.
[59] Boyd Dawkins, "On Fossil British Oxen. Part I," 394.
[60] Richard Lydekker, "Bison and Aurochs," *Nature* 42, no. 1072 (May 15, 1890): 53.

Wisunt."[61] From there Lydekker conceded "[i]f this be really correct, English zoologists must accept the emendation."

The etymology of "aurochs" and associated terms had their place in these discussions, too, as has the occasional toponym in anthropological work since.[62] Boyd Dawkins, for example, suggested that the word *urus* had a Sanscrit root of "ur, aur, or or," referring to a "forest of stony waste," and was a root "preserved without change in the old German *ur.*"[63] Even Newton could not help himself with his etymological inference that "aurochs" stemmed from "ox of yore." But for all the etymological deciphering, the aurochs and the bison were often referred to interchangeably by the same name, including in the twenty-first century by the *Merriam-Webster Dictionary of English*.[64]

The debate over the existence of one or two wild bovines in Europe was curtly summarized by Newton and Lydekker's letters in *Nature.* Newton's critique of the use of 'aurochs' by Lydekker in *Nature* drew on Herberstein and Wrześniowski, as well as Herberstein's side-by-side engravings in *Rerum Moscoviticarum commentarii*. For his own part in seeking to rectify the "common error" of conflating the aurochs and European bison, Newton remarked in his last *Letter to the Editor* in this squabble that he recommended the educational nature of the mounted specimens in the Cambridge Museum of Zoology: "I may add that any visitor to the Museum of Zoology of this University may see therein a skeleton of the Aurochs and of the Bison, as well as of the American 'Buffalo' – all standing side by side."[65] The European bison and the aurochs were, by the end of the nineteenth century, understood more

[61] Lydekker, "Bison and Aurochs."
[62] Van Vuure, *Retracing the Aurochs,* 81-83.
[63] Boyd Dawkins, "On Fossil British Oxen. Part I," 393.
[64] Jurkowlaniec and Herman, *Reception of the Printed Image* point out this modern confusion.
[65] Newton, "Bison not aurochs" (May 22, 1890).

broadly as two separately existing species, and Newton's public correction of Lydekker represents a last gasp of resolving a centuries-long debate. At the same time, Boyd Dawkins' uniting of the urus of the historical texts with the *B. primigenius* of fossil form was a critical step in understanding the temporality of the animal as straddling Prehistory and History, and thereby the deep past fossil record and the recent historical record.

This episode in the history of natural history is referred to frequently in the literature consulted here as "unique," or "special," or "specific."[66] Narratives of naming and confusion abound in the history of science, especially in the Early Modern period, and yet the case of the aurochs and bison is exceptionally revealing to broader patterns of how the historic record informs and obfuscates the aims of early naturalists. The possibility of eyewitness accounts to speak to the animals' existence could only go as far as the eyewitnesses were trustworthy, and as far as the texts and images were later decipherable. Still, the aurochs had lived in proximity to humans into the mid-seventeenth century, and a record – albeit in need of verification – of not only its life but also its eventual wild extinction was kept.

Since the thirteenth century, the aurochs had been largely managed as a royal and ducal prerogative, leaving records of its keeping as far back as the fifteenth century. These "Inspection Reports" recorded the numbers of animals and any contributing causes of changes in their population.[67] By 1599 only 24 aurochs were reportedly found in the forests of Poland, and the Inspection Reports raised alarm, suggesting fewer domesticated cattle be allowed to graze where aurochs lived, that sheds be built for them, food laid out, and the numbers of hunters curbed.[68] While the local climate had shifted over thousands of years, with marshes drying up and forests

[66]Jurkowlaniec and Herman, *Reception of the Printed Image*, 18 for example.
[67] Wrześniowski recounts that Schneeberger refers to these reports, as does Gessner. Wrześniowski, "Studien zur Geschichte."
[68] Van Vuure, *Retracing the Aurochs,* 70-71.

turning into steppe-land, the largest contributing factor to the aurochs' decline and eventual extinction was humans.[69] Hunting, as described above, was a long-held custom for those in the vicinity of the aurochs, but ousting the wild animals from their habitats and cutting down forest to make room for farmers and their cattle accelerated their decline.[70] In Jaktorów, the location of the last-known wild living aurochs, the meadows dotting the rivers which had provided the aurochs with food became increasingly dominated by domesticated cattle and farmers, and the activity of chasing pigs into the forest in Autumn to eat acorns likely created competition for the aurochs whose diet also included acorns.[71] In 1602, four animals were reportedly left in the wild population:

> In these forests at Jaktorów, aurochs are hiding, of which at this moment there are only four, which we have seen for ourselves, three bulls, one cow. The hunters let us know that before, there were more of them, but many of them have died through other cattle contaminated with the pest [possibly rinderpest, "powietrze zarazeni"]. We asked about their hides and horns, and an official of the starost [district manager] told us that they have been sent to the king. However, these aurochs died while the district was being managed by managers given to them by the king. Under the present starost only one was shot, which is the subject of the legal inquiry.[72]

In 1620 the final wild aurochs bull died, leaving to history a horn on which was written its importance; the horn is currently housed in the Livrustkammaren in Sweden.[73] In 1627, according to the 1630 report, the last wild aurochs cow died. In captivity, however, a small population purportedly persisted in Zamósc, Poland, kept in a little menagerie by the Zamojski

[69] K. Heymanowski,"The last mainstay of aurochs and the organization of their protection in the light of contemporary documents," *Sylwan* 116, no. 9 (1972): 9-28.
[70] See Van Vuure, *Retracing the Aurochs,* 77 for a graph charting the decline of the aurochs population from 1557 (Herberstein) on.
[71] Wrześniowski describes Schneeberger and Gessner referencing this.
[72] Quote from 1630 Inspection Report has been reproduced translated into English in Van Vuure, *Retracing the Aurochs,* 71.
[73] Van Vuure, *Retracing the Aurochs,* 71.

family, though it is uncertain whether the population at the zoo lasted longer than the wild ones.[74]

Figure 13. Monument to the last aurochs in Jaktorów, reads: “The Aurochs – *Bos primigenius Bojanus,* the ancestor of domestic cattle, lived in this forest Jaktorów until the year 1627.”[75]

The fairly detailed census of the aurochs and its decline reported through the years via Gessner, Schneeberger, and eventually Wrześniowski, is a fascinating case of the documentation of animal extinction. The records also reveal to the historian that during its final extant days in the Early Modern period, it was not understood as its own entity. Its conflation with the European bison surpassed, or was even facilitated by, eye-witness records, specimens gifted for diplomatic purposes, linguistic traces, reproduced images, and classical texts taken to be ancient

[74] A manuscript mentioned by Brincken and written by Count Johann Ostrorog is repeated by Wrześniowski. The manuscript, according to Wrześniowski, refers to Zamojski’s Thiergarten that held both “Tur” and “Zubr,” and a letter from Ostrorog from 24 January 1610 in which he adds the post script: “How many Tur and Zubr do you have, please let me know, and how many males and how many females.” Wrześniowski, “Studien zur Geschichte.” 518-519.
[75] Image from Tomascz Kuran, 2017. The monument was erected in 1972.

authorities on the topic. Its scientific naming by Linneaus and later Bojanus reinforced the discrepancy over the aurochs' existence, as well as its association to domesticated cattle and the European bison. In summary, its relation to humans and the various historical records they created of the animal added layers of elusiveness to the aurochs in its life and eventual wild extinction. At the end of the nineteenth century, Newton could argue that Lydekker had committed a sin of conflation that stretched back centuries, and mount enough evidence in a convincing manner for Lydekker to back down. Wrześniowski's 1878 work which brought so many of those historical threads of evidence together would help establish the historic existence of the true aurochs. Boyd Dawkins' work would help unite the Urus of written record with the *Bos primigenius* of the paleontological. And all the while, this discourse about the historical legacy of the aurochs was occurring alongside the discovery of its paleontological remains, which were themselves being unearthed next to early human fossils. If the historic existence of the aurochs and its wild extinction confused its timeline and knowledge of its existence through the foibles inherent in the transmittance of historical knowledge, the *Homo* fossils found in association with the paleontological aurochs specimens problematized the earlier temporal locus of the aurochs in relation to humanity. The historic record led to questions about what the aurochs was, but the earlier timeline of the paleontological record led the aurochs to inform questions about who we were.

STRADDLING HISTORY AND PREHISTORY

The aurochs in its final days was coextensive with humanity, that much was finally demonstrated by Wrześniowski, among others. But the aurochs had also been coextensive with humanity's beginning as well. It straddled two records: the historic and the prehistoric, which were still being defined in relation to one another during the nineteenth century. In no other way was this distinction more pressing than in the archeological and paleontological discoveries of early *Homo* fossils and associated flint instruments, found in situ and in cave sites throughout the nineteenth century.[76] Prior to the nineteenth century, extending the scientific imagination to a world before humanity had been a strained enterprise. While stone implements, human fossils, ancient human texts, and artifacts had been discovered, the interpretations of those finds often fit within a shorter (and often Biblical) chronology for humankind, either located as pre- or post-Noachian flood, or through the possibility that the apparent differences between forms and artifacts of the past and present were actually due to changes in spatial distribution rather than changes over deeper time.[77] By the mid-nineteenth century, however, humanity's past was growing, with evidence stretching further back in time, and the fossil fauna and flora that were deployed indicators of deep past temporality and conditions were used to inform the periodization of humanity's prehistoric past, and what that world would have looked like.

This history of using fossil fauna to mark geological time was recounted in Chapter 1, drawing on Édouard Lartêt, Christian Thomsen, Johann Friedrich von Brandt, Charles Lyell, and William Boyd Dawkins, among others. As such, it will not be retraced in full here. But it is relevant for thinking about how the historical aurochs – the animal whose existence and nature were debated for centuries in written accounts – was made to fit within the geological scheme that made use of its fossil forms. How did these two timescales and disciplinary methods of measuring the past reconcile time with one another? Revisiting Boyd Dawkins provides some

[76] Manias, "Contemporaries of the Cave Bear."
[77] See Rudwick, chapter 5.4 "The Antiquity of Man," in *Bursting the Limits of Time*, Martin J. S. Rudwick, *Worlds Before Adam: The Reconstruction of Geohistory in the Age of Reform* (Chicago: University of Chicago Press, 2008) for a deeper history on the geology and archeology that facilitated the thinking of human origins in the deep past.

interesting insights, as he often provided quite thoughtful methodological reflections on his chosen tasks.

Roughly a decade after Charles Lyell's *Geological Evidences of the Antiquity of Man,* Boyd Dawkins published his tome on *Cave Hunting, researches on the evidence of caves, respecting the early inhabitants of Europe* with the aim of bringing together the varied published works on fossil and early human finds in European caves, and provided his main conclusions "in one connected and continuous narrative."[78] While Buckland's Kirkdale discovery described in Chapter 1 was in many ways a watershed, much discovery had taken place since and "revolutionized the current ideas as to the antiquity and condition of man," including cave art found in Britain, France, Belgium and Switzerland.[79]

Caves, then, were an incredibly rich site for investigation into the past for several reasons: as Boyd Dawkins put it, bones of domesticated animals found therein would "necessarily lead to the further examination of the appearance and disappearance of breeds under the care of man," while their use as shelter by man and wild animals allowed for "biological" discovery as well as consideration of the "general question of the ancient European climate and geography."[80] It was no surprise then that those caves, such as the Kirkdale hyaena dens explored and described by Buckland in the early 1800s, had become important sites of ancient faunal and artifact preservation and research. Boyd Dawkins brought those finds together, presenting his work as a discussion of the physical geological significance of caves and their formations, as well as the biological and climate evidence provided by the former dwellings, burial sites, and dens of early humans and the animals that populated their world. He subscribed

[78] Boyd Dawkins, *Cave Hunting,* vii.
[79] *Ibid.*
[80] *Ibid.,* 8-9.

in his tract to what he referred to as a tripartite classification for the ‘Bone-Caves’ then being discovered throughout Europe: from most recent to older they were Historic caves, Prehistoric caves, and the Pleistocene caves, all firmly “Post-Tertiary”.[81] Boyd Dawkins resisted Lyell’s own distinctions of the “Post-Tertiary formation”, as well as the term “Quaternary” used by French geologists, instead arguing that Historic, Prehistoric, and Pleistocene would be sufficient, as the other terms suggested a break in the continuity of life, “which does not exist.”[82] His discussion of the fossil rich caves would work, as he noted, “backwards in time,” beginning with the firm basis of history, rather than with the oldest cave division of the Pleistocene and working up to the present day.[83]

For his divisions of Pleistocene, Prehistory, and History, Boyd Dawkins cited the ways in which archeologist classifications did or did not align with his chosen system. Archaeology, which in his words had “grown from a mere antiquarian speculation into a science” had since “proved the truth” of what were taken to be three divisions in human progress: the Stone, Bronze, and Iron Ages.[84] John Lubbock had divided the first into the Palaeolithic, or older, and Neolithic, or newer, which constituted “the only refinement” of the earlier tripartite classification from Boyd Dawkins’ vantage point. Boyd Dawkins’ *Cave Hunting* was conveyed to readers as a supplementary system to those worked out by Lyell and Lubbock; one which was not without its own frictions when set beside those classifications of the archaeologist, historian, or paleontologist. Indeed, his aim to “treat of the formation of caves, and of the light thrown by their contents on the sojourn of man in Europe, on the wild animals, and on the changes in climate and geography” was such that his writing also became a meditation on the boundaries

[81] *Ibid.,* 10.
[82] *Ibid.*
[83] *Ibid.*
[84] *Ibid.,* viii.

between history and prehistory, and the various methods that had been enacted to delineate between them.[85]

For his classification, "founded in part on the principle of change in the animal world, and partly on the basis offered by history," only the former part would coincide readily with the system of the archaeologists. The Pleistocene would be taken as equivalent to the Paleolithic ("that of rude unpolished stone"; the oldest subdivision of the oldest age of human progress, the Stone Age), while the Prehistoric aligned with the polished Stone, Bronze, and part of the Iron ages; the "Historic" period only covered the last portion of the Iron age.[86] Within the Historic period, a further subdivision was smuggled in by Boyd Dawkins – an epistemic one more than an ontological one: "it is extremely difficult, if not impossible, to define with precision the point where legend ends and history begins."[87] Nonetheless he drew the line marking where history could enter the endeavor as a reliable discipline and informer of the past: "the line may be drawn with convenience at the first beginning of a connected and continuous narrative, rather than at the first isolated notice of a country."[88] In other words, Boyd Dawkins' definition of the Historic period of any nation – for the exact temporality may differ between places – could only be extended so far back as a continuous narrative would allow. For Britain, he cautiously suggested that the temporary invasion by Julius Caesar would be the furthest back anyone could claim for the Historic Period of Britain, as "no documentary evidence" as to the events that happened before the invasion existed in a continuous form. To go further back, one would need to attend to the "modern method of scientific research…to extend the narrative away from the borders of

[85] *Ibid.,* vii.
[86] *Ibid.,* 10-11.
[87] *Ibid.,* 75.
[88] *Ibid.*

history far back into the archaeological and geological past."[89] Science, therefore, picked up where history could not reach in Boyd Dawkins' scheme.

Not only was the historic and prehistoric record different in its forms of evidence, but it also differed place to place. The wild animals in Britain, for example, underwent "great changes" during the historic period, with their numbers diminishing and the habitats "narrowed by the increase of population and the improvement in weapons of destruction." In Britain, the brown bear, the wolf, the wild boar, the stag, and the roedeer had all gone extinct or extirpated from Britain during the historic period, according to Boyd Dawkins, while only the common rat, *Mus decamanus,* had migrated in and thrived during the historic period, and "contrary to the will of man" no less.[90] The "great Urus" had by the time of the English invasion, overtaken the smaller "aboriginal" *Bos longifrons,* believed to have been present in Prehistoric and Roman times.[91] In his chart on the "Classificatory Value of Historic animals," the changes in the fauna of Great Britain were used to "ascertain the approximate date of the deposit in which their remains happen to occur." Urus was listed as before circa 449 AD, suggesting that any aurochs finds in Britain could not have been of a later date than that.[92]

In his 1866 "On the Fossil British Oxen," he had clarified the temporality of the aurochs in Britain: its extirpation began to happen at the close of the Pleistocene, being "exposed to exterminating causes that did not obtain in the far larger and wilder areas of the European mainland; it was rare in the two latter periods, and probably became extinct as a wild variety several centuries before the species (or variety) on the continent was driven away from the

[89] *Ibid.*
[90] *Ibid.*
[91] *Ibid.,* 77.
[92] *Ibid.,* 78. The date refers to the Anglo-Saxon invasion, commonly reported as ca 449 after Bede.

Hercynian Forest and the banks of the Danube."[93] Such calculations in which the presence of the aurochs could only indicate a deposit no older than c. 449 AD in Britain, but potentially as late as the seventeenth century in Poland suggested that the table he provided was not applicable to Europe in general. The *Bos primigenius* specimens across Europe and the urus of written texts were one and the same, as he had noted in 1866, but the abundance and timing of either fossil or the written animal varied from place to place.

Boyd Dawkins' system for classifying prehistory and history by way of animals can be read as one of several systems for classifying periods of the past in the nineteenth century. Édouard Lartêt, Christian Thomsen, Johann Friedrich von Brandt, John Lubbock, and Charles Lyell devised their own systems too, or reworked those of others. Those that focused their designs on the Tertiary/Post-Tertiary, or those recent geological periods in which history reached its furthest limits, used a variety of classificatory signals: human material culture, stages of social evolution, ratios of fossil fauna. Boyd Dawkins' own system actively explored the boundaries between the records of prehistory and those of history in devising his own scheme. As he saw it, there was no firm break in the history of life from the Tertiary to its subsequent period, as prior catastrophists had reported. Instead, Boyd Dawkins sought the finer resolution of mammalian evolution and extinction to depict change over time, and reasoned that the differing disciplinary records of the past offered a natural way to classify in different regions. Each region entered its "historic" period at different times, a nuance recognized by his system. The work of Wrześniowski had demonstrated what the historic period of the aurochs up to the seventeenth century had to offer those seeking knowledge about it. Despite the potential for recent eyewitness accounts of the animals, the records were prone to perpetuating confusion. In Boyd

[93] Boyd Dawkins, "On Fossil British Oxen. Part I," 398.

Dawkins' scheme, study of the aurochs across the prehistory/history divide certainly required different disciplinary aptitudes. Yet, Wrześniowski, a scientist, had made many of the Early Modern accounts of the aurochs accessible, and refined which were to be believed.

The aurochs, in its fossil and recently living forms, factored into discussions about how to chart the past by some reliable and correlative system. In the nineteenth century, the biological and written signatures used to mark time across Europe were extended to the colonies, and comparative measures were explored to mark the progress of civilizations throughout history. The aurochs, one of many signals on charts of time, such as Boyd Dawkins', would continue as an indicator of something in the temporality of human development and evolution – though what it indicated was not always clear. In the next chapter, the consequences of correlating relative human progress and the frameworks that underpinned those efforts will be considered in the British colonial presence in India. There, in the early nineteenth century, an Indian aurochs had been unearthed.

Chapter 3: Indian Aurochs in Colonial Time

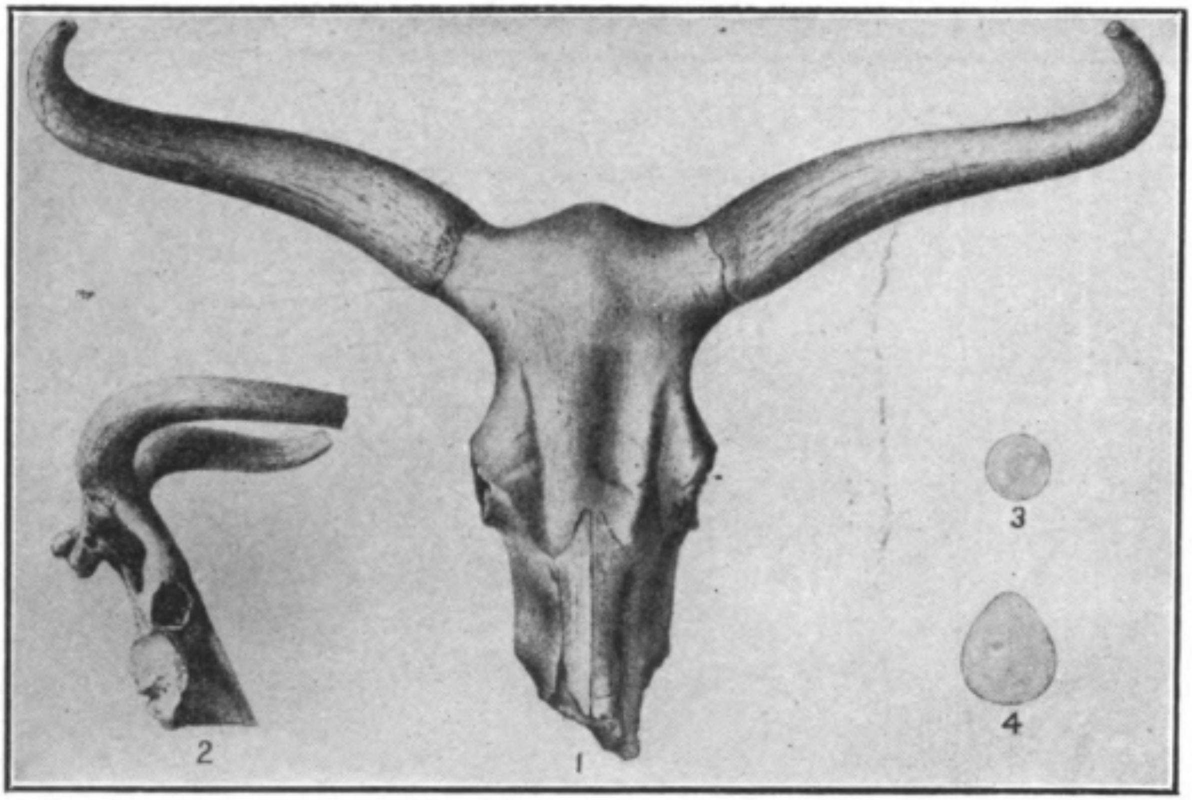

Figure 14. *Bos namadicus* skull in two views, with cross section of horn near tip (3) and near base (4). Image reprint, figure 11 in E.W. Morse 1910, originally from Lydekker 1880.[1]

In 1832, a carpenter in Narsinhpúr, India spread word of a remarkable discovery made near the Narmada River (also anglicized at the time as the Nerbudda or Narbada).[2] Soon, a message reached the surgeon to the Nerbudda Commission, Dr. G.G. Spilsbury about the unearthing of a giant, with fingers up to a foot long.[3] The find, a fossilized elephant, would merely be the first of several important specimens excavated from the Nerbudda Valley. The following year, a man living on the banks of the river noticed something beneath his home,

[1] Lydekker, "Crania of Ruminants," Plate XI, 101. Reproduced in Elisha W. Morse, *The Ancestry of Domesticated Cattle* (Washington: Government Printing Office, 1912), 196.
[2] Now called the Narmada River.
[3] James Prinsep, "Note on the Fossil Bones Discovered Near Jabálpur," *Journal of the Asiatic Society of Bengal* 2 (1833): 585.

sending Spilsbury immediately to the site once again.[4] What followed was a massive excavation in the centrally located Nerbudda, reported in the *Journal of the Asiatic Society of Bengal.* After wrapping each specimen carefully the "bulky masses weighing from one to two maunds each" were carried up to 400 miles by carriage, before being transported another 600 miles to Calcutta.[5] In this haul, was what Spilsbury referred to in the report as "a real acquisition" – the head of a horned creature encased in stone.[6] The ossified skull initially drew indifference from some amateur naturalists in India, including a Dr. Irvine who supposed that the Nerbudda deposits were not ancient enough to be of any significant interest.[7] The age of the deposit was far from determined, however, and it was precisely the possibility of that beast being of a more recent age that would make it all the more intriguing for the remainder of the nineteenth century as more of its kind would be found in the Siwalik hills, formations drawing attention for their production of human and ape-like fossils. In 1859 the animal to which the horned skull once belonged, described by Spilsbury as a "fossil buffalo," was identified as a previously unknown extinct organism – the Indian aurochs, or *Bos primigenius namadicus*.[8] This discovery and subsequent identification was part of a wave of paleontological insights made during the nineteenth century that sought to correlate the geological past on a planetary scale. Through the discovery of the Indian variety, the temporality of the aurochs was made global. The patterns of investigation into different timescales in the past were extended beyond Europe, introducing their own complications and possibilities, as correlation of past periods between continents

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[4] Prinsep, "Note on the fossil bones of the nerbudda valley, discovered by G.G. Spilsbury, near nersinhpur," *Journal of the Asiatic Society of Bengal* 3 (1834): 396.
[5] Prinsep, "Fossil Bones Discovered Near Jabálpur," 585. A maund is roughly 82 lbs.
[6] Prinsep, "Fossil bones of the nerbudda," 396.
[7] *Ibid.*
[8] G.G. Spilsbury, "Notice of new sites of fossil deposits in the Nerbudda Valley," *Journal of the Asiatic Society of Bengal* 6 (1837): 488.

necessitated wrestling with larger-scale processes of migration and continental change in connection to evolutionary relationships.

This chapter extends the difficulty of ordering time introduced in the previous chapters and makes it global, on a faunal and human register. The use of fossil fauna to set the geological clock on a broader scale by correlating strata beyond Europe has until recently received less focus.[9] Yet it was in the British colonies of the nineteenth century in particular that European naturalists sought to extend their picture of the past and compare and correlate it to the geological beds unearthed through large colonial projects, including canal digging and railroad cutting.[10] In India, the use of fossil fauna turned up from such projects was given significant weight in efforts to correlate the stratigraphic layers described across Europe, and ultimately revealed the expansive scientific conclusions that could be drawn when resting reconstructions of the earth on the backs of deceased giants.

There was also a political and social dimension to the nineteenth-century European projects to reconstruct the earth's deeper past. Specifically, the sciences of geology, paleontology, and archaeology – those that dig in the dirt, and interpret corporeal evidence – were, as Pratik Chakrabarti has convincingly demonstrated, placed alongside the nineteenth-century human sciences of ethnography, philology, and Eastern history, that probed the deep past of civilizations. India has been the site of much of this latter body of work, with historians such

[9] The most recent contribution to address this dearth is Pratik Chakrabarti's *Inscriptions of Nature: Geology and the Naturalization of Antiquity* (Baltimore: Johns Hopkins University Press, 2020). David Arnold has explored the scientific endeavors of the colony in particular in his *Science, Technology and Medicine in Colonial India* (Cambridge, UK: Cambridge University Press, 2000). Matthew T. Carrano, Jeffrey A. Wilson and Paul M. Barrett have provided a general history of *dinosaur* fossil collection in India in their "The History of Dinosaur Collecting in Central India, 1828-1947," in *Dinosaurs and Other Extinct Saurians: A Historical Perspective*, edited by R.T.J. Moody, E. Buffetaut, D. Naish and D.M. Martill, (London: Geological Society of London, 2010).
[10] Chakrabarti, *Inscriptions of Nature*.

as Thomas Trautmann exploring the colonial construction of 'Ancient India' beginning with the earliest days of the British rule of Bengal.[11] The comparative projects of language, nation, and race that burgeoned from the eighteenth into the nineteenth centuries saw India placed alongside a "primitive" past Europe by the likes of Hegel, Marx, and James Mill. The colonial context of British India gave British, German, and other European so-called Orientalists access to Sanskrit texts, such as the *Manu* lawbook, first translated in 1794 by philologist William Jones, founder of the Asiatic Society of Bengal and proposer of the common origin of Sanskrit, Latin, and Greek. Colonialism itself also existed in many ways as an operational framework of comparison between metropole and colony. The colonial endeavor was carried out alongside, and legitimated by, a European view of history that saw the world through a lens of progress or stagnation, and sought to correlate the relative standing of European imperial encounters through that lens.[12]

In India, naturalists, antiquarians, and ethnographers challenged a neat divide between histories of deep-time science on the one hand, and those of humanistic reconstruction on the other.[13] Those efforts – the development of geology, paleontology, and archaeology in European and colonial settings, and the invention or reconstruction of ancient histories, languages, and people through humanistic studies – had clear affinities, and often overlapped in the pages of journals, were carried out by the same minds, and could be deployed as evidence to bolster

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[11] Trautmann, *Clash.* The German context of the complex reconstruction of the alleged Aryans has been intensely studied; see Suzanne Marchand, *German Orientalism in the Age of Empire: Religion, Race, and Scholarship* (Cambridge: Cambridge University Press, 2010) and Bruce Lincoln, "Dumézil's German War God," in *Theorizing Myth: Narrative, Ideology, and Scholarship* (Chicago: University of Chicago Press, 1999), 121-40. The construction of an image of medievalism in colonial India, and the use of Tacitus's *Germania* to that effect is discussed in Ananya Jahanara Kabir's "An Enchanted Mirror for the Capitalist Self: The Germania in British India," in *Medievalisms in the Postcolonial World: The Idea of 'the Middle Ages' Outside Europe,* ed. by Kathleen Davis and Nadia Altschul (Baltimore: Johns Hopkins University Press, 2009), 51-79.
[12] Bowler, *Invention of Progress*.
[13] Chakrabarti, *Inscriptions of Nature*.

arguments on either. The colonial backdrop of both pursuits - the humanist framing of an Indo-Europe and a seeming changeless and ancient India, on the one hand, and the paleontological and archaeological evidence of human evolution and cultural development on the other - ensured their relation to each other. In this setting, the 'empirical scientific' status of disciplines such as geology and archaeology were able to naturalize narratives of the deep past that were being drawn from the more 'humanistic' sources: the historical, ethnographic, and even mythical. This chapter demonstrates a case in which such connection between 'scientific' material and humanist views of the past were present, and yet the fossils added more complexity and in some ways pushed back on any easy integration of historical narrative and material science.

Through the institutional bonds formed by scientific societies such as the Royal Society of London, the Geological Society of London, and the Asiatic Society of Bengal, explorers of the earth's deep past worked to correlate the deep past and compare their findings between India and Europe.[14] The aurochs, *Bos primigenius,* and its genus, were one set of many organisms eventually used in these endeavors, but their presence in European discussions and physical abundance in India rendered them interesting to commentators on the past long after their discovery. That also allows them to serve as an illuminating case demonstrating the layered registers of temporality in which the aurochs was discussed, through the disciplines that studied the earth's past, and those that attempted to chart its relative societal progressions.

This chapter has three sections. The first section follows the difficulties of setting the geological clock discussed in Chapter 1 to 'colonial time,' by recounting the institutional infrastructure developed to sustain fossil discovery and interpretation in India. It introduces the Indian aurochs within that context, and traces it and its genus' role in correlating the important

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[14] Arnold, *Science,* 29.

Tertiary and Post-Tertiary geological beds of the Jumna, Siwalik, Nerbudda, and Sind. The second section explores the enterprise of "cattle origins research," and how its evolutionary picture expanded with the fossil finds in India; the presence of fossilized bovine species in India raised enough questions about bovine evolution and biogeography to spin a remarkably wide picture of evolution, extinction, migration, climate, and mountain uplift. Eventually, the Indian aurochs was considered much older than the European variety, and the finding of an even older purported ancestor to both, *Bos acutifrons,* cemented India as the site of bovine evolution. The third section explores the relation of the Indian aurochs discourse to theories of human societal development and the role of cattle domestication in advancing civilizations. The British colonial project on the Subcontinent was turning up fossil fauna and early hominin evidence, while Sanskritologists and archaeologists continued pursuit of the deep past of India, which some argued to be fascinatingly static and in need of explanation.[15] The past domestication of the aurochs in India and in Europe was considered concomitant with human societal development, and indeed indicative of societal progression. The temporality of the aurochs, therefore, accrued another layer and another discipline to study it: that of the ethnologists and Orientalists who leaned on the comparative and anachronistic process of mapping contemporary peoples in colonial contexts onto past stages of civilization.

GEOLOGICAL CLOCKS ON COLONIAL TIME

Following that first documented Indian aurochs find in 1833, it was clear that an important and notably rich mammaliferous vein had been opened in India's geologic past. Over the remainder of the nineteenth century, the *Journal of the Asiatic Society,* once named *Asiatick*

[15] Trautmann. *Clash,* Chapter 2, "Indian Time, European Time."

Researches, played host to paleontological discourse on the Indian aurochs. In the nineteenth century a wealth of fossil discoveries was published in the *Journal of the Asiatic Society of Bengal*. They were hailed as increasingly filling a gap in knowledge of India's faunal past – a gap which European naturalists had been lamenting. Richard Owen, for example, provided a brief but telling summation of the state of European research into the geological past around the globe. He claimed that in order to determine the geological relations between fossil fauna and then to correlate their deposits, much more work was needed, particularly beyond Europe.[16] Over the nineteenth century, initially through the work of isolated amateurs such as Spilsbury, and eventually under the direction of the Geological Survey of India, those able answered the call for more data. The efforts began as scattered collection trips, the hauls of which were identified in the Asiatic Society's museum in Calcutta. From there, geologists set about ordering India's geologic past in a project reminiscent of that of Europe, represented by the Geological Survey's 1877 first edition of the *Manual of the Geology of India*. That compilation of geological and paleontological work demonstrated how much the gap in knowledge had been filled towards the end of the nineteenth century.[17] It is towards that 1877 publication that this section builds.

The community of scholars in pursuit of this work made their home in the Asiatic Society. In 1784, a meeting of European citizens living in Calcutta and led by philologist William Jones resolved to found a society for investigation into the literary, historical, artistic, and natural objects of India.[18] With the establishment of the Asiatic Society, an institutional bridge was formed between British colonial science in India and its metropolitan counterparts,

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[16] According to Owen, "the researches by which such knowledge is to be attained are far from being complete. In many countries the fossil remains of former races of animals have neither been found nor sought; where the quest has commenced it dates but a few years back." Owen, *British Fossil Mammals,* xiii.
[17] Medlicott and Blanford, *Manual of Geology of India*.
[18] Monie Bagchee, *The Asiatic Society: A Brief History* (New Dehli: People's Publishing House, 1984), 5.

including the Royal Society and the Geological Society of London.[19] In 1832, the *Journal of the Asiatic Society of Bengal* was formed.[20] The first issue of the *Journal*, edited by James Prinsep, included the very first notice of the fossil finds from the Nerbudda, including the Indian aurochs.[21] The journal's pages also boasted content on natural history, religion, geology, language studies, and literature.[22] In scope, the *Asiatic Society* was to encapsulate the "geographical limits of Asia;" including the "study of man and nature; all that is performed by the one and produced by the other."[23] The society and its products, therefore, sought to plumb the depths of India's past through custom, language, and natural history – complementary projects serving to link Europe and India in the deep past. In this way it mirrored its founder's own contribution: William Jones' proposition of a shared origin for Sanskrit, Greek, and Latin, and the peoples that had written in those languages.

Despite the headway made by the founding of the Asiatic Society, colonial scientists still bemoaned a lack of scientific infrastructure in colonial India for the difficulty in identifying and correlating the fossil-rich geological strata. Those Nerbudda deposits were turning up interesting finds, ones that evidenced its possible relation to the Tertiary/Post-Tertiary divide discussed in Europe at the time as marking the Biblical deluge. In 1834, Prinsep targeted the lack of logistical supports in India that would have otherwise been enjoyed in Europe had specimens such as the

[19] *Ibid.*, 26.
[20] *Ibid.* In 1793, the Asiatic Society published the first volume of its original periodical, *Asiatic Researches,* which was sold in England five years later and then translated into French to be sold in Paris. In 1832, the *Journal* subsumed the papers of *Asiatic Researches,* promising frequent and, most importantly, regular publication, unlike its predecessor. See Bagchee, *Asiatic Society* for more.
[21] James Prinsep, "Note on the Jabalpur Fossil Bones," *Journal of the Asiatic Society of Bengal* 1 (1832): 456-458.
[22] Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900* (Hampshire, UK: Palgrace, 2006), 106.
[23] *Ibid.,* 121.

"fossil buffalo" been found there instead.[24] According to Prinsep, there would certainly be more such intellectually lucrative finds in India,

> even by the persevering exertions of one individual; but a field of so great promise, were it in Europe, would not be left to such slow cultivation. It would be made the object of a special expedition of scientists (as they are called at Cambridge), from the Government, or from some geological association, and the impatience of theorists would soon be satisfied with a full history of the antediluvial or postdiluvial tenants of the Nerbudda fossil basin: for it is by no means clearly established yet to what epoch the debris belong.[25]

The need for further information about the Nerbudda beds, furnished by supported expeditions, would be met. Further excavation in the proven fossil grounds of the Nerbudda and the Sub-Himalayan deposits by Scottish surgeon and botanist-turned-paleontologist, Hugh Falconer, and by Proby Cautley a decade later provided the impetus for greater geological and paleontological backing. By 1851, Thomas Oldham, the former director of the Geological Survey of Ireland, was sent to develop the Geological Survey of India in its official formation, affording British naturalists even greater support and opportunity to explore geological, zoological, botanical, and paleontological India.[26] With collections being amassed at an increasing rate from the 1830s on, the task of the naturalists became two-fold: maintain the influx of specimens and analyze them. Even with the growing institutional support, dating the Indian fossil beds proved tricky.

The early publications on the Nerbudda fossil deposits indicated that the formations contained an astonishing abundance of ruminants – those same regurgitating creatures to which bovines, and the aurochs, belonged. In particular, the genus *Bos* was noted, and publications about its findings drew directly from the work of European heavy hitters, such as Cuvier and Lyell. The intellectual as well as faunal links between geological work in Europe and India were

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[24] Prinsep, "Fossil bones of the nerbudda," 402.
[25] *Ibid.*
[26] Arnold, *Science*, 25.

strong. In 1834, the *Journal of the Asiatic Society's* report of Spilsbury's horned animal skull drew heavily from the work of Cuvier. Using a copy of Cuvier's plates of genus *Bos,* Prinsep compared the cranium of the Indian fossil beast to the largest fossil ox cranium at the Jardin des Plantes of Paris and found the Indian variety to be larger in every aspect considered.[27] Prinsep noted how fortunate it was that the skull of the animal had been preserved, recalling Cuvier's specific argument for the ruminants: namely, that "the forehead and skull, with or without horns are the only parts upon which reliance can be placed for determining the specific character of the ruminatia."[28] Prinsep concluded that the characteristics of the skull suggested it was something other than the domestic ox or even the aurochs described in Europe.[29]

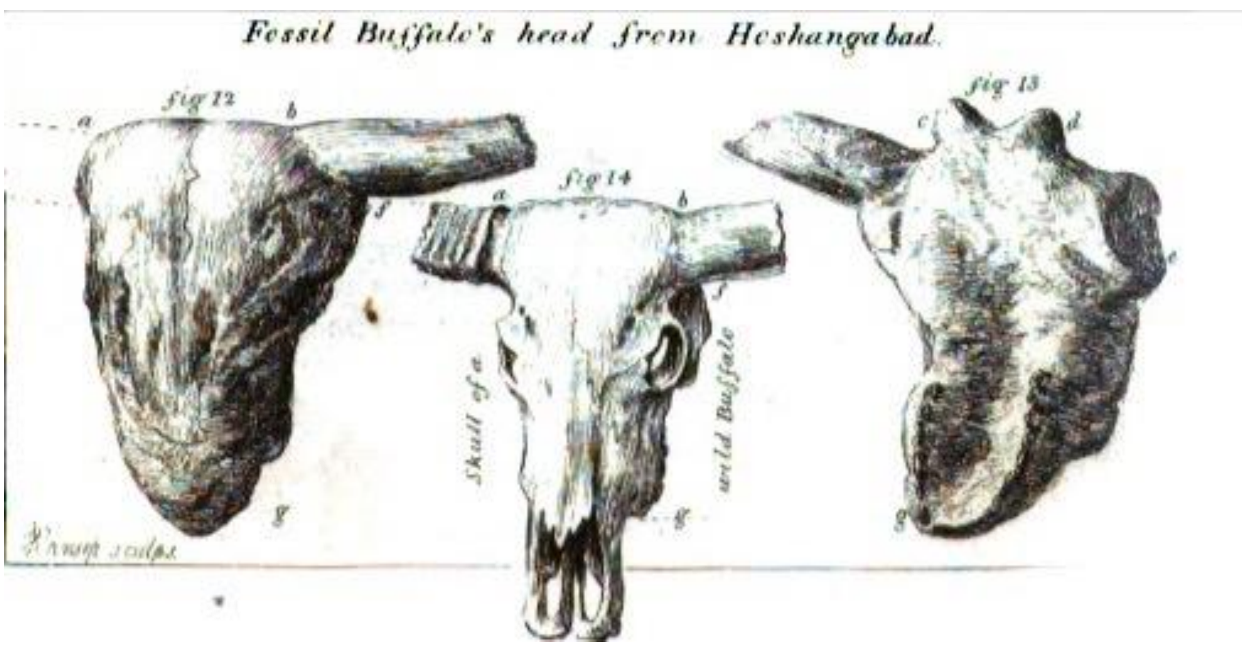

Figure 15. "Fossil buffalo" described by Prinsep in the Nerbudda Valley. [30]

Hugh Falconer, who would go on to win the Wollaston Medal from the Geological Society of London for his work on the Siwalik hills, later labeled those original 1832 and 1833

[27] Prinsep, "fossil bones of the nerbudda," 397, 401.
[28] *Ibid.,* 400.
[29] *Ibid*.
[30] The "fossil buffalo," figure 3 in Prinsep, "fossil bones of the nerbudda," 400.

"fossil buffalos," as Spilsbury had referred to them, under a new name: *Bos namadicus,* named for the river near which it was found. Using horn-core fragments, Falconer resolved that there was "conclusive evidence of a fossil species of *Bos* from the Nerbudda distinct from both *Bos palaeindicus* and Gour [*sic*] and Gayal, or any other described existing form."[31] The specimens which Falconer described as *Bos palaeindicus* would later be resolved into the extinct Asian buffalo, *Bubalus palaeindicus,* while the gayal was a domesticated large cattle believed to be related to the extant humped gaur (figure 16). Two more specimens, both donated by Spilsbury were given the name *Bos namadicus*.[32] In the description of the final specimen that Falconer classified as *Bos namadicus,* he used Cuvier's methods to make a comparison: *Bos namadicus* appeared to exhibit "a considerable resemblance to the taurine division of *Bos* as represented by *Bos primigenius,"* the European aurochs.[33] The same European aurochs that continually featured in attempts to identify the Tertiary/Post-Tertiary divide in Europe had an Indian relative. Its genus *Bos* was found in striking abundance in the Sub-Himalayan Siwalik deposits named by Falconer and Cautley, which ensured its repeated cameos in attempts to describe and date the beds and determine the Tertiary/Post-Tertiary divide in India.

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[31] Hugh Falconer, *Descriptive Catalogue of the Fossil Remains of Vertebrata: From the Sewalik Hills, the Nerbudda, Perim Island, &c. In the Museum of the Asiatic Society of Bengal* (CB Lewis, Baptist Mission Press, 1859), 232.
[32] *Ibid.*, 232, 241.
[33] *Ibid.*, 243.

GAUR.

BULL GAYAL.

Figure 16. Illustrations of two bovines that are not aurochs: “Gaur” and “Bull Gayal” from Lydekker 1898.[34]

[34] Plate I of Richard Lydekker, *Wild Oxen, Sheep, and Goats of All Lands, Living and Extinct* (London: Rowland Ward, Ltd., 1898).

Falconer, though poised to be the right naturalist for the job of taking *Bos* to its full analytical potential in India, never published his planned ruminant volume of his massive compendium on the paleontological findings in India, *Fauna Antiqua Sivalensis*.[35] Nevertheless, *Bos* continued to rear its massive horned head, and geologist Charles Murchison took up the mantle of editing Falconer's works after he died, publishing *Palaeontological Memoirs and Notes of the late Hugh Falconer* in 1868. The work provided an entrée into the abundance of Indian fossil ruminants, to which the previous decades of scattered publications in the *Journal of the Asiatic Society* had been hinting. The fossils, "either collected at the foot of the cliffs, or blasted out of rock, or excavated" from the Siwalik Hills revealed the "surprisingly rich" trove of ancient ruminants.[36] Those fossils of the Siwalik Hills reappeared as a central element nine years later in the first edition of the official *Manual of the Geology of India* published by the Geological Survey Office. There, they became possible evidence, albeit burdened by the same kinds of inferential constraints of the aurochs in Europe, of an elusive Indian Tertiary/Post-Tertiary divide.

With the hordes of ossified *Bos* excavated and identified across India, naturalists could begin attempting to date the strata, and perhaps identify that essential divide of the latest geological era. In Europe, several tactics, including changes in fossil fauna and presence of glacial vestiges, were discussed as possible reliable indicators of the divide. If naturalists in India could correlate the strata of the mammaliferous beds of the Sind, Siwalik, Narbada, and Jumna,

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[35] Falconer and Cautley planned to publish their work in 12 parts, each dealing with a different fauna, including one on ruminants. The only one completed was their first volume on pachyderms in 1849. Hugh Falconer, "Prospectus for publication, under the auspices of Her Majesty's government, and of the Honourable the Court of Directors of the East India Company: A Work to be Entitled, Fauna Antiqua Sivalensis," *Journal of the Asiatic Society of Bengal* XIV (1845).

[36] Charles Murchison, ed., *Palaeontological Memoirs and Notes of the Late Hugh Falconer: With a Biographical Sketch of the Author Compiled and Edited by Charles Murchison* II (London: Robert Hardwicke, 1868), 22.

among others, to the European epochs of the Eocene, Miocene, Pliocene, and Pleistocene/Recent (and thereby Tertiary/Post-Tertiary), they could connect the geological world at an incredibly important bygone time – a potentially catastrophic global cold period and the arrival of humanity.

By 1877, the myriad paleontological and geological findings of India, including of the Tertiary/Post-Tertiary divide were compiled by the Geological Survey of India into the first edition of the *Manual of the Geology of India.* The *Manual,* published at the Calcutta Geological Survey Office, was largely assembled from Geological Survey observations under the direction of the Survey's then-superintendent, Henry Benedict Medlicott.[37] The *Manual* authors acknowledged the difficulty faced by geologists attempting to delineate the Tertiary/Post-Tertiary boundary in the strata examined. This difficulty mainly stemmed from the imperfect faunal fit between the European strata and the Indian deposits. In 1877, the *Manual's* authors would describe the difficulty of their task as follows: the "great European sub-divisions of the geological sequence – palaeozoic, mesozoic, and tertiary or cenozoic – are ill adapted for the classification of the Indian beds."[38] The *Manual* acknowledged decades of largely unsuccessful attempts to adapt the European geological sub-divisions to Indian geology, in which it was "very difficult to draw a clear and distinct line between tertiary and post-tertiary formations."[39] While the boundary between the two in Europe was understood by the 1870s to clearly "coincide with

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[37] Medlicott and Blanford, *Manual of Geology of India*, 11. Medlicott is credited with the term "Gondwana." For more, see Alison Bashford, Pratik Chakrabarti, and Jarrod Hore, "Towards a Modern History of Gondwanaland," *Journal of the British Academy* 9s6 (2021): 5–26, https://doi.org/10.5871/jba/009s6.005.
[38] Medlicott and Blanford, *Manual of Geology of India*, xii.
[39] *Ibid.,* 371.

the glacial epoch," there was no physical evidence, such as glacial traces, of the "cold period" in the peninsular regions of India, leaving fossils as the main boundary marker to be used.[40]

Despite the difficulty of correlating European and Indian strata, the European geological chronology was not relegated to the footnotes of the *Manual*. After all, establishing an entirely new stratigraphical chronology in India would have not only been more laborious in the eyes of the British geologists, it also would have conceded deficiency in the fine-tuned stratigraphic system being worked out in Europe, increasingly seen as a natural standard by its creators. The *Manual* therefore conceded that it would "often be necessary to refer to particular beds in Europe" in the discussion of Indian strata, and provided a list "arranged in the accepted sequence" of the minor formations and larger groups of strata from England, France, Germany "and some other parts of Europe" in order to aid readers.[41] The *Manual* thus established in its introduction the major aim of the compiled decades of work – an attempt to find European correlates in distinct Indian geological deposits. In other words, to map India's deep time using as much as possible the benchmarks of Europe's past.

The *Manual* put forward several lists of Indian formations correlated, as much as was possible, to their European counterparts. Four formations in particular are worth highlighting for their placement along the Tertiary/Post-Tertiary: the peninsular Narmada (or, Narbada/Nerbudda as used by Spilsbury and Prinsep); the peninsular Jumna alluvium; the extra-peninsular Sind; and the extra-peninsular Siwalik (or, Sewalik as used by Falconer).[42] The Narmada, referring to the

40 *Ibid.*
41 *Ibid.,* lxxv.
42 The *Manual* uses "Narbada" to refer to the same "Nerbudda" used by earlier publications, such as those by Spilsbury and Prinsep. Several other formations discussed to some extent in the *Manual* also correspond to an age within the Tertiary/Post-Tertiary time span – these include Assam, Perim Island, and the deposits of Cutch. They are not addressed in this paper due to relative dearth of discussion in the *Manual* and their less contentious ages.

sites explored by Spilsbury beginning in the early 1830s, and the Jumna alluvium, surrounding the Jumna River just west of the Ganges, were correlated to a Post-Tertiary deposition, though their ages relative to one another was decidedly more contentious. The Sind formation in the northwest, and especially the Siwaliks of the Sub-Himalayas required much more nuanced reasoning to correlate to their analogues in Europe. The determination of age for each of these formations relied in part on the absence, presence, or in some cases, abundance of *Bos* specimens.

Figure 17. The 1877 Preliminary Sketch of the Geology of India Map.
Arrows indicating fossiliferous Narbada, Jumna, Sind, and Siwalik localities.[43]

As in the centrally located Narmada, from which that first haul was excavated, the sub-Himalayan deposits of the Siwalik formation suggested that an important and notably mammal-rich vein had been opened in India's geologic past. The Siwalik formations, located most

[43] "Preliminary Sketch of the Geology of India," Calcutta: Office of the Surveyor General of India, 1877, University of Chicago Special Collections, QE295.A51.

abundantly in the Sub-Himalayan hills, were given that name by Colonel Proby Cautley on his 1830s expeditions with Hugh Falconer.[44] Though named for a site east of the Jumna River, the classic beds of the Siwaliks that generated the bulk of those original fossil collections came from the Nahan area of the Punjab.[45] There, the Geological Survey first studied the Siwalik formations and distinguished between upper, middle, and lower Siwalik beds based on the relative composition of clays, sandstone, and conglomerates.[46] The establishment of such a distinction based on the sediments themselves, would, according to the *Manual,* "always be necessary," even if that distinction "should not be maintained by fossil evidence" later on.[47] Comparing the rock composition – or, lithography – across Indian formations could greatly aid correlation, and yet the *Manual* still proceeded to build the arguments for the ages of the formations around the complicated nature of the fossil fauna and not the lithography. Correlating strata within India was a different beast than correlating between Europe and India. The seeming impossibility of the same sediment being deposited at the same time in the past in both Europe and India ruled out using lithography alone to set the global geological clock. The possibility of a shared fauna between the two regions, however, offered a promising analytical tool that naturalists in India put to the test in the Siwalik and Sind formations.

Hugh Falconer and Proby Cautley had explored the deposits full of diverse genera and species. The abundance of ruminants in the Siwaliks was striking. Falconer had noticed the wealth of ruminants in the sub-Himalayas in notes that were published posthumously. He reported that the "fossil ruminants of the Sewaliks are surprisingly rich, and include almost every

[44] Medlicott and Blanford, *Manual of Geology of India*, 541.
[45] *Ibid.,* 535.
[46] *Ibid.,* 536.
[47] *Ibid.*

type, fossil or recent, known in the order," especially "numerous species of Bovidae."[48] The Siwalik Hills promised a fossil record from which Indian strata could be correlated to those of Europe. In their published proposal for *Fauna Antiqua Sivalensis,* Falconer and Cautley initially dated the Siwalik beds without much precision to the Tertiary or Post-Tertiary.[49] Despite the rich findings of the Siwaliks, including ruminants, the age of the beds was contentious. Even in the 1877 *Manual* arguments for the age of the Siwaliks were presented without conclusion.

By the 1893 *Manual* edition, those ruminants were still seen as a potentially useful, but presently problematic, tool. According to that edition, "investigating the question of age" meant geologists were "consequently forced to depend, first upon the vertebrata, and especially the mammalia."[50] From there, using ruminants, and in particular *Bos,* made sense given their abundance. Of course, as was known in Europe, ruminants and *Bos* came with confusing preservation peculiarities, anatomical affinities between extinct and extant forms, unclear extinction timelines, and even less certain ancestral relationships that would all need to be somewhat resolved if they were to serve as successful tools for correlating strata. Attempts to date the Siwaliks using *Bos* would compel naturalists to address those broader lines of inquiry.

Initial consideration of Siwalik fauna revealed a puzzling picture: the fauna overall resembled that of the European Miocene (mid-Tertiary) deposits, yet it exhibited a much larger proportion of recent and living genera than did the European Miocene beds. The picture was thus: based on overall fauna, the deposits might be correlated to mid-Tertiary deposits, but then explanation was needed for the unexpected presence of recent and living genera that were absent in the European beds. The surprisingly well-represented recent genera included the ruminants

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[48] Murchison, *Palaeontological Memoirs*, 22-23.
[49] Falconer and Cautley, "Prospectus," xlvi.
[50] Richard Dixon Oldham, ed., *A Manual of the Geology of India* 2nd Edition (Calcutta: Geological Survey Office, 1893), 359.

and the genus *Bos*.[51] Within the Indian Siwalik beds were four extinct genera that in Europe were found only in the Miocene (mid-Tertiary) formations, and sixteen "more recent" genera, found in the Pliocene (late-Tertiary) and Post-Tertiary formations of Europe, in an odd mixture of extinct and recent, Tertiary and Post-Tertiary forms.[52] A clearer distinction between recent – or, similar in form to living species - and extinct *Bos* were used to determine the comparative ages of the Jumna and Narbada beds with relative ease. In the Siwaliks, however, the blend of fauna similar to European Miocene, Pliocene, and even Post-Tertiary fossils complicated matters. Thus, the "difficulty, already noticed, of drawing a definite line between the tertiary and the later beds is exemplified, for, in the uppermost beds of the Siwalik series, some mammalia are represented, of which the bones are also found in the older valley deposits of Peninsula."[53]

Two options were therefore available to naturalists: the Siwalik formations were old (dated to some time during the Tertiary), and the recent genera like *Bos,* had simply evolved into forms that conformed to their recent, specialized types much earlier in India than in Europe, and therefore appeared quite early in India's fossil record in that recent conformation. The other option was that the Siwalik formations were young (Post-Tertiary), and the extinct fauna in the Siwaliks that resembled the older Tertiary of Europe had simply survived much longer in India than in Europe. The authors of the *Manual* went with the latter option, citing the presence of *Bos* in the deposits.[54] Fossil *Bos,* including the Indian aurochs, appeared so similar to living species of cattle, and therefore the Siwalik beds were most likely young, they argued, albeit with an

[51] *Ibid.,* liv.
[52] *Ibid.,* 580.
[53] *Ibid.*
[54] Medlicott and Blanford, *Manual of Geology of India,* 580. 'Specialized' here is used in the nineteenth-century sense employed by the editors of the *Manual.* It stands in contrast to the kinds of rudimentary, unspecialized forms like the "intermediate" pig-ruminant form found in the Miocene Manchhars of the Sind.

abundance of early Tertiary fauna that had gone extinct in Europe at a much earlier period than in India. India, according to the paleontological evidence of the *Manual*, had not only evolved an aurochs around the same, younger, period as Europe had; it also had remained largely unchanged in its older fauna, with older types persisting into the recent periods. Such a picture in some ways paralleled Orientalist depictions of an unchanging India – an India without history – by matching India's paleontology to Europe's geological clock, while also allowing for slow changes of fauna, imperceptible to the paleontological eye. Yet to the geologists, the presence of the older faunal forms in the Siwaliks were not due to stasis, they were due to migration.

Upon its exhumation, the fossilized genus *Bos* in India offered a means to correlate geological periods between Europe and India – one that spoke directly to the advances made in evolutionary theory during the same period. Its potential utility in this vein stemmed from its abundance in the Indian rock formations. Yet the same inherent difficulties of the genus discussed in Europe forced colonial scientists to steep themselves in questions of bone preservation, migration, and extinction in order to solve the puzzle of the Indian aurochs' age. In anatomical form and epistemic challenges posed, the European aurochs it seemed, had an Indian cousin.

Finding connections between bovine fauna across vast geographies was not only the purview of naturalists in India. The colonial enterprise of the French in North Africa yielded yet more aurochs-like fossils and deepened associations between early *Homo* and cattle evolution. In 1881 Philippe Thomas, an army veterinarian based in Algeria published his findings and classification of the Eocene formations in Algeria. His "Recherches sur les bovidés fossils de l'Algérie" ("Researches on the bovidae fossils of Algeria") was circulated in the bulletin of the Zoological Society of France, and described what he determined was an African variety of the

European aurochs, *Bos primigenius*.[55] A tibia and astragalus bone were found in Algeria, and Thomas provisionally attributed them to *Bos primigenius,* placing them at the end of the Tertiary period. From his observations across Algeria, from the Mediterranean coast and into the Sahara, Thomas concluded that the end of the Eocene yielded the ancestors to Bovidae, but only towards the end of the Tertiary did the first true Bovidae appear.[56] In those intervening epochs of the Oligocene, Miocene, and Pliocene, the Bovidae slowly took their form, passing through a series of successive transformations that led, according to Thomas, from pachyderms to ruminants. Thomas described only two fossil Bovidae of Algeria in the text, reportedly found in the Algiers and Constantine provinces in low-level alluvium, and dated to what in the predominantly French system would be called the Recent Quaternary period, or the "Post-Tertiary." One was a "huge buffalo," which he deemed analogous to species extant in India such as the gaur; the other was a large ox which he called a variety of *Bos primigenius* from Europe, and to which he gave the name *Bos primigenius mauritanicus* to signal the geographic distinction of this aurochs variety.[57] Such ox remains resembled the "Neolithic species" described by Rütimeyer as *Bos primigenius,* and Thomas noted their existence also in the Tertiary in northern Africa, as the tibia and astragalus were found in Pliocene deposits around Constantine Province.[58]

It was clear at the end of the nineteenth century that the geographic distribution of aurochs varieties had been far broader than the expanse of Europe. By the early 1900s, wild oxen of the *Bos primigenius* type could be said to have existed alongside man on every continent except the Americas, Australia, and Antarctica. In 1910, Elisha Wilson Morse, at the Office of

[55] Phillippe Thomas, "Recherches sur les bovidés fossiles de l ' Algérie," *Bulletin de la Société Zoologique de France* 6 (1881): 92 – 136.
[56] Thomas "Recherches," 135.
[57] *Ibid.,* 136.
[58] *Ibid.*

Experiment Stations in the US Department of Agriculture synthesized the findings of fossil bovines from the prior century in a work dedicated to understanding animal breeding, dairy production, and domesticated animals. His *The Ancestry of Domesticated Cattle,* published by the Government Printing Office in Washington as part of the Annual Report of the Bureau of Animal Industry, sought to bring together the scattered progress made by all – "zoologists, paleontologists, anthropologists, and historians" – who worked on the "difficult problem" of cattle origins.[59] In it, he tabulated the geographic and temporal distribution of bovines, signaling a largely synchronous early existence of *Bos primigenius* in Asia, Africa, and Europe (figure 4).[60] Falconer's findings in India and Thomas's discoveries in Algeria piqued interest for their relation to the Tertiary/Post-Tertiary divide, and through their very existence in different places and at different depths of the past a more global picture of cattle evolution could be formed in the wake of Darwin and these discoveries.

[59] Morse, *Ancestry of Domesticated Cattle,* 187. Morse's 1910 *The Ancestry of Domesticated Cattle* in the 27th Annual Report of the Bureau of Animal Industry was reprinted as Elisha W. Morse, *The Ancestry of Domesticated Cattle* (Washington: Government Printing Office, 1912).
[60] *Ibid.,* 193.

PLIOCENE EPOCH.

Geolcgical distribution of the principal species of wild oxen.

Geological epoch.	Asia.	Africa.	Europe.	America.
Recent.	*Bos primigenius.* *namadicus.* *indicus* (zebu). *Bibos gaurus* (gaur). *frontalis* (gayal). *sondaicus* (banting). *Peophagus grunniens* (yak). *Bubalus* (many species).	*Bos indicus.* *Bubalus caffre* (5 races).	*Bos primigenius.* *Bison bonasus.* *caucasicus.*	*Bison bison.*
Pleistocene.	*Bos primigenius.* *namadicus.* *Leptobos fraseri.* *Bison priscus.* *Bubalus palæindicus.*	*Bos primigenius.* *mauritanicus.* *Bubalus antiquus.* *Bison priscus.*	*Bos primigenius.* *Bison priscus.* *Bubalus pallasi.*	*Bison latifrons.* *occidentalis.* *antiquus.* *crassicornis.* *alleni.* *ferox.* *bison.*
Pliocene.	*Bos acutifrons.* *planifrons.* *Leptobos falconeri.* *Bison sivalensis.* *Bubalus triquetricornis.* *acuticornis.* *platyceros.*		*Leptobos elatus.* (*etruscus.*)	Bison [?].

Figure 18. Chart of Geological distribution of principal species of wild oxen.[61]

GLOBAL CATTLE ORIGINS

Through colonial expansion and its infrastructure supporting natural history collections and expeditions, the nineteenth century rapidly generated wide spanning pictures of faunal evolution and migration, as living and extinct forms around the globe indicated deep natural relations between continents. Biogeographical insights yielded theories of migration, climate change, evolutionary relations, and even continental movement. Prior to Alfred Wegener's 1912 paper arguing the existence of continental drift, naturalists had hypothesized and raised doubts about the possibility of continental movements, and few naturalists in the nineteenth century

[61] Morse, *Ancestry of Domesticated Cattle*, 193.

escaped without commenting on the possibility.[62] The period made good use of the mad dash to collect knowledge of the natural world, creating broad synthesized theories about large-scale world processes based on the collections.

Almost a decade before British naturalist and biogeographer Richard Lydekker, who himself would join the Geological Survey of India in 1874, published his 1898 tome on the *Wild Oxen, Sheep, and Goats of all Lands, Living and Extinct,* he released a string of works of his own evaluations of the vertebrate fossils that had been found in India. As part of his work, he revisited Falconer's writing, aiming to add clarity to a mess of fossils whose corresponding descriptions were not always clear. In some cases, the specimens were lost, leaving only Falconer's written words. Lydekker took his own measurements of the specimens, comparing them to Falconer's work along with descriptions of relevant forms by the likes of Boyd Dawkins and Rütimeyer, and published his *Crania of Ruminants from the Indian Tertiaries,* as part of the *Memoirs of the Geological Survey of India* in 1880. This publication was based on and then followed up by several publications in the *Records of the Geological Survey of India,* from 1877, 1883 and 1887. Taken together these publications served as a posthumous completion and revised addition to the volume of *Fauna Antiqua Sivalensis,* which were left unfinished by Falconer after his death in 1865.

Lydekker furthered his examination of the origin of familiar domesticated animals in 1898 with his *Wild Oxen, Sheep & Goats of All Lands, Living and Extinct.* The work began with

[62] Alfred Wegener summarized his theory in "Die Herausbildung der Grossformen der Erdrinde (Kontinente und Ozeane), auf geophysikalischer Grundiage," *Geologische Rundschau* 3 (1912): 276-292. See Janet Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven, CT: Yale University Press, 1983) and Alan de Queiroz, *The Monkey's Voyag*e: *How Improbable Journeys Shaped the History of Life* (New York: Basic Books, 2014) for more on biogeography in general and its history. Predecessors of Wegener included Alfred Russel Wallace, Charles Lyell, James Dwight Dana, Edward Suess, Roberto Mantovani.

the aurochs, what he called the "wild race," and continued to be widely cited well into the mid-twentieth century. Lydekker's task was a tricky one, and beneath his often dry and methodical writing was a vast undertaking: to synthesize disparate publications on scattered fossils and living animals from around the world, bringing together scientific tracts in a range of languages and of different caliber. Some of the difficulties incurred in sorting the mess of unidentified, misidentified, and otherwise contentious forms included rectifying "newly discovered" species that were simply females of already known species – a frequent conundrum even for vertebrate paleontologists today. Through his work and the citations he brought together, Lydekker created a web of connections between separate findings: he operated as an arbiter on whether certain specimens truly were separate or the same species, classifying when in time they had existed, and then based on geographical location, offering a picture of their distribution and migration. As part of his work, Lydekker referred to climate and mountain formation. The presence of fossil forms such as the Indian aurochs would lead those thinking about the deep past to reconstruct what the environments may have been like when bovines, and perhaps even humans, had evolved. Through the prism of works such as Lydekker's, evidence was marshalled to reconstruct a world according to the aurochs and its ilk. Sorting out the ilk, however, was quite a feat itself.

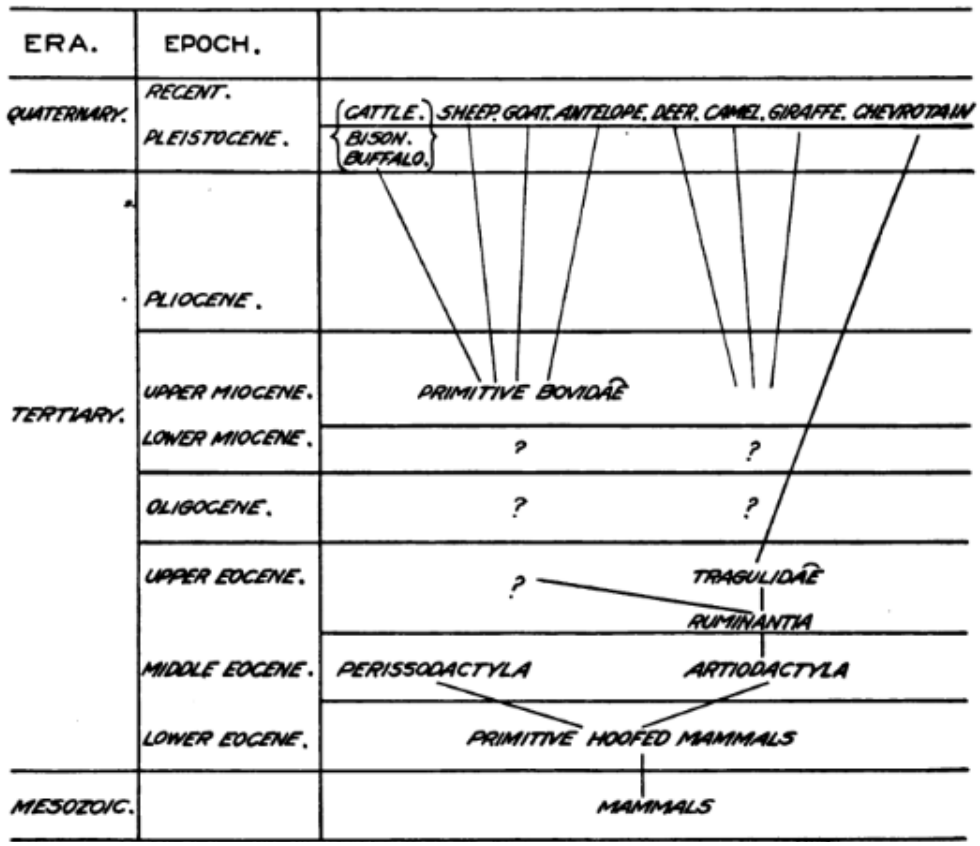

Figure 19. Diagram showing understood geological position of Bovidae in 1910.[63]

[63] Morse, *Ancestry of Domesticated Cattle*, 190.

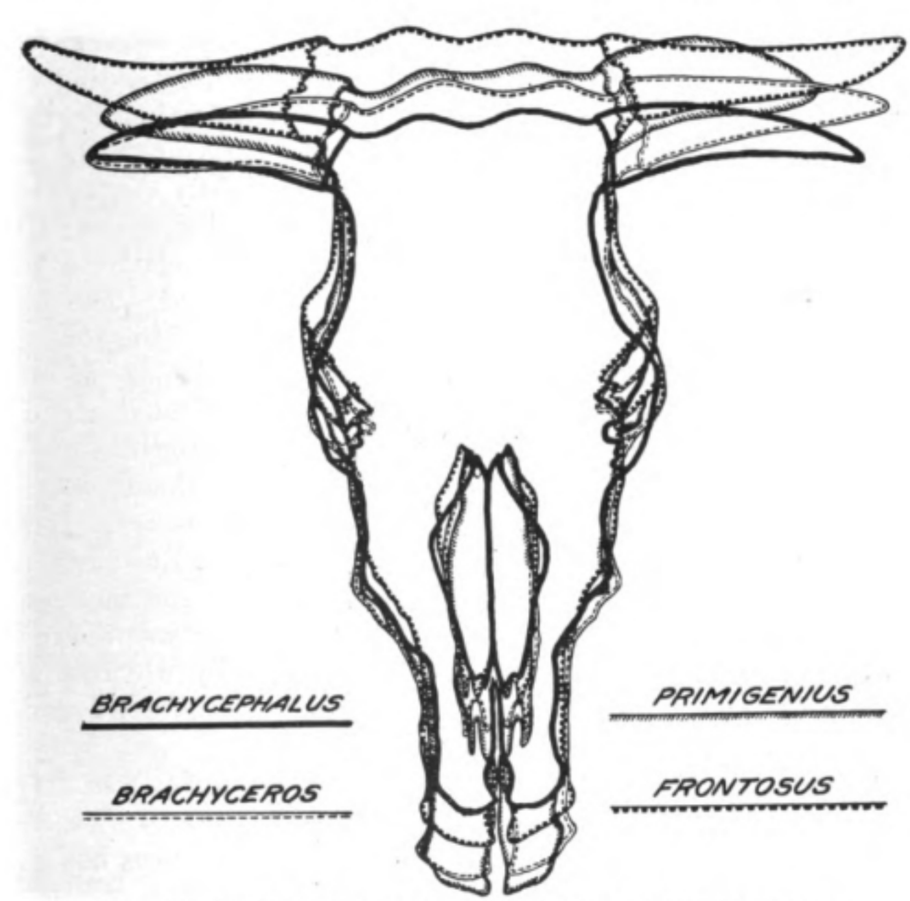

Figure 20. Frontal view of four types of skulls.[64]

Since the eighteenth century, uncovering the origins of cattle drew the attention of naturalists. Several systems for classifying fossil finds and living domesticated cattle existed, though skulls and horns were predominantly used in German and several British studies.[65] Through predominantly their skulls, the true relation of *Bos namadicus,* the Indian aurochs, to

[64] *Ibid.*, 197. He used Wilckens, 1876 for the measurements as well as the image.
[65] Marleen Felius, Peter A. Koolmees, Bert Theunissen, European Cattle Genetic Diversity Consortium, and Johannes A. Lenstra, "On the Breeds of Cattle—Historic and Current Classifications," *Diversity* 3, no. 4 (2011): 660-692. https://doi.org/10.3390/d3040660. Felius, Koolmess, Theunissen et al. had argued that cranial horn-type classifications were largely adopted by German-speaking individuals, while British "largely ignored the German cranium theories." For those working with paleontological specimens, however, such as Lydekker and Falconer, other means of discerning classifications such as coat color were unavailable.

the European aurochs was sought, but it was not a ready fact. *Bos namadicus* resembled in some ways the sub-genus *Bibos,* represented by the gaur, gayal, and banting in South Asia.[66] In particular, some specimens of the Indian aurochs displayed horn cores that were a bit flat towards the base, in a way similar to the Bibovine type (figure 14 demonstrates the somewhat flattened cross-section of one such specimen). As Morse wrote in 1910:

> *Bos namadicus,* the Narbada ox (fig. 11) [figure 14 in this thesis], first described by Falconer and later called paleogarus by Rütimeyer, is one of the best known species of extinct Indian oxen. It is so closely allied to *Bos primigenius* that it is now considered as the Asiatic and probably older form of primigenius. In some specimens the horn cores are somewhat flattened at the base, which shows a close relationship to the Bibovine type. Lydekker suggests that it may have been the ancestor of both the Bibovine and Taurine types, and at the same time a descendant of *Bos acutifrons. Bos namadicus* was a contemporary of early man in India during the Old Stone period and has recently been found in the lowest layers of the deposits at Anau, Turkestan.[67]

The distinct elements that aligned *Bos namadicus* more closely to *Bibos* than the type species of genus *Bos* were not enough to rule out the Indian aurochs' relation to the taurine type, inclusive of the European aurochs. These evolutionary relationships relied on acute anatomical observation, as well as consideration of any evidence that would help pinpoint the distribution of the animals in time. Often comparative observation of skulls of the animals proved the most useful in classification, a priority dating back to Cuvier, but aligned with classification under evolutionary theory by Rütimeyer (figure 20 demonstrates a comparison of oxen using skulls, including *Bos primigenius* and a form of domesticated ox, temporarily given the name *Bos frontosus,* from 1910).[68] Lydekker interpreted the similarity of the Indian aurochs to the European aurochs and the Asiatic Bibovine group as indicative of it being the progenitor to

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[66] Lydekker, *Wild Oxen*, 22-43.
[67] Morse, *Ancestry of Domesticated Cattle,* 195-196.
[68] Felius, Koolmees, Theunissen, et al., "Breeds of Cattle," for more on Rütimeyer's skull type theory.

both.[69] Rütimeyer too had recognized both the Indian and European aurochs, but considered the Indian aurochs to be the progenitor of the European.[70]

As in Europe, extinctions and their causes could help create bounds for interpreting evolutionary relations. Lydekker reflected on what he saw as three possible explanations for the extinction of the Indian aurochs:

> The Nerbudda ox [the Indian aurochs, *B. namadicus*], owing to the discovery of a paleolithic implement by Mr. Hacket in the beds in which its remains occur, was at all events, during a certain portion of the period in which it existed, a contemporary of early human inhabitants of India; and the genus *Bibos,* if we adopt the view that it is descended directly from *B. namadicus,* must also have acquired its characteristic modifications of cranium within the same period. Whether man was instrumental in causing the final disappearance of the Nerbudda ox, or whether it was unable to compete against the modern oxen, or whether the disappearance of the sal forests from the Nerbudda valley, which Captain Forsyth in the "Highlands of Central India" considers as the cause of the disappearance of *Bubalus palaeindicus* from that district, was fatal to the existence of *Bos namadicus,* we are at present unable to decide; but I am inclined to think that the second of the three hypotheses is more probable.[71]

Competition between "modern oxen," extirpation and extinction at the hands of humans, or changes in environment had been considered in similar discourse about the extirpation of the European aurochs. While Lydekker saw competition with the younger forms of ox as the likely hypothesis for the Indian aurochs' extinction, others saw more planetary factors as likely causes of extinctions worldwide, including those of the aurochs. Robert Knox, anatomist and polygenesist in Edinburgh during the nineteenth century, and the man implicated in the notorious body-snatching murders of Burke and Hare, had also wondered at the causes of such extinctions and landed on one main culprit: climate. In his *Races of Men,* Knox prompted his reader to "extend the phrase climate to times past and to times to come." "Ask yourself," he prompted,

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[69] In the wake of Darwin's 1859 *Origin,* "intermediate forms" would frequently be reinterpreted as ancestral to diverging groups.
[70] Ludwig Rütimeyer, *Versuch Einer Natürlichen Geschichte des Rindes* (Zürich: Zürcher und Furrer, 1867).
[71] Lydekker, "Crania of Ruminants," 143.

"what climatic changes destroyed the mammoth, the aneplotherium, the dinotherium, the sivatherium? The fishes of the ancient world? The saurian? Man destroyed them not; yet their race is run."[72] The extinctions were not something restricted to a distant past, and he trotted out examples of some closer to hand: "why dies out, almost before our eyes, the apteryx? The Irish elk, the gigantic fossil ox, the dodo, have not long ceased to exist. The destroying angel walks abroad unseen, striking even at the races of men. But nature dies not; ever young; ever returning; ever reviving; she is eternal. The form is immaterial; the essence is the same; first and last."[73] In discussions of evolutionary relation, temporal loci, and global distribution, evidence of extinction and the looming culpability of climate were never too far away for Knox. Its perennial influence held appeal when theorizing about changes at more global scales.

At the same time that India became a site to untangle the string of cattle breeds and bovine types found and spread across the world, a deeper investigation of the evolution, migration, and extinctions of the megafauna found in Europe and now Asia and Africa was underway. India had a prime seat in these discussions. The fossils exhumed and described in large measure by Hugh Falconer in the mid- to late-nineteenth century had surprising overrepresentation of the Bovine group. With discoveries such as the Indian aurochs, and its purported ancestor, *Bos acutifrons,* was suggested a tantalizing idea: the ancestor to all cattle, bisons, and bibovine groups that encompassed the aurochs, domesticated taurine cattle, American and European bison, gayal and gaur, was of Asiatic origin. India's deep past offered

[72] Robert Knox, *The Races of Men: A Fragment* (Philadelphia: Lea and Blanchard, 1850), 314. For more on Knox, see Evelleen Richards, "The 'moral anatomy' of Robert Knox: The Interplay between biological and social thought in Victorian scientific naturalism" in *Ideology and evolution in nineteenth century Britain: Embryos, monsters, and racial and gendered others in the making of evolutionary theory and culture* (New York: Routledge, 2021), 89-143.
[73] Knox, *Races of Men,* 314.

possible insights into early human civilization, perhaps human evolution, and the coevolution of humanity's most broadly dispersed and widely deployed companion: bovines.

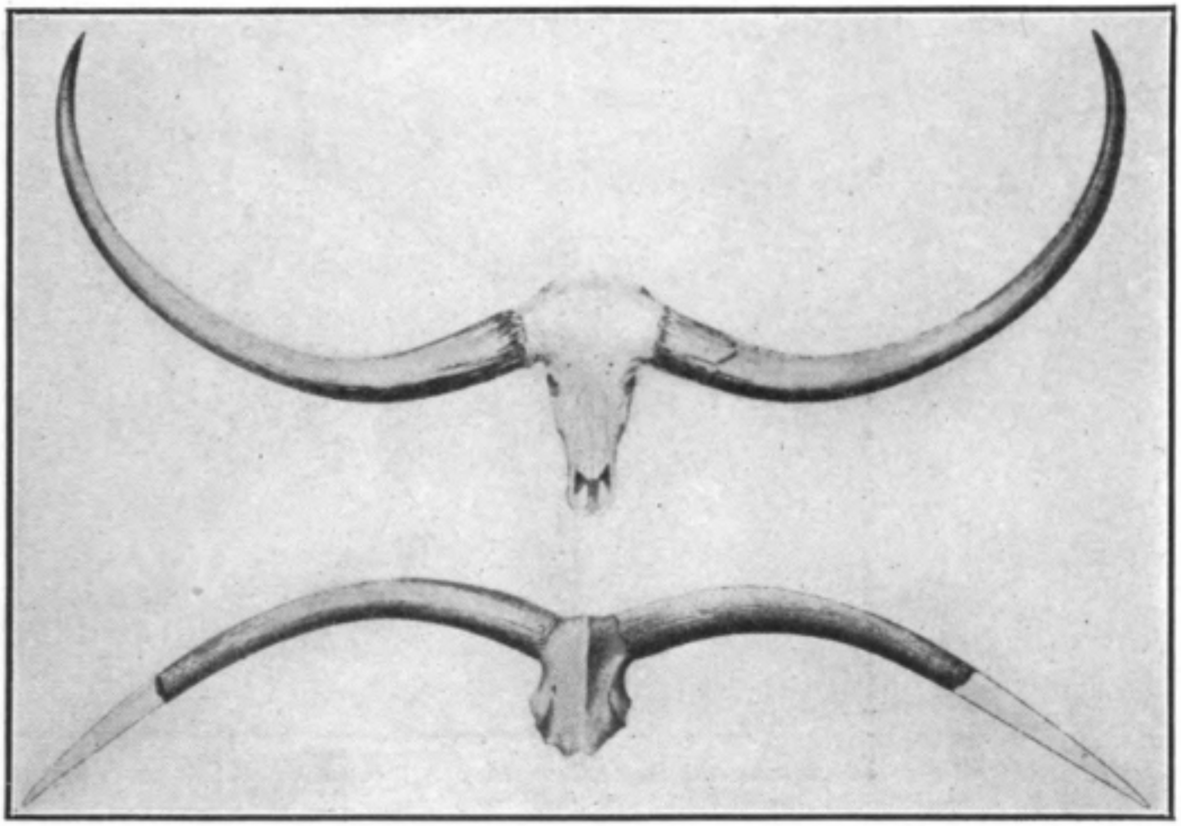

Figure 21. Comparison of *Bos acutifrons* skull (below) from India to Algerian Buffalo (above).[74]

The hypothesized South Asian ancestry of bovines was treated in the 1877 *Manual of the Geology of India.* The work called upon the writings of Cuvier, Bell, Owen, Rütimeyer, Darwin, and Geikie and their treatment of the origin of British domesticated cattle, particularly as it sought to recreate the migration and evolutionary history of the aurochs. According to research summarized in the *Manual*, "that a great portion of the temperate fauna and flora of the Southern Indian hills has inhabited the country from a much more distant epoch than the glacial period

[74] Morse, *Ancestry of Domesticated Cattle,* 195. Morse reprinted Lydekker's illustration of the *acutifrons* skull.

may be considered as almost certain, there being so many peculiar forms."[75] The distribution of these peculiar forms, including members of the genus *Bos,* and their particular similarities to "Ethiopian fauna" necessitated an understanding of past migrations, and any blockades to such migrations, such as the Himalayas.[76] The timing of the Himalayan uplift became a seemingly tangential, but quite crucial fact for exploring any possible migrations of ruminants in and out of the Subcontinent. The bulk of the Himalayas were "generally supposed to have been upraised in late tertiary times," and possibly even Post-Pliocene.[77] With such a date for the Himalayan uplift, the authors of the *Manual* could claim that "at the close of the miocene epoch no such mountain barrier as exists at present separated the Indian peninsula from Central Asia."[78] The possibility for migration remained.

Spurring these theories was an influx of data on the strange affinities and differences in fauna across global deposits. The presence of older European fauna in supposedly younger Siwalik deposits was one such sticking point. While one explanation for the 'older' fauna found in the young Siwalik deposits was its persistence and longer duration, another explanation was afforded by an analogous deposit across the globe. Only one other deposit on earth then discovered had the same odd admixture of extinct old Tertiary forms and living ruminant genera like *Bos* – those were the Pikermi deposits in Attica, Greece.[79] In that case, naturalists supposed that the older fauna had migrated southward into Greece, and within the *Manual*, geologists were

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[75] Medlicott and Blanford*.* *Manual of Geology of India,* 375.
[76] *Ibid.,* lxix.
[77] *Ibid.,* 520. Current knowledge about the Himalayan formation places the beginning of its slow uplift at about 50 mya, when the Eurasian and Indian continental plates first came into contact, placing their initial, albeit slow, upheaval within the early Tertiary. The Himalayas still rise every year at a pace of roughly 1cm/yr. See The Geological Society of London website: https://www.geolsoc.org.uk/Plate-Tectonics/Chap3-Plate-Margins/Convergent/Continental-Collision.
[78] Medlicott and Blanford*.,* 585.
[79] *Ibid.,* 583.

arguing that the same could have occurred in South Asia, where the climate was similar to that of Greece. Perhaps, posited the authors of the *Manual*, the fauna did so to avoid the plummeting temperatures across Europe during the concurrent 'glacial epoch.'[80] The authors of the *Manual* next considered the depletion of species richness in genera like *Bos* as potential faunal evidence of a glacial catastrophe that was as present in India as in Europe. The disappearance of diverse forms of genera between the Tertiary and Post-Tertiary bolstered the original argument that a climate-induced southward migration accounted for the odd admixture of the Siwalik fossils, and therefore meant that they were at least Pliocene (late-Tertiary) in age, and certainly not older, as the late-Tertiary/Post-Tertiary glacial epoch spurred their migration. With migration as the possible solution to the puzzle, and recognition of the affinity between *Bos* forms in India and Europe, especially in the case of the European and Indian aurochs, the ancestry and domestication histories of *Bos* and the aurochs were considered in order to reconstruct the migration and evolutionary of the genus.

Bos namadicus, the Indian aurochs, recognized to have a close relationship to the European variety, could be used to finesse the larger picture of the world during the Tertiary/Post-Tertiary. Lydekker chimed in on the evolution, migration, and fossil relationship of the Indian and European aurochs.[81] Most significantly, he placed the ancestral form of the oxen in India, dating from the Pliocene epoch "and represented in Europe in the latter portion of that epoch."[82] Lydekker supported this notion by reminding his readers that the earliest appearance of *Bos* in Europe was much later than its earliest appearance in India; in Europe, its earliest appearance was by then understood as Post-Tertiary in age.[83] Additionally, the sheer abundance

[80] *Ibid.,* lxiv, 585.
[81] Lydekker, *Wild Oxen,* 6.
[82] *Ibid.*
[83] Lydekker, "Crania of Ruminants," 92.

of ruminants found in India, as noted by Falconer and the *Manual* of India, "point[ed] to the conclusion that the group originated in the Eastern Hemisphere, and not improbably in Asia."[84] For Lydekker, oxen must have migrated to Europe sometime before the Himalayan uplift. Echoing the arguments made almost two decades prior, Lydekker combined a reconstruction of the Indian *Bos* geographical range with the timing of the Himalayan uplift. According to Lydekker, "the outer ranges of the Himalaya (in which its remains are found) were non-existent, while the central ranges and plateau of Tibet were almost certainly much lower than at present," during the early geologic lifetime of *Bos.*[85] This meant that it was "quite possible that animals like bos may have been able to range from the Punjab into Central Asia," and from there, to Europe.[86] Such broad reconstructions of the past through large-scale and long-term processes such as migration, evolution, and mountain uplift fit well with the deep time reconstructions of human evolution, societal development, and migration undertaken at the same time.

PALEO PROXIES FOR STADIAL HISTORIES

There is a deeply embedded distinction in the history of European colonizations between differing conceptions of time.[87] At its most basic, it notices and amplifies linear versus cyclical views of time, crudely mapped onto European, and non-European, respectively. Through linguistic studies, archeology, and textual translations of ancient texts, Europe played with what

[84] Lydekker, *Wild Oxen,* 7. This was supported by Lydekker's identification of what is still the oldest known fossil of the genus *Bos,* the *Bos acutifrons,* found in India. The description of *B. acutifrons* as well as a striking illustration of the specimen and its impressive estimated horn span can be found in Lydekker, *Wild Oxen,* 20.
[85] *Ibid.,* 60.
[86] *Ibid.*
[87] The history of the distinction goes back to at least the 1700s, through a growing nineteenth-century Orientalist fascination with seemingly ahistorical societies encountered during colonial projects. In many ways this is part of the larger domination of the concept of "Modernity" and its postcolonial afterlives. See Chakrabarty, *Provincializing Europe,* for more.

seemed to be radically different formations of deep time in the nineteenth century. India was foremost in the minds of those Europeans leading the comparative charge, such as William Jones, and those reflecting on the wave of texts emerging from Colonial India, including Hegel, Marx, and John Stuart Mill.[88] The emergent picture from Hindu texts, such as the *Manu* lawbook, was one of an India void of linear history – the myths inscribed in the texts depicted a cyclical understanding of time, such that European theorists saw only an absence of an attempt to document a chronology of India's history.[89] In the nineteenth century, these distinctions reinforced colonial rule, placing colonies 'behind' European advancement on a linear trajectory of progress.[90] Progress, interestingly, came to be measured by retaining records and knowing one's history, and those societies without such a focus were relegated to a lower rung in the ladder of development. In light of what the British deemed a dearth of Indian history, they sought to reconstruct it themselves. Recovering a chronological narrative of India's past was an even more messy enterprise for the synchronous excavation of precolonial, colonial, medieval, classical, and deep time relics during the British exploration and infrastructural overhaul of India.[91]

Later in the nineteenth century, these different timescales would be sorted from what Pratik Chakrabarti has called "a rather chaotic mess" of geology, archeology, and anthropology during a moment of "disciplinary innocence."[92] The fossils of *Bos* were excavated in this messy milieu, and though written about largely through a paleontological lens, the significance of the

[88] Trautmann, *Clash.* See also, Marchand, *German Orientalism.*
[89] And yet, as Thomas Trautmann has recounted, due to India's post-Vedic scholarly interest in astronomy, they created a vast chronology at scales much deeper than any pursued by those in Europe. This Puranic chronology, narrated in the epic Mahabharatha, the Puranas, and the Ramayana, spans thousands of years. Trautmann, *Clash*, xix-xx, and Chapter 2.
[90] Trautmann. *Clash.*
[91] Chakrabarti, *Inscriptions of Nature,* 15.
[92] *Ibid.*

findings transcended mere paleontological conclusions. The previous section has shown the significance of the Indian fossil bovines to reconstructing evolutionary relationships, climate, Himalayan uplift, and migration. This section explores the relevance of the fossils to the growing problem space of relative societal developments, deep human history, and competing views of time. As the European aurochs had been a witness to early human development in Europe, the Indian aurochs would open the door to paleontological connections to theories of stage-like development of civilizations and the role of domesticated livestock including cattle in those stages.

In those same Siwalik Hills that contained fossil bovines, lay the remains of other organisms that would ignite great debate over the evolutionary origin of humanity and the seat of its development. Hugh Falconer would play a large and better-known role in the discourse around those hominin fossils. For this thesis, however, detail of that fascinating history is beyond the scope.[93] Still, the synchronous developments of tracing humanity's origins and tracing origins of our close co-evolved cattle companions, and players like Falconer who loomed large in both discourses, suggested a relationship between cattle and humans, domestication and civilization, and India and Europe. The purported deep time connection would be reconstructed in its most consequential way through the invention of the proto-Indio-European language, and the so-called Aryans who were to have spoken it.[94] The connection was not always so explicit, however, as to conjure images of a shared history under the name "Aryan"; it can also be found

[93] Chakrabarti, *Inscriptions of Nature;* Thomas Simpson, "Historicizing Humans in Colonial India," in *Historicizing Humans: Deep Time, Evolution, and race in Nineteenth-Century British Sciences,* eds. Efram Sera-Shriar and Theodore Koditschek (Pittsburgh, PA: University of Pittsburgh Press, 2018), 113-137; Emily Kern, "Out of Asia: A Global History of the Scientific Search for the Origins of Humankind, 1800-1965" (PhD diss., Princeton University, 2018).
[94] Bruce Lincoln has traced the reconstruction of the so-called Aryans, as have Carlo Ginzburg, and Suzanne Marchand. The interest in Aryans would reach its apex during German mythologizing under the Nazis. See Marchand, *German Orientalism* and Lincoln, "Dumézil's German War God."

lurking in that sometimes-maligned space of the history of ideas. There has been large scholarly consensus about a nineteenth-century milieu invested in origins that radiated from intellectual cores like Darwin's evolutionary theory.[95] The consensus has formed one of the most productive and steady grand narratives of nineteenth-century intellectual and political endeavors. The unexpected appearance in India of the supposed originator of the family Bovidae, and of the aurochs itself, existed in conversation with evolutionary, geographical, linguistic, and kinship connections between India and Europe. Those deep time projects used various methods to chart the relations between past and present, and East and West.

The presence of *Bos* fossil discussions alongside philological reconstructions of India's past in the pages of the *Journal of the Asiatic Society* is just one way in which the Indian aurochs existed in the same epistemic and political matrix as historical reconstructions of the perceived origins and development of peoples. Other conceptual parallels existed for using the domestication of wild oxen as cultural, biological, and zooarchaeological signals for societal progression. In the eighteenth century, the historical development of knowledge in human societies formed a type of study, birthed out of the Scottish Enlightenment and given the name "theoretical" or "conjectural" history. Those "conjectural" histories of societal development told a potential universal story of societal development through the accrual of knowledge, and especially useful knowledge, which was said to have aided the advance of civilizations.[96] The development of societies was depicted in ladder-like stages, allowing linear progress, often called "stadial theory." Such histories were exemplified by Adam Ferguson, William Robertson,

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[95] See for example, Bowler, *Invention of Progress.*
[96] Sarah Irving-Stonebraker, "Nature, Knowledge, and Civilisation. Connecting the Atlantic and Pacific Worlds in the Enlightenment," *Itinerario* 41, no. 1 (April 2017): 93–107, https://doi.org/10.1017/S0165115317000092.
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Adam Smith, John Millar, and David Hume. Within stadial theory, the historic domestication of wild members of *Bos*, became widely treated as an indication of an early stage of civilization in the stepwise progression of civilizations.[97] In late eighteenth-century Scotland, for example, William Robertson argued that early German tribes "were more civilized than the Americans," as they had some agriculture and "almost all of them had flocks of tame cattle."[98] Comparisons between Europeans past, and contemporary, often indigenous peoples, and in particular Native Americans, were commonplace in the practice of stadial theory. Contemporary ethnographic research of peoples stood in as valid indication of early societies, and as a glimpse of Europe's "primitive" past, in a practice that has been deemed "anachronistic."[99] Denoting the first major shift from "savage life" was often the taming of cattle: Cornelius de Pauw's *Researches Philosophiques sur les Américains* (1768-69), Montesquieu's *The Spirit of the Laws* (1748), and

[97] Stadial Theory of the Enlightenment has been widely studied. For helpful overviews, see Ronald L. Meek, *Social Science and the Ignoble Savage* (Cambridge: Cambridge University Press, 1976), 131-176. Nathaniel Wolloch has argued that the Enlightenment has sowed the seeds for some of Western civilization's attitudes towards nature today, both negative and positive contributions. Nathaniel Wolloch, "The Civilizing Process, Nature, and Stadial Theory," *Eighteenth-Century Studies* 44, no. 2 (December 2011): 245–59, https://doi.org/10.1353/ecs.2011.a411979.

[98] William Robertson and Dugald Stewart, *The Works of William Robertson* Vol I (London: T. Cadell, 1840), 372.

[99] Anne McClintock has characterized the mapping of human and natural time following Darwin's *Origin* as "panoptical time" and "anachronistic space." Anne McClintock, *Imperial Leather: Race, Gender, and Sexuality in the Colonial Contest* (Abingdon: Routledge, 1995), 36, 40. Scottish thought in the Scottish Enlightenment has been shown to be a collaboration of different strands between natural history, economic theory, stadial ideas on progress, and imperialism. See Fredrik Albritton Jonsson, *Enlightenment's Frontier: The Scottish Highlands and the Origins of Environmentalism* (New Haven, CT: Yale University Press, 2013), on the connection of the environment at the root of the Scottish Enlightenment; Linda Andersson Burnett, "Northern Noble Savages?: Edward Daniel Clarke and British Primitivist Narratives on Scotland and Scandinavia, c. 1760-1822" (PhD diss., University of Edinburgh, 2012); and Silvia Sebastiani, *The Scottish Enlightenment: Race, Gender, and the Limits of Progress* (New York: Palgrave MacMillan, 2013) on the connection of natural history, colonial contact with indigenous peoples, and stadial views of progress. See also Irving-Stonebraker, "Nature, Knowledge, and Civilisation."

John Millar's *Origin of the Distinction of Ranks* (1779) also all pointed to taming cattle as a signifier of progress.[100]

While the fossil presence of wild cattle ancestors alongside *Homo* traces did not indicate any domestication, and therefore any progressive development, there is evidence that the fossil record and the presence of wild cattle in it was considered as possible material evidence in arguments about the relative timing of shifts from savagery towards civilization. Robert Knox came remarkably close to arguing for its successful use. He routinely returned to reflections on the relative historic progression of *The Races of Men*, and in his work drew on his anatomical tracts on the aurochs and its domesticated descendants, drawing parallels of the aurochs to a "pre-civilized" wildness of "primitive" races.[101] The cultural significance of the aurochs was ripe for entanglement with European studies of civilizations by the nineteenth century, at the same time that it was used to correlate the geological past. Yet its domestication was perhaps more a matter for the archeological or even historic records, than the paleontological. Knox's work demonstrated a vexing question that was making its rounds in the nineteenth century: when in time exactly could one draw the line between wild and tame?

Often, that answer was given a temporal dimension. For Philippe Thomas, describer of the African aurochs, inferring the domestication of Bovidae from paleontological data could never be certain.[102] To those biblically minded, tame animals were a providential gift from God, in which nature was given to humankind for its uses. John Stark, fellow of the Royal Society of Edinburgh and its museum's assistant curator, pushed against stadial thinking and the relation of

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[100] See Meek, *Social Science,* 131-176, for a characterization of the "stages" discussed in some of these works.
[101] Robert Knox, *Races of Men,* and Robert Knox, "The Anatomical Examination of the Wild Ox," *Quarterly Journal of Agriculture* 9 (1838).
[102] Thomas, "Recherches," 135.

stepwise views of societal development to taming animals. In his "On the Supposed Progress of Human Society from Savage to Civilized Life, as Connected with the Domestication of Animals and the Cultivation of the Cerealia," he argued that domesticated animals were always domesticated, that mankind was always possessed with its current faculties, and that therefore the idea of progressing from hunting, to pastoral life, to agriculture was false.[103] If anything, according to Stark, mankind lived with domesticated animals that were docile from the very beginning and the only changes wrought on the system had been degenerative, pushing humanity towards barbarism. His piece leaned on centuries of Christian exposition about the original state of nature and the Fall of mankind.[104]

To stadial thinkers, tame animals were not an initial condition of the earth, but rather developed as useful knowledge over time as humankind progressed through its stepwise path from hunting to pastoral existence with domesticated livestock, to fully agricultural settlements. In this view, domesticating animals was associated with achieving a certain character of society: an achievement of power over nature, of civility in relations that could be nurtured in an environment rid of wanton violence and territoriality. That such a self-view of civilization in the West could be cultivated in the midst of violent colonizations executed by those same "civilized" societies was often, though not always, lost on the perpetuators of those views. In India, in which archeology and rich mythology suggested an ancient robust culture that had thrived while European civilization was still a mere glimmer in the world's eye, there was at once veneration

[103] John Stark, "On the Supposed Progress of Human Society from Savage to Civilized Life, as Connected with the Domestication of Animals and the Cultivation of the Cerealia," *The Edinburgh New Philosophical Journal* 31 (1841).
[104] Stark's essay would later be critically annotated by Cossar Ewart in Edinburgh. Ewart will be a prominent voice in the following chapter. "Notes in Ewart's hand quoting from the Proceedings of the Royal Society of Edinburgh, 01 March 1841, [c. 1910]," Coll-14/9/16/48, University of Edinburgh Archives, Edinburgh, Scotland.

and dismissal from its European voyeurs. India's culture impressed and yet was accused of stagnation, in part due to interpretations of a specific Hindu view of time that had been translated and studied from post-Vedic scholarship which was generating European interest in the nineteenth-century colonial landscape.[105]

A conception of a linear development of peoples was extended to humanity's origins in its earliest records. In France especially the linear narrative of human domination from its earliest days was favored.[106] In the mid-nineteenth century, Louis Figuier articulated a model of human development from the dangerous natural threats faced by early humans to human power over nature achieved through ingenuity in the development of technologies. Domestication of cattle came in the final Bronze Age, and to figures like Figuier and John Lubbock, domestication was a crowning achievement, one that signaled a shift from humankind at the mercy of the wild to humankind as the tamer of nature.[107]

By the early 1900s, placing the history of domestication in time had migrated out from religious natural historians, archeologists, and anthropologists into livestock breeders' own appraisals of the value and legacy of their work. In 1902, George Andrew Brown, an Australian stockbreeder who taught himself French and slowly made a name for himself though his writings on the science of breeding, would write about the links between the development of civilization and the role of livestock breeding – that art which extended and perfected upon the initial labor of domesticating wild animals and plants.[108] Brown placed livestock work in direct relation to the first steps of civilization during a continued push in Britain towards ever-perfected

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[105] Trautmann. *Clash.*
[106] Manias, "Contemporaries of the Cave Bear," 23.
[107] John Lubbock, *Pre-Historic Times as Illustrated by Ancient Remains and the Manners and Customs of Modern Savages* (London: William & Norgate, 1865). For more, Manias, "Contemporaries of the Cave Bear."
[108] George Andrew Brown, *Studies in Stock Breeding* (Melbourne: Walker, May, and Co., 1902).

industrialized animals when he wrote “Live stock husbandry is the earliest industry of the human race, for it came into existence immediately after man emerged from the condition of the savage hunter, and took his first step towards civilization.”[109] The livestock industry was undergoing its own fascinating development in the nineteenth century, during which colonial holdings served as experimental sites for understanding the role of the environment in stabilizing or degrading breeds that were to be exported to far-away colonies to support a European existence across the world.[110] Yet the deep-time significance of the initial domestication of livestock was never so remote as to be entirely separate from the self-view of breeders. In the case of cattle in particular, a corner of the livestock breeding community would increasingly lean on archeological and paleontological discourse to understand the origins of their breeds and their potential for reversion. This is the subject of the next chapter.

CONCLUSION

By the time of Lydekker’s *Wild Oxen, Sheep and Goats of All Lands, Living and Extinct* at the end of the nineteenth century, the proposed Indian ancestry of the European aurochs, and therefore domesticated European cattle, echoed humanist discussions of the shared ancestry of European and Indian human populations. Yet, they never fully integrated in those spaces, despite a deep history of rumination on India’s own cattle culture. Discussion of the fossilized aurochs, both European and Indian, instead revolved around minutiae of anatomy, relative resemblance to older and more recent forms, and larger conceptual abstractions, such as the location of a Tertiary/Post-Tertiary divide. At the close of the nineteenth century, discussions of Bos had

[109] *Ibid.,* 2.
[110] Rebecca J.H. Woods, *The Herds Shot Round the World: Native Breeds and the British Empire, 1800-1900* (Chapel Hill: University of North Carolina Press, 2017) gives a sweeping account of the development and discourse around livestock breeding in colonial settings.

returned to the undetermined nature of the animal's ancestry, extinction, and age with a broader geographic dimension. In India, Bos lived in abundance in the wild and laid in abundance in the fossil beds. Its overwhelming presence ultimately provided a key to understanding the age of the Siwalik beds and the broader history of Bos. The similarity of the Siwalik and Pikermi beds of Greece led naturalists to further grapple with glacial epochs, biogeography, Himalayan uplift, and a fuller picture of the ancestry and extinction questions that had dogged British writings on the aurochs. In these measures it facilitated the broader scientific and colonial interests in biogeography and the setting of a geological clock across the world. However, its history also suggests that a reliance on fossil fauna to articulate a standardized chronology of the particularly troublesome periods of the Tertiary and Post-Tertiary injected those attempts with added complexities, limitations, and possibilities, all derived from the nature of the beasts themselves. Perhaps those complexities, limitations, and possibilities kept this particular ossified object from being fully assimilated into the humanist projects of European-Indian pasts that it subtly resembled. In India, the aurochs gained temporal registers. It became an early relative, if not direct ancestor, to European cattle, and discourse about its domestication made it a signal of societal progress. Those registers of the deep and prehistoric past expanded the aurochs' global profile as a fossil animal with a sticky temporality. In Europe, interest in its domesticated relatives would see a new temporal dimension added to the aurochs: that of its synchronic presence in its living descendants.

Chapter 4: Living Descendants

Figure 22. Photographs showing the visitors at Chartley, 1898 (above), and the white cattle, labeled "The Herd Studies the Visitors."[1]

The aurochs had caused quite a stir in its fossil form. It was not long, however, before its living legacy drew the attention of naturalists. Those distant descendants of the aurochs – by the

[1] "Photograph of visitors," 72067.3, and "Photograph showing the cattle," 72067.2 in Box 5 WBD, F219-226 Correspondence re. Chartley and Chillingham Cattle with photographs and ms. notes. 1898-1904, Boyd Dawkins Archives, Derbyshire County Council, Buxton Museum and Art Gallery, Buxton, UK.

end of the nineteenth century, considered by many to be the ancestor of all European domesticated cattle – could perhaps inform those outstanding questions of bovine evolution, domestication, and extinction. With its domesticated descendants on farms and ranches across the world, perhaps naturalists were looking at the aurochs in living form all along. The domesticated cattle might allow those interested in the aurochs to themselves become eyewitnesses to its existence. Whether naturalists viewed purportedly wild herds, such as the Chillingham cattle in England, as direct vestiges of the aurochs, or they saw the wild bovine's presence in trait reversions in livestock breeds, the living legacy of the aurochs added a synchronic temporality to its growing deck of timescales. This chapter is a fulcrum in the narrative, that brings the past and present-oriented knowledge of the aurochs together, by exploring how its existence as a synchronic ghost, reasserting its presence in living breeds, brought timescales of the deep and recent past together with living and breathing evidence of cattle origins. This lens allows for comparison of how those studying the aurochs through different phenomenal objects at different time scales, such as fossils in the deep past and coat color in the present, brought their evidence and timescales into conversation, and foregrounded time in articulations of their own biological work.

Livestock breeding, a pursuit which nineteenth-century naturalists had traced back to the earliest days of domestication in societal progress, developed in more rigorous ways in the eighteenth century and with it, a cultural, scientific, and practical interest in the relations of domestic breeds to one another blossomed.[2] Britain had been the dominant site of such

[2] There is an extensive literature on the history of agricultural improvement and livestock breeding: Margaret Derry, *Masterminding Nature: The Breeding of Animals, 1750-2010* (Toronto: University of Toronto Press, 2015); and Margaret Derry, *Made to Order: The Designing of Animals* (Toronto: University of Toronto Press, 2022); Bert Theunissen, *Beauty or Statistics: Practice and Science in Dutch Livestock Breeding, 1900-2000* (Toronto, University of Toronto Press, 2020); Nicholas Russell, *Like Engend'ring Like: Heredity and Animal Breeding in Early Modern England* (Cambridge, UK: Cambridge

developments, and its colonial enterprise facilitated its breeds' domination around the globe. While in India, Falconer's Indian aurochs spurred the intellectual debates discussed in the previous chapter, other British holdings such as New Zealand became proving grounds for the "improved" British domesticated breeds of sheep and cattle.[3] In the colonies, as historian Rebecca Woods has shown, the same tensions that occupied British breeders back at home, between improving breeds towards market ends and maintenance of breed phenotypic, heritage, and regional identities were further complicated by direct tests to theories of environmental influence in the shaping and maintaining of breeds.[4] In new climates, such as those in the pastoral economy colonies of Australia and North America, acclimatization and malleability of British breeds to new environments was imperative, and resultingly blurred the lines between what "nativeness" meant for a colonizing force spreading their historically place-specific breeds across the globe.[5]

Informing this colonial production was a deep history of experiential knowledge of the complicated patterns that appeared in breeding practice. Of primary concern to practical breeders into the eighteenth century, were the tradeoffs between maintaining breeding types and increasing the health and productivity of their animals.[6] Maintaining a type forward in time could

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University Press, 1986). For more specific discussion of the changing role of pedigrees, portraits, and conformation in breeding aims, see: Ritvo, *Animal Estate;* Emily Pawley, "The Point of Perfection: Cattle Portraiture, Bloodlines, and the Meaning of Breeding, 1760-1860," *Journal of the Early Republic* 36, no. 1 (Spring 2016): 37-72; John R. Walton, "Pedigree and Productivity in the British and North American Cattle Kingdoms before 1930," *Journal of Historical Geography* 25, no. 4 (October 1999): 441-62, https://doi.org/10.1006/jhge.1999.0161.

[3] For a full account of this history see Woods, *Herds Shot Round the World.*

[4] *Ibid.,* 5-6.

[5] For the prime example of these tensions within cattle breeding and colonial politics, see Woods, *Herds Shot Round the World*, 78-105.

[6] This was the case for plants, as well. Linneaus, *Philosophia botanica,* 1751. Linneaus would form a hybridist tradition with his study on hybrids, including experiments with plants. "Hybrid vigor" would be sought by some breeders, using inbreeding to achieve uniformity, and then outcrossing to return health and fertility. This method did not pass on the improvement to the next generation, however, and so constant hybridization was needed. The method, popular prior to the 1700s, would return in the early

be threatened by reversions, decreased "vigor," or environmental factors.[7] Many scholars take the work of eighteenth-century breeder Robert Bakewell as a formative moment in structuring breeding methods to make sense of and avoid such complicating elements, in order to generate reliable and productive agricultural animals. Bakewell sought greater uniformity of animals at larger quantities, and devised laws from his and others' first-hand experience. He emphasized inbreeding to maintain types, selecting for quality and health via "progeny testing," in which animals used in breeding were selected based on the productive output of their offspring.[8]

By the nineteenth century, Bakewell's methods for livestock breeding were pervasive, but began to be combined by breeders with methods used by thoroughbred horse breeders, such as Thomas Bates. The result was purebred breeding. Purebred breeding, popularized by Bates, combined the thoroughbred breeding fixation on "purity" and its maintenance through the tool of pedigrees with Bakewell's method of inbreeding. As a result, inbreeding increasingly became associated with notions of "purity," and the pedigree supplanted the progeny test in breeding selection.[9] As historian Margaret Derry has noted, purebred breeding became the dominant strategy of improving breeds in the west by the late nineteenth century; at the same time, as

twentieth-century in the form of the "double-cross hybrid," and would form the basis of the separated industry structure for chickens and plants, in which companies produced their biologically patented hybrid eggs and seeds, sold to farmers to be raised for market. The farmers would then rely upon purchasing new eggs and seeds each season. See Derry, *Made to Order,* 19-20 for more on hybrid vigor, and 35-38 for more on the double cross.

[7] Prior to the eighteenth century, and stretching back to the Classical works of Varro and Columella, what Margaret Derry has called "environmental breeding" dominated theories of breeding. In the 17thC, this trend was retained most prominently in thoroughbred horse breeding, in which breeders drew on Aristotle's four humors and Galen's balancing in opposites. For more on Varro and Columella, see Derry *Made to Order,* 16. For more on the role of Aristotelian and Galenic ideas in 17thC breeding, see Derry, *Made to Order,* 104-105.

[8] For helpful accounts of Bakewell and standardizing of breeds see Margaret Derry, *Bred for Perfection: Shorthorn Cattle, Collies, and Arabian Horses Since 1800* (Baltimore: Johns Hopkins University Press, 2003), Russell, *Like Engend'ring Like,* Ritvo, *Animal Estate.*

[9] Derry, *Made to Order,* 22-23.

Rebecca Woods relays, British breeds "had conquered the world."[10] In 1902, Australian breeder George Brown would accurately claim that "During the last half-century Britain has become the stud-farm of the world."[11]

At the same time that practical breeding for agriculture was undergoing methodological developments, and following the domination of British purebred breeding methods and their resulting breeds, naturalists – those early scientists in pursuit of knowledge of the natural world – used inbreeding and outcrossing for experimental purposes, seeking to understand the laws of heredity and looking for patterns in deviation and variation. Recognition of patterns of heredity had existed in scattered strains of thought prior to the mid-nineteenth century. Where consideration of generational transmission appeared, it was often entangled with concerns of conception, embryogenesis, and pregnancy.[12] Physicians and breeders, therefore, were the groups largely considering heredity as its own phenomenon prior to the mid-nineteenth century.[13] While histories of heredity, and later genetics, often stretch back to a lineage of writers including Aristotle, Linnaeus, Darwin, Millais, De Vries, and Francis Galton who considered theories of generation, development, and heredity, a more modern biological notion of heredity developed in the late nineteenth century, most notably with Darwin and Galton's theories.[14] This history of heredity, prior to cell theory, Mendelism, the Biometricians, and classical genetics, has occasionally made its way into agricultural history scholarship (with Galton and Basset Hound originator Everett Millais being foremost examples); but even then, the work of naturalists and

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[10] *Ibid.,* 23; Woods, *Herds Shot Round the World*, 4.
[11] Brown, *Stock Breeding,* 4.
[12] Müller-Wille and Brandt, *Heredity Explored,* 3.
[13] Müller-Wille and Brandt note that it was physicians and breeders who first described "transmission of traits using legal metaphors of inheritance," through interest in diseases' permanence and the fixing of new traits. *Ibid.*
[14] Müller-Wille and Brandt, *Heredity Explored,* 3.

later scientists on heredity until the mid-twentieth century was often treated as a separate endeavor that so-called practical breeders had limited interest in, no use for, or outright resistance to.[15]

Indeed, practical livestock breeders who bred for improvement of breeds towards agricultural ends, or for hobbyist enjoyment and show or sport, operated in a largely separate and sometimes oppositional theoretical and motivational space than did naturalists and later scientists.[16] Scholars Margaret Derry and Bert Theunissen have emphasized this divide that existed from the eighteenth century onwards, as well as the moments in which scientists challenged breeders' longstanding methods, and the rare times those challenges were embraced by the breeders. Practical breeding, therefore, and scientific interest in the mechanisms underneath it cannot be conflated. While naturalists and scientists sought to understand hereditary processes and materials, breeders proceeded largely with an assumption of hereditary laws born from experience, not knowledge of underlying causes.[17]

This chapter, however, seeks to bring those literatures together, because it is the only way to make sense of these individuals who worked on questions surrounding the aurochs and its descendants. In the study of the aurochs, these domains of knowledge – practical breeding and studies of heredity – were sometimes collapsed, drawing on one another. What they had in

[15] The science of heredity and the aims and methods of livestock breeding have complicated histories in their own right, that have in some ways been maintained in their complexity by a separation in current scholarly literature between the history of science and agricultural history. This separation is not without historical justification, though.
[16] Narratives of the different realms in which breeders and naturalists and later scientists operated, and the less than successful attempts to bridge those gaps in the early to mid20thC can be found in Derry, *Made to Order,* 4-7. Bert Theunissen, "Breeding Without Mendelism: Theory and Practice of Dairy Cattle Breeding in the Netherlands 1900–1950," *Journal of the History of Biology* 41, no. 4 (December 2008): 637–76, https://doi.org/10.1007/s10739-008-9153-0, and Theunissen, *Beauty or Statistics* take this tension as their central explanandum.
[17] Derry, *Made to Order,* 16-17.

common was far more important in these contexts than their differences: they studied phenomena of living animals, which were observable, could be experimented upon, and conveyed knowledge – practical or explanatory – about heredity and descent. Some of the individuals in the network in this chapter straddle both scientific and agricultural worlds; some are firmly in one camp or the other but correspond across disciplines and expertise. This chapter draws on historical sources in zoology and paleontology - evolutionary disciplines that were investigating questions of origins - and literature on the development of Mendelism and genetics. In addition, it draws on experiments in practical animal breeding. The work of naturalists such as Charles Darwin provides an exemplary case of how these spheres and their different aims and methods of work could be brought together when the research was of ontological concern. The moments of overlap between livestock breeders and scientists in their questions, organisms, and theories stand out in this chapter against the backdrop of otherwise separated spheres: purebred breeding for agricultural improvement, sciences of evolutionary origins, and heredity and genetical theories of inheritance.

This chapter pivots into the living legacy of the aurochs, including investigations into a group of cattle that were consistently interesting not because their timescale fit a preferred, or even contained, method of investigation. In Britain, the 'wild' white herds of cattle, now best represented by the Chillingham breed, captured public fascination from the eighteenth century to today, and spurred research interest into their relationship to an ancestral ox, the aurochs.[18] The British cattle, like their purported ancestor, the aurochs, had an underdetermined past, and therefore presented multiple methodological opportunities for study. In short, the 'wild' British

[18] For an introduction to the popular history of the Chillingham cattle, see Harriet Ritvo, "Race, Breed, and Myths of Origin: Chillingham Cattle as Ancient Britons," *Representations* 39 (1992): 1-22.

cattle were considered over time from historical, zoological, and experimental methods, each delving to different depths of the past, or seeking answers some number of progenies into the future. Tensions existed between the suitability of the temporally-distinct methods for different incidental ends: agricultural innovation and production found common ground with the crossbreeding investigations, for example, while probes into the historical and paleontological evidence of the living cattle's heritage suggested insights into hereditary patterns that could be gleaned from living and extinct animals. Each epistemological approach persisted in studies of the wild cattle, often within the same monographs or experiments, and continue to do so today.

The chapter moves from the 1870s, with a particular series of crossbreeding experiments, to the 1920s, following the early development of genetics. It straddles the year 1900, a favorite 'turning point' in the history of biology, marking the re-discovery of Gregor Mendel's heredity studies, later paired with chromosome inheritance to form classical genetics. The chapter follows nineteenth-century historical and paleontological tracts on the origin of the British cattle to the development of a breeding program at Edinburgh that coalesced into the Institute of Animal Genetics (which morphed several more times, including into the Roslin Institute, responsible for Dolly the Sheep). It showcases reflections on the heritage of the British cattle, through deep-time excavations, historical writing, and newly generated data in the form of experimentally bred successive offspring and suggests that each of these methods for approaching the origin of the cattle stretched and layered the temporal landscape of the discussion. Fossils presented the farthest-reaching past of the animals, while historical ancient, Medieval, and Early Modern accounts offered evidence from which to draw. The living cattle, however, presented an opportunity to witness the aurochs in synchronic time.

In the three chronological sections that follow, the chapter examines largely British work on cattle breeds and their extinct ancestors to demonstrate that during the pervasive rise of Mendelian genetics, standardized experimental organisms, and scientific experimental farms, the quiet persistence of cattle's deeper past retained a relevance to livestock breeders and some scientists. It examines how late nineteenth-century research into the British Chillingham cattle offered a useful portal into the paleontological past by which domesticated breed ancestry could be understood; how Edinburgh zoologist James Cossar Ewart's early twentieth-century experiments left open the relevance of distant ancestors in the context of early experimental farms; and finally, how the vitalist philosophies of Cambridge-trained biologist Arthur D. Darbishire centered the role of time in considering the vital whole of an organism, even in the wake of Mendelian discontinuity. In each case, the biology and constraints of the living cattle and their lifecycles are considered as a layer added in the aurochs' own temporality.

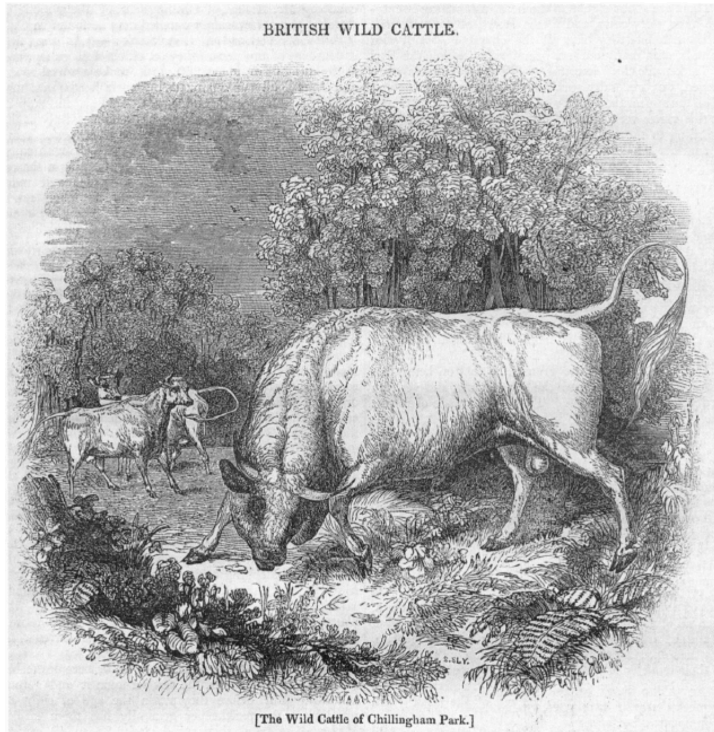

Figure 23. British Wild Cattle, from *Penny Magazine* (1838)[19]

WILD HERDS CONNECTING PAST AND PRESENT

At the close of the nineteenth century, questions about heredity vexed breeders and naturalists alike. Unexpected ancestral reversions were undesirable in livestock due to their disruption of the domesticated forms produced through careful breeding. At the same time public and scientific interest flourished surrounding the question of autochthonous breeds and local cattle's connections, and seeming reversion to, distant ancestors. In one illuminating case, living cattle herds in Britain were taken to be proxies, if not direct descendants of the extinct aurochs, and therefore served as a living record of the deep past to agriculturalists and naturalists.

[19] "British Wild Cattle [the wild cattle of chillingham park] signed by S. Sly (wood engraver fl.1836-47, Bouverie Street, London)," *Penny Magazine* (1838). Reprinted in Stephen J.G. Hall, "Caring for the Legend of the Wild Bull: An Interpretation of the Georgian Landscape of Chillingham Park, Northumberland," *Garden History* 38, no. 2 (Winter 2020): 213-30.

The white "wild" British herds at Chillingham, Chartley, and Hamilton, were long considered the crown jewel of the aurochs' alleged direct descendants. Later genome sequencing would reveal that the animals were not direct remnants of the lost aurochs, but rather feral cattle that descended from diminutive, domesticated animals. Still today, however, the herds' tenders advertise both their wildness and aurochs-ancestry as unique and direct, demonstrating that the aurochs itself has come to mean "wild" or "pre-domesticated." Whether direct relics of the aurochs or not, seemingly wild herds have been claimed since at least the nineteenth century as "aurochs-like," and as offering glimpses into the aurochs and its former behaviors. The Chillingham cattle are not alone in this boastful association - many local breeds across Europe are hailed as directly related to the aurochs.[20]

These supposedly wild herds of diminutive cattle, scattered across England and Scotland were most famously represented by the Chillingham, Chartley, and Hamilton (or Cadzow) herds. They were well known for their white coat color, their alleged wildness, and their ancient heritage. Historian Harriet Ritvo has beautifully demonstrated the many layers of interest that these herds held for the Victorians, and the ways in which local pride and symbolic meaning prevented scientific consensus about the wildness of the animals.[21] As Ritvo has argued, the breeds were particularly of interest to the British, and were often described as embodied symbols of Britain and its history. They were also of international interest given their alleged status as living relics and the peculiar portal they offered into heredity and the past. While the white cattle's supposed inbreeding and deep history suggested uniformity of traits such as color, historical mention of occasional offspring with patches of non-white challenged the cattle's

[20] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.
[21] Ritvo, "Race, Breed, and Myths."

unbroken line while at the same time offering naturalists a purported glimpse into even more distant ancestors. The questions surrounding the ancestry of the white cattle became a focus of naturalists in North America and Europe, who saw them as providing knowledge about the past and the present simultaneously.

Walter Scott's 1802 poem "The Ballad of Cadyow Castle" furthered the interest in the cattle, as it was often cited as both proof and publicity for the significance of the Chillingham cattle and their relation to the aurochs. The stanzas were quite evocative in their imagery of an old Scottish hunt, in which a dangerous encounter with a "mountain bull" occurs:

Mightiest of all the beasts of chase
That roam in woody Caledon,
Crashing the forest in his race
The mountain bull comes thundering on.
Fierce, on the hunter's quivered band,
He rolls his eye of swarthy glow,
Spurns, with black hoof and horn, the sand,
And tosses high his mane of snow.[22]

Many writers of the time, from famed naturalists Richard Owen and William Boyd Dawkins, to amateur authorities on cattle such as Reverend John Storer, drew on the stanzas, suggesting that the "mountain bull" to which Scott referred was the aurochs. The imaginary encounter in the poem could convey the cultural weight of their research into the aurochs, while also drawing a link between the aurochs and the still-living wild herds that readers may have encountered in their own literary or artistic pastimes. In several respects, Scott's mountain bull resembled the famed British breeds of seemingly wild cattle. The breeds, and particularly the most famous of them, the Chillingham cattle, grew in cultural appreciation from the eighteenth century to the

[22] Walter Scott, "The Ballad of Cadyow Castle," taken from Jacob Wilson, "The Chillingham White Cattle," *Land Magazine* 3 (1899), 19.

early nineteenth, when the eventual 6th Earl of Tankerville was nearly killed by one.[23] The tale, retold by many over the next century, depicted the 6th Earl in the throes of dire threat while attempting to shoot one of the Chillingham bulls.[24] The painter Edwin Landseer was on site in Northumberland to paint a portrait of the cattle, commissioned by the 5th Earl of Tankerville. The 5th Earl's son, Lord Ossulston, eventual 6th Earl of Tankerville, decided to provide Landseer with an up-close anatomical look at the animals, by shooting one of the bulls. The shot was botched, and the bull charged in response, goring and nearly killing the keeper who was saved only by the intervention of Ossulston's deerhound.[25] Landseer's painting was finished and displayed in 1836 at the Royal Academy show, and a follow-up portrait exhibited 31 years later showcased a mighty Chillingham bull within a family structure. From the paintings and the story of their creation, the Chillingham cattle, and their majesty and ferocity, were legendary.

[23] In fact, they became so popular that these breeds were depicted in paintings on estates that never had them. Ritvo, "Race, Breed, and Myths,". 1.

[24] Page 4 of Earl of Tankerville, *The Chillingham Wild Cattle. Reminiscences of life in the Highlands,* 7204.c.17.(10.), in *Zoological Tracts etc. 1824-94,* British Library, London, UK.

[25] Ritvo notes that the deerhound, Bran, was awarded a place in the portrait for his noble efforts. Ritvo, "Race, Breed, and Myths," 4.

Figure 24. “Wild Cattle of Chillingham,” Landseer, 1867.[26]

The public captivation with these breeds cast the animals themselves in a shroud of mystique, with observers layering meaning onto the animals through associations with their own Victorian societal identity and history.[27] The charisma of the cattle furnished more than paintings and associations with a wild British past, however. The contemporary herds themselves became the site of dedicated investigation into their natural history, the phenomena of trait reversions, wildness, and the ever-confounding puzzle of their relation to the extinct aurochs.

[26] Commissioned to be displayed in Chillingham Castle.
[27] Ritvo, “Race, Breed, and Myths,” 1-22.

Figure 25. Photograph of Chillingham cattle skeleton, Oxford Museum of Natural History.[28]

The relation of the Chillingham herds to the aurochs was both an open question, and, depending on one's answer, a possible avenue by which to know the aurochs. Much debate abounded over the potential direct descendancy of the wild white cattle, such as the Chillingham herd, from the aurochs. Morphological comparisons done by Ludwig Rütimeyer convincingly demonstrated to many the connection between the white herds and the aurochs. His conclusions would make their way into any seriously considered work on the cattle for decades thereafter, until skepticism about the connection would be mounted by William Boyd Dawkins at the end of the century. In 1861, Charles Darwin wrote to Rütimeyer to offer his services in procuring a Chillingham bull skull or skeletal specimen to send to Switzerland.[29] Darwin had read

[28] Photo by author.
[29] Letter to Ludwig Rütimeyer from Charles Darwin, December 5 1861. Accessed via Darwin Correspondence Project, "letter no. 3339."

Rütimeyer's 1861 work on the Swiss Pile Dwellings.[30] In it, Rütimeyer lamented that while researching the origins of domestic cattle, "a significant gap in my observations arose from the impossibility of comparing the skeleton or skull of the white wild cattle of Chillingham-Park..."[31] Darwin facilitated Rütimeyer's desire to examine the bones of a Chillingham bull, and Rütimeyer's conclusion about the relation of the Chillingham cattle and the aurochs was noted by Darwin in his *Variation of Animals and Plants Under Domestication,* and from there his conclusions were widely cited. [32] The British agricultural breeder Jacob Wilson, for example, quoted Rütimeyer as claiming "The Chillingham skull is an elegant diminished copy of the mightier and stronger diluvial oxen of Europe, and the historical descent of the first from the last cannot be doubted."[33] While some naturalists disputed the direct descendancy, including Boyd Dawkins, others used the alleged morphological connection of the white herds to the aurochs to suggest that the aurochs too must have been white.[34]

The Chillingham cattle presented a possible window into the hypothesized ancestor of all domesticated European cattle. Their long history suggested a relation to living domesticated breeds as well. In 1874, the American agriculturalist Edward Lewis Sturtevant published a tract on "The Wild Cattle of Scotland, or White Forest Breed" in *The American Naturalist.*[35] In the

[30] Ludwig Rütimeyer, *Die Fauna der Pfahlbauten in der Schweiz* (Basel: Schweighauser, 1861).
[31] *Ibid.,* 148. Translation is mine. Original: "Eine empfindliche Lücke in meinen Beobachtungen entstand durch die Unmöglichkeit, Skelet oder Schäudel des weissen Wildviehes von Chillingham-Park, des sogennanten Bos Taurus ferus, von welchem die englischen Vierhkenner eine grosse Zahl der heutigen zahmen Schläge Englands ableiten, mit in den Vergleich zu ziehen. Eine genaue osteologische Untersuchung dieser so wichtigen Viehrace fehlt meines Wissens noch durchaus..."
[32] Letter to Charles Darwin from Henry Holland, January 1862. Accessed through Darwin Correspondence Project, "Letter no. 3388." Associated letters: no. 3389, no. 3339, no.3443., accessed via Darwin Correspondence Project. Charles Darwin, *The Variation of Animals and Plants under Domestication* I (London: John Murray, 1868) 81.
[33] Wilson, "Chillingham White Cattle," 20.
[34] Letter from William Boyd Dawkins to Charles Darwin, 19 October 1869. Accessed from the Darwin Correspondence Project, letter no. 6944.
[35] Edward Lewis Sturtevant, "The Wild Cattle of Scotland," *The American Naturalist* 8, no. 3 (March 1874): 135-45.

article, he considered the relations of the white herds of Britain to other British breeds, including the West Highland and Ayrshire breeds. Sturtevant's knowledge of the Ayshire breed went back to his own experimental "Waushakum Farm," founded with his brothers in 1867 in Massachusetts.[36] The Americans' interest in British white herds was by no means unusual. The supposed inbreeding and deep ancestry of the cattle, recorded in historical documents from the seventeenth century, suggested that the herds could be used as stable stand-ins for ancestral forms of domesticated breeds.[37]

The coat color of the white cattle presented a phenomenal element of the animals in which reversions and heritage could further be explored. Coat color had been a priority for cattle breeders to confirm breed purity conformation to expected types.[38] For some interlocutors, such as the Reverend John Storer, the coat color of the wild white herds was a reliable indicator of the Chillingham cattle's ancientness.[39] In fact, the occasional birth of white cattle in non-white

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[36] C.S. Plumb, "Edward Lewis Sturtevant: A Biographical Sketch," *Missouri Botanical Garden Annual Report* (1899): 71-84.

[37] Ritvo shows how these allegations of mixed blood, though likely true, were often leveled to smear the reputation of a different herd. Ritvo, "Race, Breed, and Myths," 150.

[38] See Derry, *Made to Order,* Chapter 5 "Implications of Breeding for Color." Also, Felius, Koolmees, Theunissen, et al., "Breeds of Cattle" for breeding practices that were attuned to coat color, and classification systems for cattle based on color.

[39] The color of the Chillingham cattle coat and of the aurochs was the subject of extensive debate during the nineteenth century. This is quite striking given that specimens existed, and paintings of the aurochs could be found. Still, a particularly interesting published debate between Reverend John Storer and paleontologist William Boyd Dawkins on the subject shows, once again, that any line of evidence was necessary to take into account. In Storer's popular work *The Wild White Cattle of Great Britain*, several chapters were devoted to arguments supporting the possibility that the extinct aurochs was white, based on the coat color of its living wild descendants. Boyd Dawkins similarly referred to the living white cattle in his introduction to the chapter on Bovines in his renowned work *Pleistocene Mammalia.* Associating the living cattle with the extinct aurochs on the basis of their coat color suggested some questions to the interlocutors: did whiteness of coat itself signify ancientness?; did white signify domestication or wildness?; and ultimately, did it suggest a close relation between living white cattle and the extinct aurochs? Though Storer acknowledged that among domesticated animals "nothing is so fleeting and variable as colour," the Chillingham cattle displayed a "persistency of the same tint during long ages." (Storer, *Wild White Cattle,* xv) That persistence of coat color indicated the "antiquity of the race" itself; essentially there was a "greater prevalence and potency of the primal white" (Storer, *Wild White Cattle,* 29). In connecting white coat with the three p's of hereditary concerns ("prevelance," "potency," and

domesticated breeds would be referred to as "reversions." Sturtevant mentioned two cases of "reversion to white with red ears" in Ayrshire cattle, and many cases of the "return" to white color within the usually black West Highland breed. He cited those color reversions as the "strongest single argument" that the white British herds were the forefathers of the contemporary domesticated stock.[40] Such reversions were of significant interest to livestock breeders and agricultural scientists by the end of the nineteenth century. The 1897 *Elements of Agriculture* textbook suggested that reversions were phenomena particularly suited to illuminating the history of a breed, "the origin of which is lost in obscurity."[41] The Chillingham cattle, their white coat, and their supposed connection to the ancestral aurochs promised to remove some of that history from obscurity.

The potential knowledge about breed history and therefore heredity patterns that could be gained by studying the British white herds made them an excellent candidate for dedicated breeding experiments. The wealthy families who owned the herds prioritized the cattle's

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"primal"), Storer indicated that the Chillingham cattle were ancient, and their associated coat color was itself indicative of that. To Storer, "the white cow" was not the "product of domestication" (Storer, *Wild White Cattle,* 17) He argued that many wild animals bear white coat, and despite observations that many domesticated animals "are subject to great alterations when they are tamed and subdued by man," including the shifting of the coat to white, not every domesticated animal would undergo the same changes when domesticated. Boyd Dawkins, however, resisted the possibility that a large white mammal could be wild. In rebuking Storer and naturalist Richard Lydekker, who both claimed that the aurochs was likely white, Dawkins wrote that the "pure white colour of this [Chillingham] breed" was "out of harmony with its surrounding." (Boyd Dawkins, "Charltey White Cattle," 5) That lack of camouflage rendered it "impossible to be concealed from its enemies," and in the process, implied domestication. Only polar bears came to mind as an example of a truly wild, white large animal, and it was clear that in their snowy environment this was not a disadvantage. Sources: Storer, *The Wild White Cattle of Great Britain: An Account of their Origin, History, and Present State* (London, UK: Cassell, Peter & Galpin, 1879). Boyd Dawkins, "The Chartley White Cattle," 1899. DERSB 72067.1 Box 5, Booklet, Boyd Dawkins Archives, Derbyshire County Council, Buxton Museum and Art Gallery, Buxton, UK. And Boyd Dawkins and Sidney H. Reynolds, *A Monograph of British Pleistocene Mammalia* Vol 3 (London: Palaeontographical Society, 1872).

[39] Wilson, "Chillingham White Cattle," 15-16.

[40] Sturtevant, "Wild Cattle of Scotland," 143.

[41] William Fream and James Richard Ainsworth Davis, *Elements of Agriculture: A Text-Book,* 6th ed. (London: John Murray, 1897), 388.

preservation, which hindered any ready crossbreeding. In 1887, the British Association for the Advancement of Science published a "Report on the Herds of Wild Cattle in Chartley Park, and other Parks in Great Britain", which floated the idea of an experiment in which calves from each of the ancient white herds in Britain be placed together to create a new herd.[42] The suggestion was that through combining blood, the new herd might revert to something close to the "aboriginal wild type." The possibility of any such experiment rested on the cooperation of the herds' noble owners, however, and never came to fruition.[43] Other experiments with the white herds had been conducted in the nineteenth century, but with different aims; often, domesticated breeds such as Herefords or Shorthorns were crossed with a member of the white herd in order to improve the domesticated breeds. One such experiment with the Chillingham white cattle conducted by Jacob Wilson was cited in textbooks and agricultural essays.[44]

Wilson's report of his experiment took the form of a traditional natural history on the animals, and discussed in brief the remains of the aurochs, the reliability of various historical records of the Chillingham herds from the Medieval period, and integrated his experiments on the living herds into that tapestry. In 1899, *The Land Magazine,* conducted by the Land Agent's Record, published Wilson's essay on "The Chillingham White Cattle." Wilson, a prominent land manager from Westmorland, worked directly with the herd for much of his life.[45] His essay wove together various records of the cattle. Indeed, those "white specks" dotting the Chillingham hills could only be described through the list of their many associations: "the famous wild cattle so

[42] E. Bidwell, William Boyd Dawkins, et al., "Report on the Herds of Wild Cattle in Chartley Park, and other Parks in Great Britain," *Report of the Fifty-Seventh Meeting of the British Association for the Advancement of Science* (London: John Murray, 1887): 135-45. The experiment idea was also referenced in R.C. Auld, "The Wild Cattle of Great Britain," *The American Naturalist* 22, no. 258 (June 1888): 498.
[43] Bidwell, Boyd Dawkins, et al., "Report on the Herds," 137.
[44] William Housman, *Cattle: Breeds and Management* (London: Vinton and Company, 1897)
[45] Rea, "Sir Jacob Wilson," 1- 18.

often described by the historian, discussed by the naturalist, and limned by the painter; the heirs of the former kings of the forest, the connecting link between the present and the past."[46] The charismatic aurochs dominated a third of the essay on the Chillingham cattle. In these respects, the essay was typical for a work on the herds.

Wilson paid attention to the historical lineage of the cattle and their presence as witnesses to England's long political history. He noted, for example, that the nearby village of Chatton was "where Edward I. held his court," and that the entire region was dotted with sites that had been "the camping ground of the moss-troopers or the scene of some wild border raid."[47] Their diminished population was even due to the rise of British modernity, according to him. The local extirpation of the numerous "descendants of the wild white cattle of ancient Briton" was attributed by Wilson to an "inevitable" "gradual extermination" of the larger animals, as the flip side of human progress.[48] That inevitable process of destruction, occurring in this ancient Briton, according to Wilson, was accelerated later during the English Civil war of the mid-seventeenth century; Parliament soldiers "destroyed everything that pertained to Royalism, from church windows to wild cattle."[49] Wilson lamented that only the Hamilton Park herd in Scotland, and the Chillingham and Chartley herds of England remained. Thus, the regrettable reduction of the white wild cattle population was shown to be at once an inevitable process in the longer turns of the "progress" of "conditions of life," and also localized in a more recent historical political episode. To Wilson, both held truth, and to eschew the recent historical memory of civil war for the longer current of unavoidable historical extinctions, would be to diminish the full reign of the cattle's distinctly British existence.

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[46] Wilso*n,* "Chillingham White Cattle," 11-12.
[47] *Ibid.,* 11.
[48] *Ibid.,* 12.
[49] *Ibid.,* 13.

The historical record continued to be relevant in Wilson's interrogation of the morphological and behavioral distinctions of the cattle. As Wilson fairly noted, "for readers of *The Land Magazine,* the place [Chillingham] has an interest all its own, at once historical and scientific."[50] "Scientific" at this time still leaned heavily on the historical.[51] Which record – historical writings or direct morphological observation – held priority in any particular question was subject to change. Within Wilson's work, discrepancies between historical records, or between historical writing and direct observation of the animals themselves, were often addressed not through immediate dismissal of one line of evidence as subordinate, but rather through external explanations that could make both true.

In one such case, the white cattle's mane, or rather, lack thereof, became a particular knot to untangle. Walter Scott had clearly indicated the mountain bull of his poem as "tossing high his mane of snow." Jacob Wilson even cited Scott's stanza. Though the white color of both Scott's mountain bull and the Chillingham cattle gained significant attention in the nineteenth century for what that suggested about the potential color of the extinct aurochs, the Chillingham cattle lacked an observable mane. If the association between Scott's bull and the aurochs were to be taken as true, this suggested that the aurochs was perhaps more distinct from the Chillingham cattle than they were similar.

Wilson was at least satisfied with the conformation of likeness between the Chillingham cattle recorded in historical, and poetic, descriptions of the animals to their contemporary living form. He compared the writing of Hector Boece, the Scottish Boethius, from the sixteenth

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[50] *Ibid.,* 11.
[51] William Coleman refers to those who studied natural history in the nineteenth century, particularly after Charles Darwin's *Origin,* as "historians of life." William Coleman, *Biology in the Nineteenth Century: Problems of Form, Function, and Transformation* (Cambridge, UK: Cambridge University Press, 1977), 166.

century, for example, describing the bulls of the Caledonian Wood as being of "the purest white" and being "so wild and untamable," to descriptions of the animals by Bishop Leslie, Queen Mary's ambassador at Elizabeth's court, as "of the purest white in color…fierce and savage, abhors the human race," finding confirmation of their descriptions in one another.[52]

Wilson offered that "there is hardly a word of the above which might not be written of the Chillingham cattle today."[53] Even down to the taste of the bulls, apparently, the historical sources had gotten it right.[54] Though not everything in the centuries-old written descriptions matched what Wilson himself observed. Leslie had written of "a mane thick and hanging down like that of the lion"; Boethius too had described "manes like that of the lion."[55] Thus, lamented Wilson, "in one point only is there a discrepancy [between historical sources and observation of contemporary cattle] - the description of the mane."[56] To address this discrepancy, Wilson suggested that the animals likely lost their manes once in the captivity of the penned enclosures. For support of his view, he identified historical descriptions of the cattle that compared them to American bison and their manes, suggesting at once that the cattle had once been maned, and that they could not be considered as wild as the American bison. He also cited evidence that Britain had undergone a change from untended forest to enclosed tracts of hunting park. And with a final flourish of evidentiary support, he touted the old Houghton family crest, sporting a

[52] Wilson, "Chillingham White Cattle," 15-16.
[53] *Ibid.,* 16.
[54] Bishop Leslie claimed that "its flesh is cartilaginous, but of the most delicious flavor." In confirmation of this, Wilson notes that "those who have eaten their flesh bear witness to its delicious flavour." Wilson, "Chillingham White Cattle," 16.
[55] *Ibid.,* 15-16.
[56] *Ibid.,* 16. Wilson credits his own direct observation of the form, color, and behavior of the cattle at several points, as well as the observations of "Michie," the park keeper who reportedly "had charge of the herd for the past 40 years, and who, with the exception of the Earl of Tankerville himself, is the greatest living authority on the habits of these wild cattle." Wilson, "Chillingham White Cattle," 24.

maned bull.[57] Taken together, "Nature may have suited herself to their altered surrounding by reducing their hirsute coverings," making it unnecessary to "explain the present absence of a mane by charging exaggeration upon earlier writers."[58] To Wilson, then, each conflicting record of the cattle and their manes – in medieval and recent historical writing, as well as direct observation of the living animals – could be justifiably brought together under the historical reasoning that maned animals, when removed from a fully wild state of nature, would lose their manes. The historical cattle, and their visage in family crests and historical writings, opened the possibility to draw on the processes of "Nature" to defend the observations of the Scottish Boethius, Bishop Leslie, and Walter Scott.

In no other matter was the continued entanglement of recent and deep past so obvious as in the questioned relationship between the wild Chillingham cattle and the extinct aurochs. The aurochs had an uncanny habit of creating puzzles for the charting of historical time in sciences such as geology in the nineteenth century.[59] Its legacy as an object worthy of inquiry was particularly persistent due to the bewildering uncertainty around its extinction and descendants. In Britain, as Chapter 1 recounted, aurochs bones were found in cave deposits, railway excavations, and tilled farmland.[60] In Europe broadly, it morphed into a Pleistocene indicator, and allusions to it were also found in the writings of Greek and Roman historians, including

[57] *Ibid.,* 16-17.
[58] *Ibid.,* 16.
[59]. The work of Harriet Ritvo and Chris Manias offer additional examples of reading societal history onto animals perceived as ancient, and connections between fossils and philology, respectively. Chris Manias, "'Our Iberian Forefathers': The Deep Past and Racial Stratification of British Civilization, 1850-1914," *Journal of British Studies* 51 (2012): 910-935.
[60] Mid-century, several aurochs fossil findings from Scotland, England, and Wales spurred interest in the aurochs, as discussed in Owen, *British Fossil Mammals.* Of course, more continue to be found. In 2004, a *Bos primigenius* [aurochs] specimen was found by the Moray Estates farm manager in Morayshire, Scotland and is on display at the Moray Estates for viewing by appointment. Andrew C. Kitchener and John Doune, "A Record of the aurochs, *Bos primigenius,* from Morayshire," *The Glasgow Naturalist* 25 (2012).

Caesar.[61] Wilson, for his part, noted that "no mention is made of the Urus as having existed in Britain in historic times," suggesting its early extirpation on the British Isles before it could appear in the written record there. This, because "it must be remembered that the historic age in Britain began late - not until the year 55 B.C."[62] Throughout the nineteenth century, bones and written record were marshaled to discuss the relative timespan of the aurochs, on the continent and in Britain, as had been done in India when *Bos namadicus* was found in the 1830s.[63] In some cases, though not all, the differing methods drawing on older or more recent forms of evidence resulted in different conclusions about the timespan of the aurochs. Its survival in Scotland, for example, was debated by naturalists Richard Owen and John Alexander Smith — as Wilson described, "one from the scientific, the other from the archaeological point of view, the latter bringing down its survival to the eighth or ninth century A.D."[64] Wilson and the debate between Owen and Smith showed the necessary incorporation of fossil and archaeological records from both the animal's more recent and more ancient existence.[65]

Still, records from the past were not the only way to investigate heritage. Comparisons between extant British breeds and the Chillingham cattle offered indication for and against the aurochs as the singular origin for all of Britain's wild and domesticated breeds (what could be

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[61] Though these references were met with differing levels of confidence. James Wilson, Professor of Agricultural at the Royal College of Surgeons, Dublin was skeptical of Caesar's writings, citing Caesar's description of "his one-horned ox, and his jointless elk," which must also be taken seriously if Caesar's description of the aurochs were to be considered accurate. James Wilson, *The Evolution of British Cattle and the Fashioning of Breeds* (London: Vinton & Co., 1909), 14. He refers to Caesar's *Commentarii de Bello Gallico,* Book 6, chapters 26-28. Caesar, *Commentarii,* 132-133.
[62] Wilson, "Chillingham White Cattle," 20. This date referring to Caesar's first invasion of Britain.
[63] Prinsep, "Fossil bones of the nerbudda," 396.
[64] Wilson, "Chillingham White Cattle," 20.
[65] Smith's arguments can be found in John Alexander Smith, "Notes on the ancient cattle of Scotland, *Proceedings of the Society of Antiquaries of Scotland* 9 (1873): 587-674.

called “monogenic” as opposed to “polygenic”).[66] The Chillingham cattle became the evidential link for connecting all of Britain’s cattle breeds to the aurochs, in part due to those morphological comparisons done by Ludwig Rütimeyer. What could still be doubted, however, was a monogenic account of the Chillingham cattle, possibly stemming “in unbroken line from the aboriginal Urus of Britain,” and whether the wild cattle and British domesticated breeds had developed through historical mixes or were each domesticated directly from the aurochs itself. The polygenetic account of the origin of British breeds was strongly put forward by several naturalists, including in the early twentieth century by James Wilson, Professor of Agriculture at the Royal College of Science in Dublin.[67] He wrote in 1909 about the origins of British breeds in excessive detail, drawing on the works of Dawkins, Rütimeyer, Darwin, Caesar, and Walter Scott. Each chapter of James Wilson’s *The Evolution of British Cattle and the Fashioning of Breeds* was organized around specific human migrations into the British Isles.[68] James Wilson warned against the urge to see British cattle breeds as descended together from one type, from the aurochs, and examined the wild white cattle as the source of that funneled conclusion.[69] The affinities of various breeds to each other, that then had affinities to wild white cattle, which then

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[66] Wilson, *Evolution of British Cattle.* Monogenesis and polygenesis were terms used in discussions of the origin of race in humankind, with scientific racists from the nineteenth century on, leaning on biblical or broadly phenotypic arguments for the different origins of races in the wake of evolutionary theory that suggested a shared history for all humans. See Terence Keel, *Divine Variations: How Christian Thought Became Racial Science* (Stanford, CA: Stanford University Press, 2018) for more on the history of how Christian thought shaped the concept of race in Europe and American sciences.

[67] In fact, the question of “alien blood” in the Chillingham cattle, and the other wild white breeds frequently came up discussion of the cattle. Popularly, it was said there had been no intermixing, but Harriet Ritvo recounts instances where mixing was said to have occurred. Ritvo, “Race, Breed, and Myths,” 12-13.

[68] Wilson, *Evolution of British Cattle*.

[69] This urge was acknowledged directly by Sir Jacob Wilson in his 1899 essay for *The Land Magazine*: “I own that I would like to think that the wild ox of Chillingham is the direct heir of the aboriginal British Urus, the descendant of ancestors on whose necks the yoke of man never pressed.” But to Wilson, that “the balance of evidence supports that theory” was not due to a selective reading of the record. Wilson, “Chillingham White Cattle,” 20.

were linked to the aurochs, did not, he claimed, prove that the British breeds were all domesticated directly from the aurochs. In order to rebuke this idea, he sought to demonstrate how the wild white cattle themselves had a mixed heritage, drawing on a familiar combination of art history, written record, and fossil and living breeds.[70] His conclusion was that every color found in British breeds stemmed from a different importation of cattle by different human migrations: white coat was brought in by the Romans, reds by English, brindles from another. Duns were one of many that came from the Norsemen.[71] Color, therefore, was not a simple signifier of degree of relation to the aurochs. Still, the coat color of cattle breeds would continue to fascinate, especially with the rise of Mendelism in the twentieth century; the later sections of this chapter will trace the continuing relevance of color and the differing opinions of James Wilson, Lydekker, and James Cossar Ewart about what it signified.

Ultimately, Jacob Wilson's 1899 essay in *The Land Magazine* placed evidence from the deep and historical past in conversation. Neither the origin of the Chillingham cattle nor their purported ancestor the aurochs were clear cases. They persisted as whole objects of interest in part due to their appearance in the records of disciplines that studied different depths of time, and the investigations incredibly drew on all lines of enquiry available. Wilson himself acknowledged that the article had "strayed somewhat from the stricter lines of agriculture, and to have rather invaded the limits of history," though that had "not been without a purpose." "It is," he claimed, "not desirable that any science should be too special or narrow."[72]

Wilson's turn-of-the-century essay in many ways resembled the range of work that had tackled the living white British breeds thus far. The introduction conveyed the romantic

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[70] Wilson, *Evolution of British Cattle,* 24.
[71] *Ibid.*
[72] Wilson, "Chillingham White Cattle," 21.

associations - ancient, medieval, royal, British - that often accompanied even the most dully anatomical tracts about the cattle. The charismatic ancestor, the aurochs, dominated a third of the essay, with the author happily conveying evidence that the Chillingham cattle "are the lineal descendants of the mighty Urus himself, the head of the house of all European cattle, whose fossil bones have been found in the neighbourhood of Chillingham and Wooler."[73] In many respects, and especially in the sheer variety of disciplines from which the evidence came, the essay was unremarkable. It trod the well-worn ground of references to Caesar, comparisons between horn shapes of several extant breeds, the coat color of oxen ancestors, and historical and proto-ecological claims about the wildness of the animals. Its reference to a breeding experiment, however, would draw the attentions of naturalists interested in the topic.

In 1875, Jacob Wilson, with the aid of short-horn breeders William Booth at Warlaby and Hugh Aylmer at Norfolk, directed experiments to "discover the effect of crossing the wild cattle with short-horns."[74] The experiments were carried out by the Estate Bailiff of Chillingham, Mr. Noble. The breeding commenced with some difficulty. The first pairing, a wild white Chillingham bull and a "highly bred short-horn cow," only produced one bull, named "Adam," and one freemartin heifer.[75] Wilson suggested that the initial pairing was made challenging because the wild male was disinclined to "approach anything that bore the taint of human hands," in reference to the domesticated female.[76] New pairings were needed to produce a female

[73] *Ibid.,* 21.
[74] *Ibid.,* 24.
[75] *Ibid*. The freemartin refers to a sterile female calf born as the twin of a male calf. It is now known that the hormones of the male twin affect the development of the female calf.
[76] *Ibid.* Of note is that the experiment was conducted using "natural service" – i.e. not through artificial insemination. In Jacob Wilson's Experiments, the preference of the wild bull for a wild heifer or cow, rather than the domesticated short-horn female, underscored the behavioral difference of the two breeds and the relative wildness of the one. Such an observation was only possible using 'natural service,' in which the reproductive behaviors of the animals were kept largely whole.

cross, and preferably without the delay caused by the wild bull's trepidation with the domesticated short-horn female. Flipping which sex of the pair was domesticated and which wild, a Chillingham cow and a short-horn bull named "Baron Bruce" were crossed, though at first only bull calves were born. Eventually, heifer calves were produced in 1885 and 1886. From these, the first cross of the longer experiment was formed, and the crossbreeding continued.[77]

Wilson provided the following details about the experiment: a tabulation of crosses showing the years of each cross, the name of the dam, the sire, and the produced female offspring. In each cross, the female offspring of the previous pairing was mated with as many as three short-horn bulls, including "The Rajah 53750," "Highland Snowstorm 62709," and, of course, "Sir Reginald Studley 58148."[78] The breeding was thus conducted through the female line; the male offspring produced were showcased as castrated steer males at the Smithfield Club Fat Stock shows in 1888 and 1889.[79]

Wilson's experiment demonstrated to him the potency of the Chillingham breed: "the wild breeds holds its own very strongly."[80] Potency of wild type traits in inheritance was of great interest to naturalists interested in heredity and domestication, and experiments into the

The history of artificial insemination attempts in livestock and humans is long, though in 1897 and in 1899 – when Wilson published – two notable achievements were made. The first, Walter Heape at Cambridge, reported the use of AI in domesticated animals. In 1899 something resembling the modern practical methods of AI were developed and published by Ivanovich Ivanov (who also attempted cross-breeding experiments with humans and apes). Common use of AI in cattle breeding did not take off until the 1940s, when the UK led the way in underscoring its use as a means to control venereal disease in cattle. G.V. Zvereva, "Professor I.I. Ivanov – founder of artificial insemination of animals," *Veterinariia* 7 (1970): 88-90. Also, Kirill Rossiianov, "Beyond Species: Il'ya Ivanov and His Experiments on Cross-Breeding Humans with Anthropoid Apes," *Science in Context* 15 (2003): 277-316.

[77] Wilson, "Chillingham White Cattle," 25.

[78] *Ibid.*

[79] The *Livestock Journal* reported on the "cross-bred ox bred and exhibited by the Earl of Tankerville" at the 1889 show. They noted that the competition's butcher, J.R. Banks said, "he never cut up a better lean buttock, and wishes there was more of the sort about." *The Livestock Journal* 30 (1889), 631.

[80] Earl of Tankerville, "On the Chillingham Wild Cattle," *The Field* Box 27 WBD 71506, 1890s, Boyd Dawkins Archives, Derbyshire County Council, Buxton Museum and Art Gallery, Buxton, UK.

persistence of wild traits in descendants were a means to explore the phenomenon. In Wilson's experiments, the results up until 1890 suggested a "ready assimilation of blood between the short-horn male and the wild female." The appraisal was given in part due to the improvement of the wild breed in the traditional agricultural measures: increased size and weight, beef production, "aptitude to fatten," and early maturity.[81] The wild Chillingham cattle, for their part, introduced "increased vigour and constitution, with lightness of bone, together with improved gait" into the produced offspring.[82] Wilson accepted the conclusion that a "close relationship of origin" existed between the British short-horn and the wild Chillingham ox, and aligned both with a descent from the aurochs.[83] Those initial results of 1890 also showed that the color was largely "unchanged," save for some red and black tint on the ears and nose.

After 1890, Wilson qualified his previous results, noting that the later crosses had lost many of the "distinctive markings" of the wild cattle, and that they had "reverted" to the short-horn type so much that they were eligible for the short-horn Herd Book, in both pedigree and appearance.[84] While the form of the later crosses had reverted to the domesticated Shorthorn, "the stately action" of the Chillingham cattle remained – the "wild, free instincts transmitted to them from their untamed ancestors."[85] From this, the Chillingham breed demonstrated to Wilson their deep ancestry and the undomesticated heritage of their stock. His experiment was included in his obituary in the *Journal of the Royal Agricultural Society:*

> "At Chillingham [Jacob Wilson] had the opportunity of exercising his well-known skill as a breeder of cattle, and it was mainly at his instigation that the late Earl of Tankerville

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[81] Jacob Wilson, "Chillingham White Cattle," 26. The competition embodied the "spirit of improvement," as historian Rebecca J.H. Woods calls it, that flourished at the end of the eighteenth century into the nineteenth. The development of pedigree cattle breeds, including the pedigreed short horn, alongside Britain's appetite for beef is recounted in Woods, *Herds Shot Round the World*.
[82] Jacob Wilson, "Chillingham White Cattle," 27.
[83] *Ibid.*, 26.
[84] *Ibid.,* 27.
[85] *Ibid.*

> carried out an interesting series of experiments by crossing specimens of his famous herd of wild white cattle with pure-bred Shorthorns, the object being to see what result would be produced by blending the blood of the wild cattle with that of the Shorthorn. Eventually two heifers, named respectively Wild Rose I. and Wild Blossom I. were produced, and these formed the foundations of two lines of families which have continued productive to the present day…"[86]

Wilson's experiment encompassed many of the associations of his other pursuits, explored earlier in his essay. The continuity between the crossbreeding and the historical investigations of the white cattle was more striking than the distinction. The crossbreeding experiments pushed the multiple temporal entries into investigation of the animals forward, by relying on decades-long production of new offspring that could furnish answers to those same entangled questions of origin and heredity. That extension forwards in time, while newly localized within the animals' bodies, simply added to an already expanding roster of appearances by the cattle in different temporal records. It did not replace it. So far, for Wilson, an agriculturalist by training, and for natural scientists including Dawkins, Darwin, Rütimeyer, and Owen, there was no imperative contraction for the scope of their research.

[86] G.G. Rea, "Sir Jacob Wilson," Obit., *Journal of Royal Agricultural Society* 66 (1905), 4-5.

Figure 26. Chillingham Bull Display, Oxford University Museum of Natural History.[87]

[87] Photo by author.

Figure 27. Members of today's herd of Chillingham cattle, Chillingham, 2019.[88]

REVERSIONS AND THE DEEP PAST

Jacob Wilson's work stemmed from a long history of practical breeding experiments prior to 1900. Around the start of the twentieth century, however, experimental farms, the development of statistics, and the promise of Mendelism renewed breeders' interest in progeny testing and a more rigorous experimental strain in agricultural farming developed. Still, through the white cattle, Americans and Europeans found links to the ossified past of their cattle breeds, and drew on historical records, paleontological comparisons, as well as new breeding experiments to trace the relationship of domesticated breeds and better understand the inheritance of behavioral and physical traits. This entangled posture perpetuated quietly into the post-1900 period.

[88] Photo by author.

The publication of Wilson's experiments in 1899 roughly coincided with the publication of a landmark work by a Scottish zoologist who had spent the previous two decades conducting his own livestock research. Born in Penicuik, Scotland, James Cossar Ewart had a long career in studying crossbreeding and inbreeding in domesticated livestock, seeking not to improve the breeds for agricultural ends, but rather to understand what was at work in phenomena such as reversions.[89] He trained in medicine at the University of Edinburgh (1871-1874), and served as an anatomy demonstrator before taking up the curator position at the Zoological Museum, University College, London. He returned to Scotland in 1878 in the post of Regius Professor of Natural History at the University of Aberdeen, before moving to a position at the University of Edinburgh in 1882.[90] During his career he oversaw the development of two experimental farms associated with the University of Edinburgh, and the founding of the Institute of Animal Genetics, which after many iterations would become The Roslin Institute.[91] The period of his work also straddled the academic development of formal Mendelian genetics and the introduction of the U.K.'s first academic position named for and dedicated to genetics, the University of Edinburgh's Lectureship in Genetics (Evolution and Heredity) in 1911.[92] It is not surprising that the University of Edinburgh was a suitable home for researchers like Ewart, who worked alongside livestock breeders, albeit with a more "academically based" focus on heredity, as historian Forbes W. Robertson has characterized it.[93]

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[89] Forbes W. Robertson, "Genetics," *Proceedings of the Royal Society of Edinburgh* 84B (1983): 212.
[90] M.F.H.A., "James Cossar Ewart, 1851-1933," *Obituary Notice to Fellows of the Royal Society* 1 (1934): 189-195.
[91] Clare Button, "James Cossar Ewart and the Origins of the Animal Breeding Research Department in Edinburgh, 1895-1920," *Journal of the History of Biology* 51 (2018): 445-477.
[92] University of Edinburgh also had the first university chair in agriculture in Britain, est. 1790.
[93] Robertson, "Genetics," 212.

Crossbreeding experiments, like those undertaken by Jacob Wilson and earlier breeders, indicated the persistent relevance of the deeper past in questions of heredity and reversions. In the early twentieth century, experimental rigor was prioritized by scientists who established dedicated experimental farms for investigation into inheritance questions, forecasting the shift towards experimental organisms in biology. Practical breeders, however, still leaned on their charts of the past, drawing on pedigrees rather than progeny in their purebreeding strategies for decades after the re-discovery of Mendel's work.[94] In the United States, the scientific promise of experimental farms was becoming clear. In 1902 Charles Otis Whitman, the American zoologist, read a paper to the Corporation of the Marine Biological Laboratory (MBL) at their annual meeting in Massachusetts. The paper was part philosophical stance on the value of experiment and observation, and part plan for the development of a proposed biological farm for the use of the MBL. Whitman argued that biological laboratories were "in design, equipment and staff" restricted to "the study of *dead* material."[95] For biologists, however, the problems of the day were the problems of vital processes: "heredity, variation, adaptation and evolution," processes which were characterized as "slow and cumulative in effects, expressing themselves in development, growth, life-histories, species, habits, instincts, intelligence." In other words, problems that were demonstrable through their temporality, and considered them as processual

[94] In the Netherlands, it would not be until broader understanding of statistics and genetics, and widespread use of AI that progeny testing for productivity would once again become the favored breeding strategy in agricultural work. That shift would occur slowly beginning in the 1950s and 60s. See Bert Theunissen, "Breeding for Nobility or for Production? Cultures of Dairy Cattle Breeding in the Netherlands, 1945-1995," *Isis* 103, no. 2 (June 2012): 278-309 and Theunissen, "Breeding Without Mendelism" for more on this context.
[95] Charles Otis Whitman, "A Biological Farm for the Experimental Investigation of Heredity, Variation and Evolution, and for the Study of Life-Histories, Habits, Instincts and Intelligence," *The Biological Bulletin of the Marine Biological Laboratory* 3, no. 5 (October 1902): 214. His paper was also printed in *Science* in 1902.

entities; problems which pointed to the "pressing need of new facilities for observation and experiment on *living* organisms."

The biological farm was to Whitman and many of his contemporaries "one of the great desiderata of biology." It could enable biologists to come face to face with animals, put them under control so that they could "handle it, photograph it, analyze it, read its history, and extort from it an answer."[96] The benefits of the scientific experimental farm were the intimate, continuous access to the animals: "uninterrupted continuance from year to year for long periods, under conditions that secure most favorable control for experimentation and study."[97] Of interest for such studies was the familiar bugbear of reversions. To address that "most interesting problem in heredity," Whitman proposed that all that was needed was stocking the farm with the proper experimental materials. Those materials would take the form of animals of "precisely defined origin," bred on the farm and therefore reliable in their ancestry.[98] Such considerations of the origins of experimental animals would only grow in the coming century, as laboratory animals became increasingly standardized. Around 1900, however, bringing knowledge of livestock's origins under control remained a puzzle to be solved for naturalists, not an established given for experiments on the farm. Still, biological farms showed promise. Ewart's work at his biological farm at Penicuik in Midlothian, Scotland illustrated exactly what such endeavors and sites could achieve. Whitman hailed Ewart's resulting work, *The Penycuik Experiments,* as "a brilliant illustration of fruit to be expected from a farm devoted to experimental research."[99]

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[96] *Ibid.,* 216.
[97] *Ibid.,* 217.
[98] *Ibid.,* 219.
[99] *Ibid.,* 215.

In 1899, Ewart released the work that Whitman would later praise, *Penycuik Experiments.*[100] In the book, Ewart compiled previous published accounts of his decades-long horse and zebra breeding work, as well as several other experiments that had excited researchers across the world and helped cement Edinburgh as an important site for developing animal breeding research. Ewart's experiments differed from Jacob Wilson's in several respects. Both were published in 1899, one year before the "rediscovery" of Gregor Mendel's heredity studies. Their respective educational backgrounds were evident in the relative meticulousness of Ewart's experiments. While Wilson organized his work as a natural historian would, bringing together various topics and evidence in a narrative-like essay, Ewart organized the introduction of *Penycuik Experiments* around the phenomenal questions that perplexed breeders and naturalists of the day: reversion, prepotency, inbreeding, "sport," and telegony. He referenced Darwin's theory of protoplasm, Francis Galton's concept of regression, and previous experiments on inbreeding in other organisms, such as insects. The bulk of the included papers, however, and the introduction he wrote for *Penycuik Experiments,* conveyed his own observation of breeding experiments conducted on his farm in Penicuik.[101] He recognized the difference between his own studies and the work done by practical agricultural breeders, when he reflected that "with the breeder, perhaps more than the biologist, superstitions are likely to flourish, for it is beyond the province of the average breeder to test his beliefs by systematic experiments."[102]

Still, Ewart's 1899 work maintained many of the sources used by Wilson and others who investigated animals rather holistically, as opposed to isolated phenomenal questions about them. Caesar makes an appearance, as do the Chillingham cattle and ancient Celtic shorthorns found in

[100] James Cossar Ewart, *The Penycuik Experiments* (London: Adam and Charles Black, 1899).
[101] The spelling he chose for "Penycuik," was a matter of preference, though at the time "Penicuik" was more commonly used.
[102] *Ibid.,* lvii.

the fossil record.[103] For the most part, his experimental conclusions were not much more successful at isolating the various conditions and possible origins of cattle and other livestock than any other works on the subject prior to 1900. As Ewart himself noted, "the creed of the biologist is ever changing, and, except in the case of mere hodmen, speculation and theory are ever in advance of the facts." Breeders, he claimed, were actually quite like biologists: "more or less guided by certain working hypotheses."[104] In the case of animals, such as the wild cattle, for which polychronic research often took into account the full and confounding record of the animals, the working hypotheses could sometimes be hard to isolate from the background noise.

For one hypothesis in particular, Ewart's experiments provided the most insight, and successfully separated out a particular phenomenon to investigate. In the case of the white Chillingham cattle, the appearance of any coat color that wasn't the snowy white which breeders expected was cause for attention. To some, the appearance of black spots, or the occasional black-coated offspring suggested the reappearance of an ancestral color, which in turn offered evidence that the ancestral aurochs had been black. The unexpected appearance of a trait different than not only the offspring's parents but also entire herds' known history was forgivably confounding. A famous instance of the appearance of an unexpected trait that was circulated among naturalists and breeders in the nineteenth century was that of Lord Morton's Mare.

Lord Morton had sent a letter about his mare in 1820 to the Royal Society, which was published the next year.[105] The mare in question, the letter recounted, had been used in a breeding pairing with a quagga – a zebra-like member of the horse family that would go extinct

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[103] *Ibid.,* l.
[104] *Ibid.,* lvii.
[105] Richard W. Burkhardt, "Closing the Door on Lord Morton's Mare: The Rise and Fall of Telegony," *Studies in History of Biology* 2 (1979), 3.

by the end of the nineteenth century – because Morton "was desirous of trying the experiment of domesticating the quagga."[106] After the breeding, the mare, which was chestnut in color and "seven-eighths Arabian blood," was given to another breeder who mated it to a black Arabian horse. The offspring of that second pairing with the same mare had "striking resemblance to the quagga" in color and pattern.[107] The subsequent explanations put forward in the year following ranged from "maternal impressions," to the changing of the female reproductive form by the "male element."[108] In response to popular examples like Lord Morton's Mare, and the occasional black head of otherwise white cattle, naturalists put forward several explanations; sometimes Lord Morton's Mare was the subject of heated debated.[109] For many, including Charles Darwin, the clearest explanation was the theory of telegony.

Telegony was given its name by its critic August Weismann in 1892. It explained the case of Lord Morton's Mare as due to the influence of a previous sire (the quagga) on subsequent offspring of the same female with a different male. While not everyone was convinced of telegony, prominent naturalists referenced Lord Morton's Mare and drew on telegony as the likely cause.[110] At the end of the nineteenth century, many experiments into telegony were carried out, including Everett Millais's work on dogs and fowl.[111] In his 1899 *Penycuik*

[106] George Douglas, Earl of Morton, "A communication of a singular fact in natural history," *Philosophical Transactions of the Royal Society* (1821): 20.
[107] *Ibid.*
[108] Burkhardt, "Lord Morton's Mare," 9-10.
[109] August Weismann and Herbert Spencer factored the reality or unreality of telegony into their debates over inheritance of acquired characteristics. Burkhardt, "Lord Morton's Mare," 10-11.
[110] Darwin cites the case in *Variation* Vol 1. He notes that "there can be no doubt that the quagga affected the character of the offspring subsequently begot by the black Arabian horse," and draws on his knowledge of plant reproduction to do so. Darwin, *Variation,* 403-405. Derry has articulated how some interest in telegony in horse breeding circles stemmed from interest in Bedouin breeding methods which purportedly made use of telegony theories. Derry, *Made to Order,* 113
[111] Including Karl Pearson, who wielded statistical arguments against telegony. Burkhardt, "Lord Morton's Mare," 14.

Experiments and his 1902 "Experimental Contributions to the Theory of Heredity," James Cossar Ewart struck a significant blow to the theory.[112] Ewart had dedicated half a decade to replicating the conditions of Lord Morton's Mare, breeding together horses and zebras, and investigating related breeding and color patterns in fowl, dogs, and cattle to determine whether a mare or cows' previous mates could hold any sway over the type of progeny from different sires. Telegony threatened to collapse the timescales needed to understand occurrences of reversion.

In fact, Ewart claimed that "telegony" was often mistakenly used instead of "reversion'": "simple reversion is sometimes mistaken for telegony."[113] Even in Ewart's day, reversion and its study and purported causes were rarely seen as "simple." The threat of "throwing back" or "reverting" to a previous type drew significant attention throughout the nineteenth century. Referred to as "reversion," or "atavism," or "degeneration" depending on the moral valance added, naturalists sought to understand how such throwbacks were hereditarily possible, and what they signified about the rigidity of animal types.[114] In reversion, as opposed to telegony, the rules and range of phenomena were more expansive. Reversions could, as Ewart noted, "be to recent, remote, or intermediate ancestors, and the tendency will in most cases be to revert to sports that here and there mark the route along which the development has proceeded."[115]

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[112] James Cossar Ewart, "Experimental Contributions to the Theory of Heredity," *Trans. High. Agr. Soc. Scot.* 14 (1902): 243-251.
[113] *Ibid.,* 244.
[114] Jean Gayon has a compelling comparison of clinicians' use of 'degeneresence,' or 'dégénérescence,' and 19thC naturalists' use of 'degeneration.' Comparing the French alienist Augustin Morel to Darwin, Gayon indicates that the physician's view was of a qualitatively negative deviation from type, while the naturalist's was the inverse: regression as an indication of *returning* to type, and therefore demonstrating the restrictive nature of types. Jean Gayon, "Natural Selection, Regression, and Heredity in Darwinism and Post-Darwinian Evolutionary Theory," in *Heredity Explored: Between Public Domain and Experimental Science, 1850-1930,* eds. Staffan Müller-Wille and Christina Brandt (Cambridge, MA: MIT Press, 2016), 168.
[115] Ewart, *Penycuik Experiments,* xxi. "Sport" in this case meant a quantum change in ability or form of an organism, for example a horse being able to leap to a height previously thought implausible. The question of heredity of such "sport" characteristics was of tremendous interest in the nineteenth century.

Reversions could often be observed in the form of the offspring bearing a different color, or in some cases, changes in limb configuration or the number of digits. For proponents of telegony, however, all that was needed to understand the unexpected appearance of a strange trait was to view records of the female's previous mates, rather than summoning and probing a breed's deeper ancestral lineage. Certainly, such a contraction of relevant scope, to within the mating history of a single cow or mare, would make the breeding choices facing cautious agriculturalists much easier. The problem of "throw-backs" became more manageable if the trait was only throwing back to a mating a few years prior, rather than to the twists-and-turns of, for example, the wild cattle's uncertain ancestry and traces. With telegony on the table, the task of answering the ancestral heritage of breeds, and their relation to the aurochs, was potentially unnecessary to the phenomenal concerns of "throw-backs."

In exploration of the question of telegony, James Cossar Ewart marshaled his network of breeders, procured funding, and conducted crossbreeding experiments over several years. The theory was entertained fairly widely by the time of Ewart's experiments.[116] Ultimately, he made a convincing case against the theory of telegony and the "infection" of Lord Morton's Mare by the quagga sire. The quagga-like patterning in the offspring, he claimed, was due to a shared ancestral heritage of horses and zebras, and Morton's Mare represented a reversion along that line. "An extended series of experiments with various kinds of animals has led me to the conclusion that if there is such a thing as telegony," Ewart reported, "it is more likely to result in

[116] Ewart described it as follows: "since Lord Morton, in 1820, addressed a letter to the Royal Society on the subject, believers in 'infection"' have been increasing all over the world." Scientists including "physicians and others interested in the problems of heredity either as a rule take telegony for granted or see nothing improbable in the 'infection' hypothesis." Ewart, "Experimental Contributions," 244.

the subsequent offspring 'throwing back' to an ancestor of the 'infected' dam than to a previous mate."[117]

Ewart's experiments struck a blow to telegony at the same time that they rekindled the importance of the phenomena of reversions and the varying depths of time needed to understand and account for them. In fact, Ewart himself remained open to exploring the deeper history of livestock animals such as cattle, sheep, and horses. [118] Consulting abroad, Ewart remained active on the aurochs and cattle question. He corresponded with Americans Henry Fairfield Osborn at the American Museum of Natural History in New York, and E.W. Morse at the United States Department of Agriculture, on questions of the "ancestry of domesticated animals," and the Tertiary Mammals.[119] In the 1910s, Ewart turned significant attention to cattle and the aurochs, procuring specimens from various breeds, and reaching out to his network of breeders and naturalists to solicit information on the presentation of horns in the cattle. In 1910, Ewart sent several letters to zoologist Sydney J. Hickson at Cambridge, Philip J. White at University College of North Wales, Bangor, and Sir Arthur Keith from the Royal College of Surgeons of England asking for sketches and photographs of their zebu skulls for osteological comparison with *Bos primigenius*, the aurochs.[120] Months before Ewart died in 1933, he received a request from the curator of State of Missouri Resources Museum, Alfred C. Burrill, for aid in setting up

[117] *Ibid.*
[118] He pursued several studies on the origin and comparative anatomy of cattle. Robertson, p 213.
[119] "Letter to James Cossar Ewart from Henry F. Osborn, 7 May, 1904," Papers of James Cossar Ewart, Coll-14/9/10/48, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK. And "Letter from E.W. Morse, "Specialist in Animal Husbandry," April 9 1912 from US Dept of Agriculture, Office of Experiment Stations, Washington DC," Papers of James Cossar Ewart, Coll-14/9/18/17, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.
[120] "Postcard to James Cossar Ewart from Sydney J. Hickson, 19 Nov 1910," Papers of James Cossar Ewart, GB 237 Coll-14/9/16/38. "Letter to James Cossar Ewart from Philip J. White, 21 Nov 1910," Papers of James Cossar Ewart, Coll-14/9/16/39. "Letter to James Cossar Ewart from Sir Arthur Keith, 18 Nov 1910," Papers of James Cossar Ewart, Coll-14/9/16/36. All from the University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.

museum exhibits "of the ancestry of our various breeds of livestock."[121] The Museum Commission, Burrill reported, had references that kept referring to Ewart's work, and they wanted access to any additional separate writings Ewart had produced on the subject. There was one issue in particular for Burrill: "we seem to have the most trouble trying to decide which author is right on the descent of the different breeds and whether Bos taurus primigenius [the aurochs] and longifrons are subspecies of the same species." Burrill also sought advice on "where to find pictures of animals before the time of Christ."[122] It is unclear whether Ewart fulfilled Burrill's requests before he died on December 31, 1933.

In June 1905, Ewart had the chance to directly consult on the breeding of the Chartley herd of wild white cattle. A relative of Ewart's, Colonel Spencer Ewart, sent a request on behalf of Lieut. Colonel Walter Norris Congreve for aid in reestablishing the Chartley herd. Of particular concern to the requester was introducing "alien blood," and whether or not the offspring of

[121] "Letter to James Cossar Ewart from Alfred C. Burill, March 18, 1933," Papers of James Cossar Ewart, Coll-14/9/38/3, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.

[122] *Ibid. Bos longifrons* was a name applied to some fossil oxen specimen, and it, *Bos trochoceros,* and *Bos frontosus* were believed to have been ancient oxen found in Britain, along with *Bos primigenius.* Darwin had repeated this view in his *Variations.* Boyd Dawkins had discredited Nilsson's *Bos frontosus* and had written that *B. longifrons* "is essentially the animal with which the archeologists have to deal," implying its distinct status was by virtue of its existence in material records that fell within archeological purview. William Boyd Dawkins, "On the British fossil oxen. Part II. Bos longifrons, Owen," *Quarterly Journal of the Geological Society* 23 (1867). To him, *frontosus* was a variety of *longifrons,* and he thus disagreed with Nilsson and Rütimeyer, whose expertise Darwin had cited in the first edition of *Variations.* In the second edition, Darwin capitulated and reported Dawkins' view. This fascinating relation between Darwin and Dawkins has been reconstructed by H. Meiring, and indicates that Dawkins exploited Darwin's patronage while attacking him through anonymous reviews. H. Meiring, "Scientific patronage in the age of Darwin: The Curious Case of William Boyd Dawkins." *Studies in History and Philosophy of Science* 89 (2021): 267-282. C. Carter Blake took aim at Boyd Dawkins' critique of *B. longifrons,* that designation which Dawkins reported being "unable to assign any characters of specific value to," in the 1868 *Geological Magazine.* Carter wrote in reply to Dawkins, "I must humbly put in a plea in favour of the animal nature of man, and express my belief that up to the present time I thought that archeologists had to deal with human works, and human remains, as well as those of horses, goats, and sheep, when found with human relics." C. Carter Blake, "Bos longifrons," *Geological Magazine* 5, no. 44 (1868): 100-102.

subsequent members of the reinvigorated herd would throw back to that “alien” form.[123] The Chartley breeder’s request, unknowingly, also stepped into a particular intellectual hornet’s nest, pertaining to the differing potential for reversions in domesticated and wild animals.[124] For navigating this mess of a question, while aiding in reviving the diminished and inbred herd, James Cossar Ewart was the right consultant. Ewart began a lengthy correspondence to aid the project of saving the herd from extinction. In the correspondence between Ewart and R.T. Wickham, who carried out Ewart’s instructions on behalf of Congreve, they considered acquiring the similar-looking Chillingham cattle for breeding with the diminished Chartley herd. To Congreve, it sounded “beastial to bring in fresh blood,” though he guessed it had been done before at both Chartley and Chillingham.[125] Concerns about purity in breeds were commonplace in the breeding world of the nineteenth century. Nonetheless, Ewart advised, in imprecise terms, that the Chartley bull should be bred with Highland cattle, and other distinct breeds.[126]

[123] “Letter to James Cossar Ewart from Spencer Ewart, 13 June 1905,” Papers of James Cossar Ewart, Coll-14/9/11/12, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.
[124] Darwin and Alfred Russell Wallace had addressed this exact conundrum, and historian Jean Gayon has used their stances on reversion as the main lens for his reading of Darwin’s work to interesting effect. Jean Gayon, “Natural Selection.”
[125] “Letter to James Cossar Ewart from Lieutenant Colonel Walter Norris Congreve, c. July 1905,” Papers of James Cossar Ewart, Coll-14/9/11/18, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.
[126] “Letter to James Cossar Ewart from R.T. Wickham, 10 Aug, 1905,” Papers of James Cossar Ewart, Coll-14/9/11/22, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.

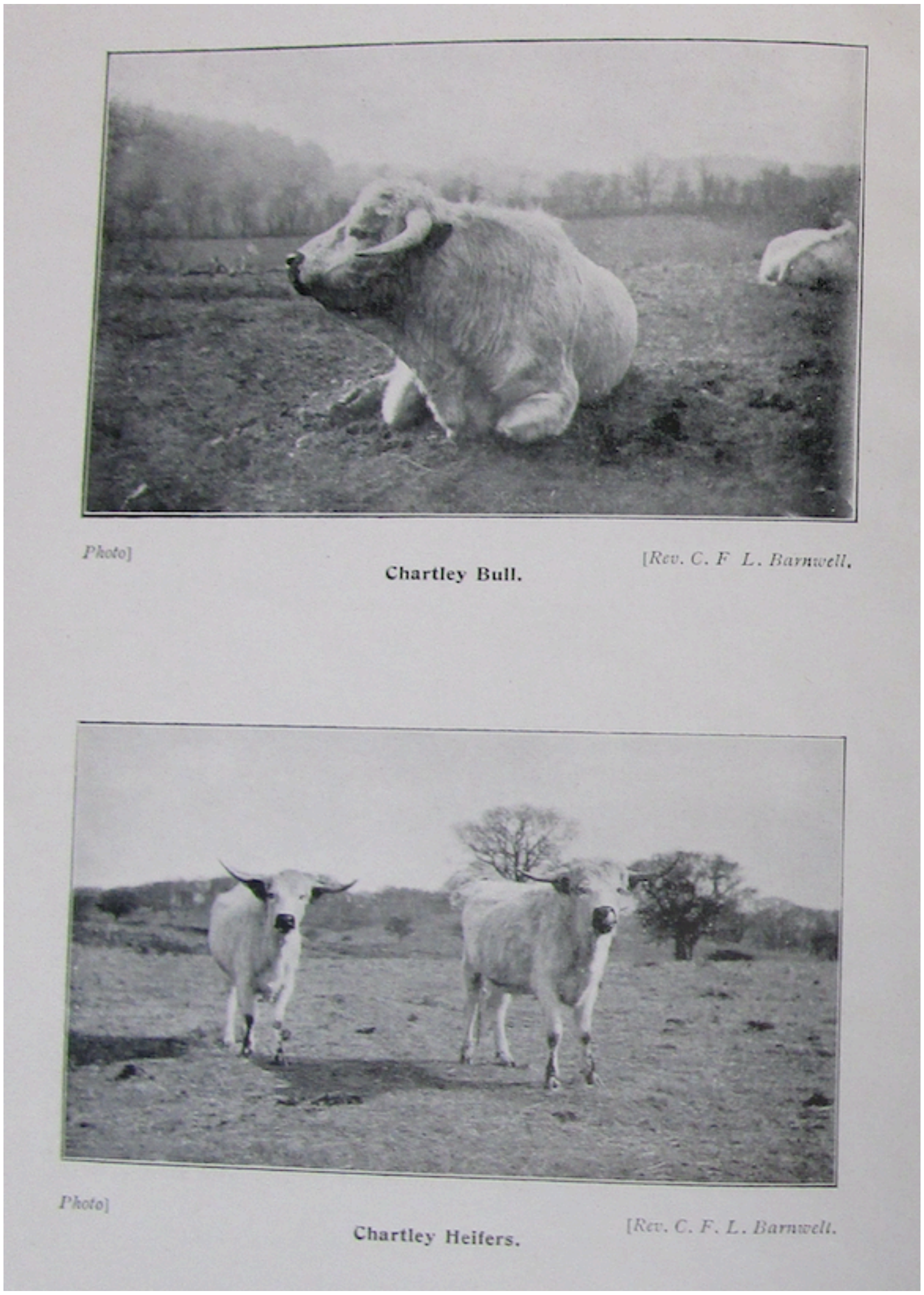

Figure 28. Plate 22 of H.E. Forrest's 1908 "The Origin of British 'Wild' Cattle."[127]

[127] H.E. Forrest, "The Origin of British 'Wild' Cattle, *Naturalist,* 1908. Photograph from Buxton Museum Archives, BB16 65771.

Ewart's career at a glimpse shows the persistence of the cattle and their ancestor as an object of study that encompassed and remained attached to a growing array of timescales. Osteological sources joined medley works such as those written by Storer, Dawkins, and James Wilson at Dublin. Ewart's career also signifies the next iteration of the work begun at Chillingham by Sir Jacob Wilson. Still, Ewart increasingly faced an uphill battle in his applications for funding and timing extensions for his experiments at the experimental stations he established at Shothead Farms and Fairslacks Farms. A current of financial support went to genetics research on *Drosophila.*[128] Eventually, even the dairy cattle were not worth their keep for the milk yield investigations at their scales of operation, and the Animal Breeding Committee voted to cease the experiments and keep some cows to sell their milk production, and sell the rest.[129] Over the course of the 1910s and 1920s, the funding for the experimental farms and the University of Edinburgh's Animal Breeding Research Department (later, the Institute for Animal Genetics in 1930), and their biological objects, resembled less the cattle that had occupied those farm spaces for so long, and increasingly organisms that were conducive to sex physiology studies, and unsurprisingly, genetics.[130] The records of the Institute into the interwar period tell a striking and

[128] "Copy of a Letter to Sir William Turner from James Cossar Ewart, 10 May 1912," Papers of James Cossar Ewart, Coll-14/9/18/28, University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.

[129] "In regard to the experiments on the inheritance in cattle of milk yield and butter fat content of milk, the Council's Committee formed the definite opinion that the genetic complexity of the commercially valuable characters under investigation is such, and the number of animals under experiment is so inadequate that the work in its present form and on the existing scale offers no promise at all, whether of scientific or practical results. The Council and the Department of Agriculture for Scotland have therefore accepted the visiting Committee's recommendation that these experiments should cease forthwith and that the best of the animals should be kept at Shothead for milk production and the remainder be sold." From "M28a (copy) – Letter to Mr. Fleming on 22nd May 1943, from E.H.E Havelock" in EUA IN1/ACU/A1/1/1, Minutes of the Animal Breeding Committee, 1928-1947 (Box: EUA-A-63), University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.

[130] Page 2 of "M8a Report of the Animal Breeding Research Committee" 2nd Oct 1930," in EUA IN1/ACU/A1/1/1, Minutes of the Animal Breeding Committee, 1928-1947 (Box: EUA-A-63), University of Edinburgh Center for Research Collections Archives, Edinburgh, UK.

familiar story: the charismatic animals that had embodied integrated research questions gave way to smaller, cheaper, and less temporally demanding organisms. The cow gave way the fruit fly and the fowl in biological investigation. Otis Whitman, the American who had lauded Ewart and hoped to establish a similar farm station for the MBL never got his biological farm.[131] Still, against this documented institutional shift in academic biology, Ewart, who slowly incorporated the new Mendelian genetics into his work, and others interested in objects conducive to polychronic study, actively reviewed archaeological works, paleontological specimens, and the production of crossbred or inbred offspring.

MENDELISM, GENETICS, AND THE FUTURE

The scientific shift to Mendelism and genetics did not make a ready mark on the world of practical breeding. And where breeders were influenced by early twentieth-century scientific developments in statistical handling of progeny testing towards improved agricultural yields, it was often with organisms whose biology offered quick and efficient data on offspring productivity. As Bert Theunissen has discussed, the biology of the animal species being bred often dictated the interplay of craft and science, the particular breeding culture that emerged, and the scientific methods that were advocated for or used.[132] In cattle, in which growth indexes and progeny testing required quite a bit of time, those methods were less used than in chickens. Commenting on Theunissen's work, Rebecca Woods has pithily put it: "chickens are not peas,

[131] Edward S. Morse, "Biographical Memoir of Charles Otis Whitman, 1842-1910," in *National Academy of Sciences Biographical Memoirs* Vol VII (Washington DC: National Academy of Sciences, 1912): 284.
[132] Theunissen, *Beauty or Statistics.*

but neither are they like cattle."[133] Such impracticalities rendered the Mendelian revolution in science practically useless to many livestock breeders for decades.[134]

Still, for scientists, the impact of Mendelism and early genetics on the science of heredity in the twentieth century should not be understated. With the rediscovery of Gregor Mendel's work on heredity in 1900, Mendelism grew as a force of explanation and mode of study for the patterns of heredity that had included confounding phenomena such as reversions. Historians of biology have carefully detailed the debates that surrounded Mendelism in the early twentieth century. Though they will not be rehashed here, it is important to note that Mendelism was often pitted against the statistical methods of the study of inheritance. Proponents of the latter went by the name "biometricians," and were influenced by Francis Galton. The difference between the Mendelians and the biometricians was scrutinized by many in the period, as well as in subsequent historical literature. Historian Margaret Derry, for example, has provided a compelling account of the discontinuity of inheritance emphasized by Mendelism, compared to the continuity of inheritance put forward by biometricians.[135] Mendelian inheritance was not antithetical to the views of the biometricians, though the two camps were often opposed. The contributions of Mendelian inheritance to heredity were often in interpreting the inheritance of discrete characters.

In no other phenomenal characteristic of animals was both the explanatory promise and underwhelming utility of Mendelism felt than the coat color. In practical breeding, attention to coat color had a long history as a means to trace ancestry, track reversions, and promise market-

[133] Rebecca J.H. Woods, "Bert Theunissen. *Beauty or Statistics: Practice and Science in Dutch Livestock Breeding, 1900-2000,"* *ISIS* 113, no. 4 (December 2022): 887-888, https://doi.org/10.1086/721996.
[134] As opposed to plant cultivators.
[135] Derry, *Masterminding Nature,* 35-43, 178-180.

standards that were culturally-driven, and therefore sensitive to market tastes.[136] Red shorthorns became favored for a while in Europe because the color was said to be an indicator of their heritage. As in the case of the Chillingham cattle, the inheritance of coat color was seen to offer insights into deep ancestry of breeds, and as Ewart demonstrated, its inheritance patterns could be demystified. Mendel's writings did much of the demystification.

For Arthur D. Darbishire, a biologist who studied at Cambridge and eventually worked with Ewart in Edinburgh on livestock experiments including Jersey and Ayrshire cattle cross experiments, the pervasive presence of Mendelism had completely flipped the temporality of breeding and heredity questions.[137] The past, and its associated pedigree charts, was useless to the breeder hoping to create productive offspring, according to him. Mendelism pushed the issue of the relevant temporality in breeding concerns further: only the future production of progeny might be valuable. Under Mendelism, and later genetical frameworks, the generation of new offspring could reveal something about the previous generations, not the other way around. As Darbishire put it:

> A few records of the milk production of the daughters of an Ayrshire bull are of much greater use as an indication of his value than all the available information with regard to his dam and granddams. You cannot tell what the breeding properties of a beast are until you have tested them. You cannot say whether a goose will lay golden eggs or not until it has begun to lay.[138]

[136] Improvement breeders could get caught in cycles in which previously fashionable focus on "conformation," or outward appearance, would come under fire, and productivity and maintenance for higher milk yields or fat content, for example, would be prioritized. Soon enough, however, general appearance would once again become the focus of breeders as a signifier of the overall health of the animals. See Pawley, "Point of Perfection" and Derry, *Made to Order,* for examples of fashioning tastes in outward appearance of breeds.
[137] See Roger J. Wood, "Darbishire expands his vision of heredity from Mendelian genetics to inherited memory," *Studies in the History and Philosophy of Biological Biomedical Sciences* 53 (2015): 16-39, for more on Darbishire, including his educational and philosophical background, and his time with Ewart.
[138] Arthur D. Darbishire, *An Introduction to a Biology: And Other Papers* (New York: Funk and Wagnalls, 1917), 279-280.

Progeny testing into the future was the future in the minds of biologists. As historians Hans-Jörg Rheinberger and Staffan Müller-Wille have argued, it just so happened that from a Mendelian perspective the best way to understand heredity was not through past generations, but through controlled breeding and study of successive progeny.[139] For practical breeders, however, the characteristics of value in their livestock were quantitative (such as milk yield), not qualitative (such as coat color), and Mendelism's offerings therefore held little value for their aims. Still, researchers on experimental farms pushed the study of Mendelian inheritance forward, at times daring to chide breeders for their backwards practices, and advocating an overhaul of agricultural breeding methods along new scientifically-informed lines.[140]

Progeny testing inspired by Mendelism offered scientists a way to not only explore better methods for improving agricultural yield, but also a way to understand ancestry through offspring. As an example of the necessity of using the animal's breeding to understand what the original animal actually was, Darbishire offered a case related to the continually confounding phenomenal part of the cow: the coat color. He cited the work of James Wilson, Professor of Agriculture at the Royal College of Science in Dublin, who had recounted an interesting case in which a bull was registered in a herd book as red, and yet its progeny with roan cows were white calves (roan meaning intermixed coats of white and another color). The case was a riddle, until upon closer inspection Wilson observed that the bull was in fact a roan himself, though one which could easily have been "mistaken for a red."[141] In his words, this case offered "a striking illustration of the change which has been brought about by Mendel's work." Prior to Mendel, a

[139] Rheinberger and Müller-Wille, "Heredity Before Genetics."
[140] Theunissen, "Breeding without Mendelism," and Theunissen, *Beauty or Statistics.* Derry also recounts episodes of scientists attempting to advise breeders. Most of the examples from these sources result in breeders dismissing or debating the scientists.
[141] Darbishire, *Introduction to A Biology*, 272.

breeder would observe the animal itself and a record of its ancestors to see what its breeding would produce. For Darbishire, “Mendel has completely turned the tables; and in the case of this bull we had to look at what his offspring had been in order to tell what colour he was!”[142]

The example of color, which appears in the historical sources referred to in each section of this chapter, was a popular trait upon which naturalists and breeders fixated. It seemed like an observable measure of form and parentage, and yet its constant use as a signifier of reversions demonstrated how its inheritance in animals such as cattle needed further study. It also demonstrated to Darbishire the kinds of discontinuous and discrete characters that Mendelism could explain. Such traits might be seen as furthering the ‘parts-based’ view of animals that the standards for livestock breeds had begun. Historians Jonathan Harwood and Brendan Matz, for example, have argued that prior to Mendelism, animals were viewed as more than an aggregation of character traits. Those traits such as color, might signal unobservable physiological processes and attributes that would be valuable to breeders, but those were correlated together and not themselves discrete or discretely inherited.[143]

Darbishire described what he saw as the difference between discrete inherited characters such as “pigment”, to which Mendelian laws applied, and the vital forces of the organism that flowed and changed through time, accruing inherited “memory,” and applying the valuable dimension of time back into an understanding of heredity.[144] He is an interesting figure for centering the analytical category of temporality in the scientific study of heredity. He himself

[142] *Ibid.*
[143] Brendan Matz, “Crossing, Grading, and Keeping Pure: animal breeding and exchange around 1860,” *Endeavour* 35, no. 1 (March 2011): 14. And Jonathan Harwood, “Linkage Before Mendalism? Plant-breeding research in Central Europe, c. 1880-1910,” in *Classical Genetic Research and its Legacy,* 1st edition, eds. Jean-Paul Gaudillière and Hans-Jörg Rheinberger (London: Routledge, 2004).
[144] Wood, “Darbishire.”
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situated time as an overt element of inheritance and inheritance models. Darbishire developed his conception of the value of time in animal development and evolution via the influence of vitalist philosophers Samuel Butler and Henri Bergson. As historian Roger Wood has shown, from these inspirations, Darbishire recognized that Mendelian explanations of inheritance did not require time in the same way that the evolutionary theories of Bergson necessitated them. Bergson's vitalist philosophy had emphasized four considerations for Darbishire: time was essential for the fixation of characters in organisms; life creates true novelty ("more is got out in the effect than is put in in the cause"); the behaviors of organisms cannot be mathematically predicted; and finally, organisms have vital and non-living parts. Darbishire contrasted these four conclusions from Bergson with the Mendelian heredity principles. First, the fixation of a character occurs at the meeting of germ cells from the parents, based on whether the germ cells have the appropriate characters; time has no place in the stability or instability of a character. Second, breeders can only recombine existing characters, not generate true novelty. And thirdly, Mendelian principles made mathematical predictions of offspring possible.[145] In a lecture given to the College of Agriculture at the University of Missouri in 1914, Darbishire reiterated his temporal framing of the turn to Mendelism by posing the question "has time anything to do with the fixation of a character?"[146]

Darbishire reconciled these two seemingly opposed views of time and heredity by suggesting that Mendelian inheritance applies to the "least vital" parts of the organism. For Darbishire, the temporal contraction that stemmed from Mendelism was, on its own, insufficient to account for

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[145] Arthur D. Darbishire, "Mendelian Practice in the light of Bergson's Biology," in Darbishire, *An Introduction to a Biology,* 98.

[146] Arthur D. Darbishire, "Notes of a Lecture Given in July, 1914 at the Graduate School of Agriculture, Held at the University of Missouri, Columbia, Missouri," in *Darbishire, An Introduction to a Biology,* 100.

the development of life. What was missing was an acknowledgement of the "essentially living parts of the body to which chemical principles do not apply" as contrasted with the not vital parts, such as pigment.[147] In the former, temporality and the individuality, vitality, or soul – all words he used – of the animal could be considered. Darbishire's account of the Mendelian ambivalence to temporality and the resulting loss of a holistic, vitalist view of organisms can perhaps be used to illuminate figures such as Jacob Wilson, Ewart, and others, who still kept the scope of their investigations broad enough to include distant past as well as procreating future while navigating the scientific changes in hereditary frameworks at the turn-of-the-century.

CONCLUSION

As the nineteenth century moved into the twentieth, and the concerns of pedigree and heritage from the eighteenth century slowly began to give way in scientific circles to concerns of progeny and future, Mendelian heredity and genetics blossomed as a tool for manipulating and studying experimentally derived offspring. To Rheinberger and Müller-Wille, the interest in future-oriented Mendelian experiments suggests a biological parallel to the future-oriented priorities of progress in nineteenth-century narratives, and their corollary concerns of degeneration.[148] They take as strong evidence of this link between Mendelian genetics and societal concern with the future, the increasing association of genetics with agriculture and its drive to "improve" and make organisms that could facilitate societal growth and efficiency. But into the twentieth century, interest in the genealogy of organisms through historical study did not disappear, and reversions were not always the horrible antithesis to presumed progress. For practical improvement breeders, pedigrees were still all-important into the mid-twentieth

[147] *Ibid.,* 97.
[148] Rheinberger and Müller-Wille, "Heredity Before Genetics," 143-166.

century; for sport and hobbyist breeders, authenticity and regional origins were paramount.[149] In this view, wild cattle breeding experiments extended the temporal plane of the objects into the future, and the horizon of the animal's temporal ontology disappeared further down the road. As scientists throughout history have attempted to keep the object and its records together as a whole, then certainly this extension makes a single discipline's scope of observation increasingly insufficient to characterize the aurochs fully.

As for the part of the multi-temporal study of the cattle that looked to the historical record, the multiple time scales invoked stemmed not from exclusively competitive traditions, nor necessarily from the ability of interested parties to apply their own meanings to the animals due to lack of information, as has been suggested before.[150] The animals themselves allowed for multiple trajectories and spans, and fascination with them often furnished a holistic approach to their study. Here, paleontology, archaeology, history, and later, breeding experiments, shared the epistemological field, largely without incident. The Chillingham cattle of the nineteenth century were not especially useful in answering targeted scientific questions; rather they generated questions, and researchers worked at many points of entry, from the deep and recent pasts, to crossbreeding experiments that lightened the evidential burden of those historical specialties but never did replace them. The animals were often taken whole – they rarely presented bodies from which scientific objects were carved. Instead, their associations with the study of heredity, wildness, and their polychronic scientific record kept them as complete objects. Borrowing from Jane Maienschein's framing of biological science research traditions, it can be said that research into the cattle and their ancestor the aurochs, was often of ontological concern, enabling

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[149] See Derry, *Made to Order,* Chapter 6 "Breeding for Authenticity," and Chapter 7 "Pedigree versus No Pedigree and the Market Value of Animals." And Ritvo, *Animal Estate.*
[150] Ritvo, "Race, Breed, and Myths," 14.

epistemological omnivory, as opposed to being driven by a singular method.[151] Even the experimental breeding of the animals did not give way to one particular epistemological approach.


8—THE CRAVEN HERALD—FRIDAY, APRIL 28, 1933

LINK WITH LONG AGO.

THE HORNS OF A PREHISTORIC WILD OX which have this week been discovered near Long Preston by Mr. T. Lord, Settle (centre), Mr. T. L. Frankland, Langcliffe (left) and Mr. E. Douglas, Settle (right).

OPPOSED TO ANY DICTATORSHIP.

Terrorism in Germany.

MR. J. P. DAVIES AND THE NEXT ELECTION.

Reference to the terrorism of the N regime in Germany and a protest against t British embargo on Russian imports w made at a meeting of the Skipton To Labour Party in the Skipton Co-operati Hall on Sunday evening, when addres were given by Mr. J. Percival Davi prospective Labour candidate for the Sk ton division, and Mr. Arthur Henders junr., the barrister son of the Foreign Sec tary in the last Socialist Government.

Mr. J. Day presided.

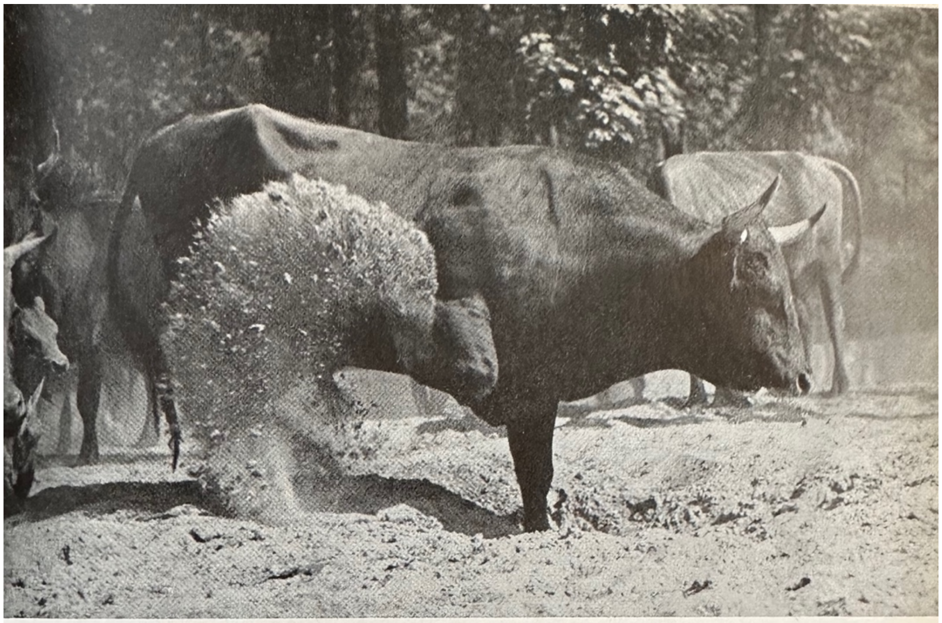
Mr. Davies referred to the terrible brut ities of the Nazis, and said it was a wick attempt to crush out by brutality and terr

Figure 29. "Prehistoric Find at Long Preston. Urus Horns Discovered," in *The Craven Herald,* 1933.[152]

The individuals in this chapter – with different disciplinary relations to agriculture, historical scientific traditions, and genetics – continued to sift through the staggered temporal record and create a holistic account of their object as they simultaneously bred it into the future. The onset of genetics and the occasional overlap between livestock breeding and scientific study of heredity emphasized the value of studying living descendants for questions about the aurochs. In inter-war and World War II- Germany, as the next chapter will show, a different emphasis on the potential of inheritance would gain support from the National Socialists, and two zookeepers would be empowered to use their own specific picture of heredity and evolution to try and bring the aurochs back into existence.

[151] Jane Maienschein. *Transforming Traditions in American Biology, 1880-1915* (Johns Hopkins University Press, 1991), 77.
[152] Newscutting at Buxton Museum Archives, Box P25 63921. Derbyshire County Council, Buxton Museum and Art Gallery, Buxton, UK.

Chapter 5: Nazi Aurochs



Neugezüchteter Auerochs. Mit dem Temperament eines Wildrindes scharrt der mächtige Bulle den Erdboden.

Figure 30. "Newly bred Aurochs. With the temperament of wild cattle, the mighty bull paws the ground."[1]

In 1938, with Hermann Göring looking on, a small herd of primeval cattle were released into the Rominten Heide hunting reserve in East Prussia.[2] On that clear autumn day, large vans containing the animals rolled up to the moors at the reserve. With one hundred and twenty acres fenced in, the land was prepared for the not-quite re-wilding of the horned beasts. As the creatures' creator later recalled, "the crates were placed and opened close to the gate of the fencing. Out rushed the first aurochsen of the new age, to wander once more in German forests,

[1] Lutz Heck, *Tiere - mein Abenteuer: Erlebnisse in Wildnis und Zoo* (Berlin: Verlag Ullstein, 1952), 160. Translation mine.
[2] Clemens Driessen and Jamie Lorimer, "Back Breeding the Aurochs: The Heck Brothers, National Socialism, and Imagined Geographies for Non-Human Lebensraum," in *Hitler's Geographies: The Spatialities of the Third Reich,* eds. Paolo Giaccaria and Claudio Minca (Chicago: University of Chicago Press, 2016), 141.

as in the legendary days of old."[3] Four years later, in the old forest of Białowieża, Poland, many more "aurochsen" were released. Over the course of three years, more than twenty thousand local people were forcibly expelled from Białowieża, or, in an early demonstration of Nazi brutality, killed.[4] Once the forest was considered 'cleared' – one of the first of the so-called "Juden frei" German territories – it could serve its intended purpose in the eyes of Göring, Himmler, and two German zoologists – Lutz and Heinz Heck. Primeval Germany was coming to life in their eyes, and its fierce, furred occupants had arrived.

The Heck brothers' aurochs back-breeding programs are a strange episode in the history of zoology, ecology, de-extinction, and the cultural history of the aurochs itself. Yet, they fit without much issue into the scientific pursuits in Weimar Germany and Germany under Nazi rule. Releasing the animals into the reserve fulfilled a German nationalist vision of reclaiming the spatial *Lebensraum* (the settler colonial concept of the space needed for the natural development of the nation), as well as the temporal goals set in a primeval yet Teutonic past. To accomplish these aims, Lutz and Heinz Heck, relied on a particularly opportune view of evolutionary temporality that suited their practical ends. Reinstating the *Urnatur* (original nature) of Germany was a project that in some ways reflected the early 1900s German amalgam of practical breeding knowledge and institutional scientific resistance to specialization that was occurring elsewhere in the world during the onset of laboratory genetics.

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[3] Heck, *Tiere,* 173. Original: "Dicht am Tor der Umzäunung wurden die Kisten aufgestellt und geöffnet. Heraus stürmten die ersten Auerochsen der Neuzeit, die wieder- wie in sagenhaften Vorzeiten – in deutschen Wäldern umherziehen sollten."

[4] Driessen and Lorimer, "Back Breeding," 149. This, one of the first "Juden frei" territories was created in order to reform an ancient wilderness suitable for the reoccupation of Nazi Germany's inclination to reform the primeval nature of Germany and create a hunting ground of European bison and aurochs. The association in this early atrocity against humans with recreating an ancient faunal reserve emphasizes the importance of the broader Nazi foundation mythologies in conceptualizing and furthering their agendas. Such myths informed and united seemingly disparate products of their aims, including their funding of research into eastern mysticism, experimental backbreeding, and structural violence and atrocities.

The Heck brothers' story with the aurochs has today attracted popular attention in splashy tabloid articles and questionable television programming that dub the Heck breed, which resulted from their aurochs back-breeding, as "Nazi cows."[5] In one case, the sensationalist piece denotes a standoff between a British farmer in 2015 and one Nazi super cow, that ended in turning the animal into sausage. As the epithet suggests, the 'Nazi' cows do have a story that can be traced back to the Third Reich (sparking yet another headline pun from *The Sun:* "The Herd Reich").

In the scholarly realm, the Heck cattle and the brothers that bred them have often been considered through geopolitical analysis. The material has been considered as space-based, and very place-aware. It is no coincidence that the main treatments of the Heck cattle breeding program so far have been written primarily by geographers, and therefore handle the spatiality of the breeds and their intended purposes with great care and insight.[6] Often these pieces come with a strong consideration of the irony of using stock from "elsewhere" to repopulate or revitalize something that is particular to a specific place; they consider the spatiality of the conservation territory itself, as when a rewilded area has a human-made fence around it. Ironies of the spatial kind make up much of the fascinating current discourse around conservation work and what it conserves. How can an animal bred from breeds strewn across a continent be a stand-in for a specific species that was lost in a specific national territory, and has become a symbol for a specific place? As such, it would be irresponsible in this chapter to neglect the role of international and national interests in the development of the first aurochs breed-back programs.

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[5] Some tabloids include: Tom Sykes, "'Nazi Cows' Tried to Kill British Farmer," *The Daily Beast,* Jan 6, 2015. Tom Bawden, "Nazi super cows: British Farmer Forced to Destroy Half his Murderous Herd of Bio-engineered Heck Cows After They Try to Kill Staff," *The Independent,* Jan 5, 2015. Steven Morris, "Devon farmer forced to offload aggressive Nazi-bred 'super cows,' *The Guardian*, Jan. 5, 2015.

[6] Clemens Driessen and Jamie Lorimer have written a few pieces on the Heck brothers' work, bringing their geography lens to bear on the fascinating history, and tracing the reaction to the Hecks' work within the Nazi establishment. See Driessen and Lorimer, "Back Breeding."

In this story, place is a vital component. The first section, therefore, offers some geopolitical context for the landscape of German science in which the Heck brothers and their particular programs emerged, drawing on scholarship on the history of the International Society for the Preservation of the European Bison to provide context for the institutions, aims, and theories which would lend support to the Heck projects. The second section explores the back-breeding motivations and methods of Lutz and Heinz Heck. Under Nazi funding, the two brothers began separate breeding projects with the same target: bring the extinct aurochs back to life. The goal was temporal as much as it was spatial, bringing back a former state of *Urnatur* to the territories deemed part of the *Lebensraum.* Counter to strands of "purity" thought in some Nazi social and biological policies, the brothers used crossbreeding of aggressive cattle breeds across Europe to generate a singular primeval organism, while also leaning on theories of inheritance to explain how such a feat would be possible in a few breeding cycles when evolution had taken millions of years to originally achieve it. Their methods, time-traveling aims, and the specific underpinning chromosomal views that infused the brothers with the confidence to believe they had achieved evolutionary reversal of an extinct animal within a decade are treated. The conclusion of the chapter considers the Heck brothers in relation to the temporal dynamics in different discourses on reversing evolution in nineteenth-century evolutionary theory, staving off societal and biological degeneration in Victorian social evolutionary thought, and the privileged place of the past in nationalist thinking. This chapter traces what happened to the concerns of small-scale reversions in practical breeding circles discussed in the previous chapter on British breeds and genetics, when they were applied to meet a broader aim of bringing something extinct back to life.

The biological views that underpinned the Heck brothers' work were no doubt informed by their motivating vision: a combination of scientific curiosity and an investment in the Nazi myth.[7] The latter was acutely expressed in the brothers' participation in Himmler's *Ahnenerbe,* which attempted to wield science as a legitimating force for Aryan mythology; they were asked to write a popular book on the aurochs as part of this.[8] To achieve a practical reinstatement of the Nazi myth and its investments in *Urnatur*, the Heck brothers pieced together the expansive records on the aurochs that had come before and what they saw as the biological tools at their disposal, to bring the aurochs back through its offspring.

CONSERVING GERMAN BIOLOGY ON THE BRINK OF INTERNATIONAL WAR

By the time Lutz and Heinz Heck began their breeding experiments at the Berlin and Munich zoos respectively, German biology was at somewhat of a crossroads. The Heck brothers, both zoologists, were born into a family legacy of running two of Germany's most prestigious zoos. Following in his father's footsteps, Lutz Heck served as director of the Berlin Zoological Garden beginning in 1932, while his brother Heinz began reestablishing the Munich Zoo in 1928.[9] From within their zoo domains, the brothers began separate back breeding experiments. Heinz began his work in 1921, and Lutz began in the early 1930s.[10] Internationally, hindsight on

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[7] Philippe Lacoue-Labarthe, Jean-Luc Nancy, and Brian Holmes, "The Nazi Myth," *Critical Inquiry* 16, no. 2 (1990): 291-312.
[8] Michael Hans Kater, *Das "Ahnenerbe" der SS, 1935-1945: Ein Beitrag zur Kulturpolitik des Dritten Reichs* [*The "Ahnenerbe" of the SS 1933-1945: A contribution on cultural policy of the Third Reich],* (Munich: R. Oldenbourg, 2006). The publication never seems to have been written, though it did inform part of the propaganda project *The Forest and Tree in Aryan-Germanic History of Thought and Culture,* which was led by Lutz. See Jamie Lorimer and Clemens Driessen, "From "Nazi Cows" to Cosmopolitan 'Ecological Engineers': Specifying Rewilding Through a History of Heck Cattle," *Annals of the American Association of Geographers* 106, no. 3 (2016): 644-645.
[9] Driessen and Lorimer, "Back Breeding,"140.
[10] Van Vuure, *Retracing the Aurochs,* 337.

this period in biology has characterized it as a time of blossoming experimental rigor and attention to the mechanics of evolution and inheritance. Genetics, population statistics, and the figure of the lab scientist were growing in esteem, and labs such as Thomas Hunt Morgan's at Columbia became the watershed image of the new era in biology.[11] Historians are well aware, however, that hindsight has a pesky tendency to obscure parochial truths in favor of global trends. Certainly, in the case of the new biology of genetics, and the influence of Gregor Mendel's work following its rediscovery in 1900, historians have turned their attentions to the diversity of biological approaches that did not neatly fit into a global trend. The previous chapter has already called attention to some of the ways in which a turn to genetics did not mean turning a cheek to older traditions such as morphology in the case of Britain.[12] And outside of the Anglo-American context, even more diversity of biological views could be found.[13] It is helpful to understand the irruption of the Hecks' strange and in some ways, superficial, efforts onto the biological and ecological scene in the 1920s and 30s, through a brief look at the German biological landscape, and the international conservation scene in which the Hecks would take part, and from which they would later be excluded.

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[11] Robert E. Kohler, *Lords of the Fly: Drosophila genetics and the Experimental Life* (Chicago: University of Chicago, 1994). And Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago, 2002).
[12] Something that scholars have explored in some detail in the United States (see, for example, Maienschein, *Transforming Traditions*).
[13] The difference between German and Anglo-American biology in the early to mid-twentieth century has often been characterized as an exclusion of German thought from the "Modern Synthesis," broadly hailed as when evolutionary biologists merged Darwinian natural selection with population genetics. Thus, "Anglo-American Synthesis" has been suggested as a more apt name for the modern development in evolutionary biology. Julian Huxley, *Evolution: The Modern Synthesis* (London: Allen and Unwin, 1942). For a history of Germany paleontology's structure and theoretical focus during the "Synthesis," see Manfred D. Laubichler and Karl F. Niklas, "The Morphological Tradition in German Paleontology: Otto Jaekel, Walter Zimmermann, and Otto Schindewolf" in *The Paleobiological Revolution: Essays on the Growth of Modern Paleontology,* eds. David Sepkoski and Michael Ruse (Chicago: University of Chicago, 2009). For more on German biology in general in the historical narrative of the Synthesis, see W.E Reif, T. Junker, and U. Hossfeld, "The synthetic theory of evolution: General problems and the German contribution to the synthesis," *Theory in Biosciences* 119 (2000): 41-91.

First, the section presents a consideration of German scientific infrastructure and its disciplinary and practical knowledge about nature leading up to the Hecks' work, leading into the period of their programs' support by the National Socialists. In this case, evolution and genetics in the German milieu can be held as distinct from that discussed in the previous section on Britain and the United States. The Heck brothers' work shows both the influence of this milieu and its drastic departure from the rigor and standards of the more academic German explorations of heredity, development, and evolution at the time. Second, a consideration of international science more broadly is necessary. New standards for scientific work, communication, and promotion developed at a rapid pace in the interwar period, all of which had to contend with regional politics and language barriers. Germany underwent a drastic shift in its international scientific role in the wake of WWI and the onset of WWII. Finally, international conservation efforts developed around the aurochs' cultural body double, the European bison, which paved the way for the conservation thinking, funding, and infrastructure that would lend themselves to the aurochs breed-back work. In particular, the development of conservation work was both international in a fraught global political scene, and deeply nationalistic, especially following Germany's plunge into National Socialism. In this section, each of these contexts - German biological science, international science, and the conservation movement - are discussed. It was amongst these developments and their scalar tensions that the Heck brothers would find support and carry out their strange breeding projects, discussed in the next section.

At the turn of the twentieth century, German biology wore evidence of its longer philosophical and scientific traditions. Following the Mendelian wave in heredity studies, German genetics developed in a way that would later be described as "backwards" in historiography, until around the 1980s.[14] It was true that, compared to the developments in genetics in the United States, most celebratedly pushed forward in the *Drosophila melanogaster* fruit fly labs of T.H. Morgan at Columbia, German genetics seemed to stall, with its more prominent historical voices treated in Anglo-American histories as having bet on all the wrong horses during a contentious theoretical landscape.[15] In a scientific world increasingly linked through international bodies, and increasingly English-speaking and lab-based, German science seemed to be a relic from a prior age. Still, Germany's biology was not, in fact, facing the wrong direction, but was rather prioritizing questions that were markedly different than the dominant investigative priorities in the United States and elsewhere, including integrating broad evolutionary questions in studies of genetics and chromosomes.[16]

The difference in Germany biology in the early twentieth century has its roots in a major strand of philosophical thinking from the prior century. That period found its icons in Kant, Goethe, and the Romantic school of *Naturphilosophie.*[17] In the early nineteenth-century, from the atomized political existence of Germany's fragmented fiefdoms, a curious holistic system of philosophy for nature and aesthetics developed, most notably through Johann Gottlieb Fichte, George Wilhelm Hegel, and the Friedrichs-three: Friedrich Schiller, Friedrich Schlegel, Friedrich Schelling. Leaning on Kant's *Critique of Judgement,* Goethe and his ilk approached the world through a holism that linked totality and parts through the fundamental forms of nature, or the

[14] Harwood, *Styles of Scientific Thought,* Chapter 1 for discussion of this historiographic tradition.
[15] *Ibid.*
[16] Harwood makes this explicit for the German genetics community in particular. Harwood, *Styles of Scientific Thought.*
[17] See Robert J. Richards, *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe* (Chicago: University of Chicago Press, 2002).

Gestalten.[18] And while the remainder of the nineteenth century would not be especially kind to this natural philosophy, it would regain its luster in cultural memory and in the German institutional resistance to specialization that has been meticulously charted by historians.[19] By the 1920s and 30s, the Heck brothers' work would take indirect inspiration from what Justus von Liebig, the German chemist, had called in 1840 "the pestilence, the Black Death, of the nineteenth century"; that is, *Naturphilosophie.*[20] The inspiration was possibly indirect, as the Hecks did not leave any record of reading the works of the natural philosophers or their inspirations.[21] Instead, they operated within a looking-glass philosophy of organism holism that initially found favor in the early days of the Nazi regime, and which would ultimately be criticized for devolving into mysticism.[22] The lines of attack ultimately leveled at the Heck brothers' scientific inadequacy resembled critiques hurled at the antireductionists of *Naturphilosophie* in the mid-nineteenth century, though in the Hecks' case any complaint that eventually circled around to calling out their superficial scientific understanding would have been fair.

While the distinctiveness of German biology, and in particular its genetics, held some continuity with prior iterations of German scientific philosophy, it perhaps maintained its uniqueness through its relative isolation in the increasingly international systems of science which were established in the wake of World War I. The Central Powers found that, following

[18] For more, see Richards, *Romantic Conception of Life.* Anne Harrington, *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler* (Princeton, NJ: Princeton University Press, 1996), Chapter 1.
[19] Harrington, *Reenchanted Science,* 7. Pushback came in the form of the "organic physicists," including Karl Ludwig and Hermann von Helmholz. See, Harwood *Styles of Scientific Thought.*
[20] Harrington, *Reenchanted Science,* 5.
[21] Lutz Heck received his doctorate in zoology from Berlin 1922, though the course of his studies is not clear.
[22] Harrington, *Reenchanted Science,* 179.

their defeat, they were as a whole iced out of international scientific exchange. German biology in this period is as much a story of betting on unlikely and largely ill-fated intellectual horses during the genetics revolution, as it is one of increasing international isolation at odds with global trends of scientific community building.

This was, after all, a period during which the International Research Council was created. In July 1919, the IRC was formed, with memberships that included disciplinary associations that had been excluded from the previous International Association of Academies.[23] Through such efforts to internationalize science, the IRC excluded the Austrian and German academies, going as far as to ban scientists from Germany and Austria from any cooperative congresses. The IRC operated in the wake of the Central Powers' defeat in World War I, and extended to its memberships the controversial sentiment embodied in the War Guilt clause of the 1919 Treaty of Versailles.[24] Even German language publications or conference presentations were encouraged to be excluded.[25] Over time, this dynamic largely reversed course, and though Germany never opted towards IRC membership once it was extended, by 1930 German scientists were turning out in large numbers to its meetings, as well as those of other international scientific bodies.

Within the sometimes-exclusionary international scientific landscape, there were realms of continued cooperation and shared international interest. In particular, concerns for nature were consistently pitched as a global interest, and within the growing conservation space, funding and

[23] Brigitte Schroeder-Gudehus, "International Science from the Franco-Prussian War to World War Two: An Era of Organization," in *The Cambridge History of Science*, ed. Hugh Richard Slotten, Ronald L. Numbers, and David N. Livingstone, 8:43–59, The Cambridge History of Science (Cambridge: Cambridge University Press, 2020), 52.
[24] Schroeder-Gudehus, "International Science," 52. The growing presence of German attendees, despite lack of membership, and the incredible reception of the German contingent to IUPAC assembly in 1930 are indicators of the changes in German reception and engagement with the international science system over this period. See Frank Greenaway, *Science International. A History of the International Council of Scientific Unions* (Cambridge, Cambridge University Press, 1996), 19-32.
[25] *Ibid.*

communications, and even live specimens could be shared between nations. Of course, with those international opportunities came international competition. A helpful demonstration of how conservation fared on the international scientific scene following World War I can be found in the case of the European bison, whose preservation history has been traced by historian Raf de Bont.

Concern grew following World War I for the preservation of the European bison, which, as recounted in chapter 2, had long been conflated with the aurochs. Prior to the war, the bison generated its own flurry of conservation concern.[26] In 1922, the International Society for the Preservation of the European Bison (ISPEB) was founded in Berlin, by Germany, Poland, Sweden, and the UK. Its initial founding attempt was impacted by geopolitical tensions. As historian Raf de Bont has traced, cancelations were made at the last minute during the deterioration in political and economic relations.[27] In addition to its geopolitical impacts, World War I had also accelerated the bison decline, as by 1923 a noticeable decrease in the bison population had occurred, especially in the forests of Białowieża, Poland. The stated cause of the bison decline there depended on who stated it: Polish poachers, German soldiers, Russian troops were all blamed for the clearing of the local bison population. The last bison in Białowieża was killed by 1919, and a remaining population in the Caucasian mountains had allegedly been killed by a group of hunters using machine guns, according to the ISPEB's journal.[28] By 1927, the European bison "as a whole could be declared extinct in the wild," according to those reports.

[26] Raf de Bont, *Nature's Diplomats: Science, Internationalism, and Preservation, 1920-1960* (Pittsburgh, PA: University of Pittsburgh Press, 2021), 115.
[27] *Ibid.,* 115.
[28] *Ibid.*

That left only the herds held by private hands, including the largest reported herd in the 1920s, owned by the 11th Duke of Bedford, Herbrand Russell; it was only ten individuals.[29]

The status of the European bison, and other growing conservation concerns, was increasingly available to an international audience. In particular, the journal *Oryx,* still published today, would recount the results of conservation efforts around the world, including about the bison and translations of Heinz Heck's aurochs back-breeding accounts. In 1904, The Society for the Preservation of the Wild Fauna of the Empire (now called Fauna and Flora International), published issue 1 of its *Journal,* one year after its formation. At first, it kept record of members and activities, until eventually publishing a more expansive array of conservation news, species status updates, and notices of conservation concerns. It touted being the only journal publishing writing on international wildlife conservation at the time. In 1950 it published its first volume under its new name, by which it still goes today, *Oryx.*[30] It was in the early days of this *Oryx,* that news of the Heck brothers' aurochs back-breeding work was circulated to English-speaking audiences, translated and published in the *Editorial Notes* section.

The journal represented an international forum for conservation work - something which was increasingly pitched in a tone of global significance. Still, tensions within the conservation community, between nations and within, were not uncommon. In the case of the European bison, international interest in conserving the dwindling populations were mixed with hyper-national competitiveness derived from limited funding and a symbolic sense of the true 'Germanness,' 'Swedishness,' or 'Polishness' of the animals. Whoever could lay claim not only to the better conservation groundwork and stability of their programs, but also to the symbolic resonance of the conserved organism as being iconic for that place would generate the most funding. In other

[29] *Ibid.,* 116.
[30] Reported on *Oryx* website, accessed February 2023.

words, the tension between parochial and global, a tension often cited and acknowledged in conservation work, was present in the case of the European bison. Its case informs not only this international and hyper-local backdrop in which the German Heck brothers would find their work in the interwar years and during WWII, but it also saw the creation of a conservation strategy, supporting conservation bodies and journals, and partnerships with senior leadership in the National Socialist party which would carry through to the Heck brothers' more outlandish work on the back-breeding of the aurochs.

The conservation of the European bison, or *Wisent* as it was known in Germany, was undertaken in several nations, each seeing the animal as a national symbol. It was in Germany, however, where this would be taken to new heights. In 1933, the same year the National Socialists took power in Germany, the German Association of Wisent-breeders and -keepers was founded. It was tightly linked to the national authorities, certainly more so than its predecessor body, the ISPEB. In this new body, Hermann Göring, who oversaw the creation of the *Gestapo* and collected an embarrassment of titles including *Reichsjägermeister,* or Master of the Hunt, was appointed the director, and Lutz Heck was named his deputy.[31] Lutz Heck's relationship to the Nazi party has been less ambiguous than his brother's, however there is some discrepancy in historical works that treat the subject. Still, it is clear from Lutz's close friendship with Göring that he had a close affiliation to the party.[32] It is less clear how affiliated to the Nazis Heinz was

[31] See Kai Artinger, "Lutz Heck, Der 'Vater er Rominter Ure.' Einige Bemerkungen zum wissenschaftlichen Leiter des Berliner Zoos im Nationalsozialismus," *Der Bär von Berlin: Jahrbuch des Vereins für die Geschichte Berlins* 42 (1994): 125-138.
for more on Lutz's connection to National Socialism.

[32] Lorimer and Driessen have shown fairly tight affiliation, through Lutz's personal friendship with Göring; de Bont has noted Lutz's membership in the party; and Gary Bruce has charted the resulting support and interest given to the Berlin Zoo by Nazi officials, including Göring in Gary Bruce, *Through the Lion Gate: A History of the Berlin Zoo* (Oxford, UK: Oxford University Press, 2017). Lutz's own memoir, written after World War II makes clear his adoration for the Nazi establishment. Not as much is known of Heinz's degree of affiliation and relations to the Nazi officials. In fact, relatively little is known

and viewed himself to be, nor whether his own breed-back work at the Munich Zoo attracted as much interest from Göring as his brother's work in Berlin.

Lutz Heck's role as deputy to Göring included his function as an ambassador abroad to gain support for their *Wisent* breeding program. As such, he leaned on contacts he had in America to generate funding for both Heck brothers' programs. This endeavor was highly contested. Poland, for example, sought to elevate awareness of their own European bison breeding program. The Warsaw zoo director Jan Zabinski, for example, replied to a piece in *The Times,* that had highlighted and lauded German breeding programs. He sent in a supplement to clarify that Poland was actually at the forefront of bison preservation.[33] The vision for these breeding programs, and their international competitiveness was on full display at the International Hunting Exhibition in Berlin in 1937. It was held there at Göring's insistence, and both Poland and Germany presented national exhibits that centered the European bison.[34] Such competitive relations between Poland and Germany over their shared interest in conserving the bison were broken over the course of WWII and Germany's occupation of Poland. Lutz Heck's foreign conservation contacts, to whom he initially wrote during the Nazi invasion of Poland to assuage any concerns about the status of European bison in the occupied territory, did not hear

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about Heinz and his work in Munich. His relative geographic distance from the seat of power compared to his brother may have kept him further from notice. Additionally, as Clemens Driessen has kindly pointed out to me, the Munich Zoo's archives have been largely inaccessible, which seems to still be the case. Given the paucity of historical record on Heinz, there still seems to have been more favored interest in Lutz's work within German circles at the time. As a twist of ironic fate, Lutz's Berlin-based Heck breed was destroyed in World War II, while Heinz's survived in Munich and today's Heck cattle are all descended from that stock.

[33] "European Bison – Saving the Species from Extinction," *The Times,* April 15, 1936. See de Bont, p. 14.

[34] de Bont, *Nature's Diplomats,* 129-130.

about the ethnic cleansings taking place, nor the later plans for the cleared areas to be used for reintroduction of the bison and bred-back aurochs.[35]

The case of European bison is illustrative of the international and intranational politics which constituted the early-twentieth century German conservation efforts, and the Heck brothers' ascendant role in the rapid shift to Nazi rule. It also demonstrates several of the key tensions present in such conservation work. This form of conservation looked radically different than the conservation efforts that had developed in the 1860s in which nature would be set aside to keep itself. Instead, this more invasive approach involved active breeding of the organisms to be conserved, the practice that had previously been oriented towards use value of livestock within agricultural breeding.[36] Practical considerations such as which animals to breed, how best to breed them, where to keep them, and what to do with them once a stable population was created quickly transcended into philosophical tensions over spatiality and temporality in conservation work. Those same tensions only escalated in the case of the extinct aurochs.

First, those at the ISPEB, and eventually its successor, the German Association of Wisent-breeders and -keepers, disagreed over where to keep the living specimens of their breeding programs. The main debate revolved around the use of zoos, which, as in the case of Berlin, already carried some stock which would be useful to their programs. Some of the concerns regarding zoos were that they would be "unnatural" as a place to keep the wild animals. Zoos in Germany had, in the 1850s-1870s, undergone an intense version of the larger zoo

[35] Simon Schama, *Landscape and Memory* (London: Harper Collins, 1995), 70-71; and de Bont, *Nature's Diplomats,* 130.
[36] For more on productive livestock breeding, see notes in Chapter 4 of this thesis. Also, Joshua Specht, *Red Meat Republic: A Hoof-to-Table History of How Beef Changed America* (Princeton, NJ: Princeton University Press, 2019); Derry, *Made to Order;* Chris Otter, *Diet;* and Schrepfer and Scranton, *Industrializing Organisms.*

movement occurring across Europe.[37] Zoos were promoted for their civic role, offering moral symbols and connection to a broader and exciting world.[38] The zoos served in part as keepers of a moral concern through caring for captive animals that may be threatened in the wild, forming what historian Lynn Nyhart has called the "earliest pioneers of the nascent nature protection movement."[39] In Germany in particular, that movement straddled an intense moral messaging and antimodern sentiment.[40] In 1859 the Frankfurt zoo founded its *Der Zoologische Garten,* later subtitled *Zeitschrift für Beobachtung, Pflege und Zucht der Thiere* (*Journal for the Observation, Care, and Breeding of Animals*) which published an array of contributions on studies of zoo animals, breeding advice, and travel reports.[41] Zoos, including those in Munich and Berlin in which the Heck brothers worked, had a history as the vanguard of protection and conservation consciousness. In the early twentieth century, however, concern was expressed about the effect of keeping wild animals in zoos, especially if the goal was to eventually return those populations to the wild.[42]

Still, for many of the ISPEB's leaders, accelerating the breeding process to meet their conservation goals mattered more. For example, as historian de Bont reports, Goerd von Groeben, eventual studbook-keeper for the ISPEB, posed it this way: "The question of today is not 'what is natural?', but rather: 'how do I get this cow pregnant again as quickly as possible?'"[43] Debates like these in the ISPEB were early precursors to later conservation organizations which would themselves end up considering temporality and spatiality in relation

[37] Nyhart, *Modern Nature,* 79.
[38] *Ibid.*, 80.
[39] *Ibid.*, 82.
[40] *Ibid.*
[41] *Ibid.*, 80.
[42] The effect of the environment on breeds was a colonial question that could be tested in zoos, in which exotic animals from elsewhere could be kept and observed for their adaptability or degeneration.
[43] de Bont, *Nature's Diplomats,* 120.

to each other. The ISPEB was in fact the second international conservation organization that was established, and so gives an early glimpse at the kinds of practical and theoretical tensions that became somewhat entrenched in later conservation work.[44]

Even if zoos, private holdings, or wildlife parks had their benefits, there was always an ultimate desire to have unmitigated wilderness into which the bison could roam; after all, the bison, like the aurochs, was an *Urnatur* icon. For the past-dwelling minds in the Nazi party, such as Göring, hunting bison and aurochs would be an act of transmogrification for the hunter towards a Teutonic masculine ideal, by virtue of the animals' own embodiment of vitality and manhood.[45] Hunting in this period had deep entanglements with conservation efforts. In the United States, which the National Socialists looked to for inspiration on codified racism, hunting and its masculine privileges had played a significant role in preservationism under Theodore Roosevelt's presidency.[46] In Nazi Germany, the colonial practice of big game hunting was exercised in the occupied territories closer to home, which Göring in particular sought to develop as preservations for Germanic primitive game.[47]

The absorption of the aurochs into this vision of primeval German hunting grounds has largely been traced to the legend of the medieval German *Nibelungenlied.* The Nazis made

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[44] *Ibid.,* 114. The first was the International Committee for Bird Protection.
[45] *Ibid.,* 116, 128-29.
[46] See Donna Haraway, "Teddy Bear Patriarchy: Taxidermy in the Garden of Eden, New York City 1908-1936," *Social Text* 11 (1984): 20-64. For more on the Nazi's use of American models of racism see James Q. Whitman, *Hitler's American Model: The United States and the Making of Nazi Race Law* (Princeton, NJ: Princeton University Press, 2017).
[47] For more on big game hunting in the British imperial context, see John M. Mackenzie, *The Empire of Nature: Hunting, Conservation, and British Imperialism* (Manchester, UK: Manchester University Press, 1988). See also Mark Mazower, *Dark Continent: Europe's Twentieth Century* (New York: Vintage Books, 2000), for more on how the European colonial projects had much in common with the National Socialists, suggesting that Nazism was not such a strange outlier in the history of Europe. Göring's interest in hunting is explored more below; for helpful histories of his vision for hunting reserves in the German *Lebensraum,* see Driessen and Lorimer, "Back Breeding," de Bont, *Nature's Diplomats,* and Bruce, *Through the Lion Gate.*

extensive use of Medieval and even Ancient texts that conveyed information on Germany's past, including Tacitus' *Germania*.[48] In the *Nibelungenlied,* the hero Siegfried hunted bison and aurochs, and to those Nazis interested in constructing a distinctly German identity and history, it rendered both animals "German."[49] The *Nibelungenlied* itself was referenced by several members of the ISPEB, and its attachments to a specific European wilderness that no longer existed only fueled ambitions to restore a European wilderness.[50] It would be cited in the Hecks' aurochs work as both inspiration and model – something discussed in more detail in the next section.

Other concerns about the bison's successful preservation were over its vitality. Many of these will be familiar to those who read popular conservation stories today. In particular, there was a fear that the bison were displaying stifled reproductive success, and were vulnerable to diseases; put simply, there were deep concerns about degeneration of the bison.[51] In response to these concerns, members of the ISPEB focused on how to stymie degeneration, with some calling for cross-breeding to inject some vitality into the blood, and others voicing concerns about losing the purity of the group if such crosses were done. In answer to the concerns, the first studbook of the bisons, and the first for any wild animal was created, presented to the ISPEB in

[48] The ideas extracted from these texts would fuel myths that resonated with and informed Nazi identity. See Christoph B. Krebs, *A Most Dangerous Book: Tacitus's Germania from the Roman Empire to the Third Reich* (New York: W.W. Norton and Co, 2011). For the connection to the Aryans and German Orientalism myths, discussed briefly in Chapter 3, see Bruce Lincoln, "Dumézil's War God," and Carlo Ginzburg, "Germanic Mythology and Nazism: Thoughts on an Old Book by Georges Dumézil," in *Clues, Myth, and the Historical Method,* trans. John and Anne C. Tedeschi (Baltimore: Johns Hopkins University Press, 2013). For an account of the use of Tacitus's *Germania* in the context of colonial India, see Kabir, "Enchanted Mirror."
[49] See Hermann Reichert, *Das Nibelungenlied: Text und Einführung* (Berlin: De Gruyter, 2017).
[50] de Bont, *Nature's Diplomats,* 117, 128.
[51] de Bont, 118-119.

1932. As historian Raf de Bont has argued, "the studbook turned the wisent into a breeding object — and thus, in many ways equaled it to domestic livestock."[52]

Lutz Heck was a vocal proponent for this so-called blood mixing method. He first advocated for bringing in American bison to add vitality into the European bison stock. At the base of his ideas were his notion of expulsion breeding, or *Verdrängungszucht.* The principle was built upon the chromosome theory of heredity that was making its way through the German genetics community. Essentially, chromosomes were taken to be mosaic-like, with linear placements of different parts; breeders could therefore swap out some of the discrete mosaic 'tiles' of the chromosome. Through this mechanism, Lutz believed the American bison could gift its vitality, with breeders selecting for the offspring that displayed such characters in form and health, and then cross out the morphological characters of the bison that may have also been bred in to exclude them from future offspring and crosses. In principle, the vitality-bestowing sections of the chromosome and those that conferred bison morphological attributes were different, separable, and therefore able to combine in a way that could cross out, or use 'expulsion breeding,' to remove the undesired characters.[53]

With Heck's insistence, crossing became a beneficial solution in the minds of many in the ISPEB to the dwindling and degenerating bison population. To secure his argument further, Lutz Heck also emphasized the close relation of American and European bison.[54] It just so happened that crossbreeding was extraordinarily practical following the population depletion during WWI. Bulls greatly outnumbered cows in the remaining populations, meaning those spare males could easily be applied to Heck's *Verdrängungszucht* program, without jeopardizing the

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[52] *Ibid.,* 119.
[53] *Ibid,* 123.
[54] *Ibid.*

society's main bison breeding work.[55] Even within the European bison population, however, there were disagreements about subspecies and the risks or benefits of mixing the Caucasian and Lithuanian populations, though in the end it was determined that those populations had intermixed in the past so their purity was already jeopardized.[56] In order to inform the breeding practices along blood purity or mixing lines, von Groeben maintained the studbook as its official keeper - his prerogative was maintaining four bloodlines by keeping them apart. This pitted him against those calling themselves "practical breeders," who argued that the purported benefits of pure bloodline maintenance was based on no observable evidence and was not a practice that they used or espoused.[57] Ultimately, both crossing and pure line maintenance were carried out by the ISPEB.

In part through his work in the bison program, Lutz Heck was given the role of Director of the Higher Authority of Nature Protection in 1940, and the program led to the release of bison in Elchwald, Prussia and Białowieża. To create these results, land was needed for the animals. In this case, it was taken from Polish territory during the German occupation. It is beyond the scope of this chapter to interrogate all the ways in which the cultural imaginary of the Third Reich sought *Lebensraum* and all the manifestations to which that imaginary contributed.[58] Nonetheless, it will be helpful to reckon with some cultural historical understanding of how the themes and practical efforts of the bison conservation programs would be put towards an altogether more ambiguous project of back-breeding the extinct aurochs. Here, one finds the truly weird temporalities of the Nazi regime which manifested as both mythological nostalgia

[55] The geographical separation of these two breeding populations became a downstream effect of wanting to keep separate the 'pure' wisent breeding program from Heck's. *Ibid.,* 123-124.
[56] *Ibid.*, 124.
[57] *Ibid.* This is in contrast to the inbreeding style popularized by Bakewell in Britain.
[58] See Giaccaria and Minca, *Hitler's Geographies* for helpful essays in this regard.

and mechanistic modernity, that fed devastating social policies and obsessive pursuits in realms such as archaeology and agriculture.[59] There are many parallels to how the European bison was bred and kept for its protection and how the aurochs would be favored and sought. A crucial difference, of course, was in the inability of the mythologically and conservation-minded to simply begin with conservation of the aurochs. In its case, they first had to create it.

MOTIVATING MYTH AND WEIRD TEMPORALITIES

Hitler's Germany has been characterized as a Janus-headed beast, that pulled itself in different directions along distinct visions of Germany's future. One was ever looking backward, conjuring myths of unity and strength from the hordes of archaeological relics and texts that Hitler sought. The other was determined to drive Germany forward, into a highly mechanized, efficient, autocratic order that would permeate down into everyday life. The heads somehow never ripped themselves apart from one another. Rather, these weird temporalities that privileged Oriental myths and archaeological obsessions while deploying quintessentially modern apparatus to frightening efficiency coexisted with relative ease. Historians have since had to excavate the presence of both, and the weirdness of their coexistence.[60]

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[59] Jeffrey Herf, *Reactionary Modernism: Technology, Culture, and Politics in Weimar and the Third Reich* (Cambridge, UK: Cambridge University Press, 1984) characterizes the "paradox" of German modernity, in the National Socialist rejection of rationalization, Enlightenment reasoning, and "scientistic modernity," that nonetheless leaned on modern technology.

[60] Again, Herf, *Reactionary Modernism* has unlocked an approach to the otherwise unwieldy forms of seemingly paradoxical postures embodied by the Nazis. See Fascist Pigs for one arena in which the tools of autocratic modernity met with the idea of the German *Volk,* in the production of what Tiago Saraiva has called "technoscientific organisms." Saraiva, *Fascist Pigs.* See also, Ute Deichmann, *Biologists Under Hitler,* trans. Thomas Dunlap (Cambridge, MA: Harvard University Press, 1996); and Susanne Heim, *Plant Breeding and Agrarian Research in the Kaiser-Wilhelm-Institutes, 1933-1945* (Dordrecht: Springer, 2008).

Of course, tensions between these postures could occasionally flare up, including amongst the scientific elite and the upper echelons of the National Socialists.[61] Still, public interest in Germany's past nature had an entrenched history, before and outside of National Socialism, notably fueled in the nineteenth century through public displays of fauna and flora from a bygone era. This nineteenth-century trend was hardly unique to Germany; the natural pasts of nations had been a booming scientific and entertainment business through zoos, museums, novels, and artwork across the globe.[62] Cultural imaginings of the prehistoric past have a deep history that has been traced in detail elsewhere.[63] What is important to note is that in Germany, as elsewhere in Europe and America, a nineteenth-century culture straddling education and entertainment developed around reconstructing the prehistoric past and brought awareness to the public of surreal other natural worlds in the past that would be claimed as superlatively national. Paintings, like those by Charles Knight in the United States, epic novels such as Oscar Fraas' 1866 *Vor der Sündluth!,* or *Before the Flood*, and three-dimensional displays and dioramas captivated public and scientific imagination and furnished national icons rooted in deep time.[64] The work of Philipp Leopold Martin, a natural historian and taxidermist in Germany, embodied what Lynn Nyhart has noted as a "practical natural history."[65] Martin sculpted reconstructions of prehistoric life, drawing inspiration from Benjamin Waterhouse Hawkins and his famous Crystal Palace sculptures in England. He turned his ambitions to creating a *Museum*

[61] Harrington traces some of the factions in the scientific sphere that can be mapped along these postures, in one case between proponents of holism and supporters of mendelian genetics and Darwinism. See Harrington, "Nazi Wholeness" in *Reenchanted Science.*
[62] This is covered in more detail in the first three chapters of the dissertation.
[63] Martin J.S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1992) reconstructs the depictions of those pasts.
[64] Mania, "Contemporaries of the Cave Bear."
[65] Nyhart, *Modern Nature,* 35. For Nyhart, this is the group whose unity represented the "growing edge" of the biological perspective, whose roots she traces in her work. Nyhart, *Modern Nature,* 36.

der Urwelt, in which visitors could walk through time, side-by-side with depictions of the present day to contrast the snapshots of the different temporal loci.[66] His case demonstrates the growing ways in which public imagination about the past landscape could be spurred. His institution was funded through private capital, and yet he sought a general audience.[67]

Such imaginaries of a nation's deep natural past draw influence from many sources, and historically have taken many forms. In the early 1930s, the minds of National Socialist authorities gave shape to a nature policy that was as much conservation oriented as it was the means to a fantasy of hunting like the hero Siegfried in a reconstituted primal German *Urnatur,* to put on displays of manhood through the killing of symbolic beasts. During their friendship, and following the establishment of nature reserves in occupied Poland, Hermann Göring and Lutz Heck would form hunting parties, dressed in traditional garb and carrying spears to hunt the *Wisent* and back-bred aurochs.[68]

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[66] *Ibid.,* 68-69.
[67] *Ibid.,* 75.
[68] Lorimer and Driessen, "From Nazi Cows," 638. They report that these hunting outings were photographed by Lutz and others.

Figure 31. Hermann Göring and Lutz Heck carrying spears, December 1934.[69]

A critical piece of manifesting that particular Nazi imaginary was to resurrect the animals that best embodied *Urnatur,* and to release them into the wild to create a form of German wilderness hailed in myth. This informed the work of the Heck brothers once the Nazis took power. Both brothers had already begun their aurochs breeding interests and research by the early 1930s. Heinz stated that his work, begun in 1921, initially began from a curiosity to see what the extinct aurochs had looked like, to share that love of natural history with visitors to the zoo, and to create a kind of reserve 'wild' cattle stock in case domestication of cattle went too far.[70] Mythologizing the past certainly played its role in the brothers' experiments, and the

[69] *Ibid.* Housed in Budesarchiv Bild 102-04224/Georg Pahl.
[70] Heinz Heck, "The Breeding-Back of the Aurochs," *Oryx* 1:3 (1941): 117-122.

autochthonous character of the wild aurochs held great appeal. As Lutz Heck reflected in 1954, "I was always attracted to the idea of tracing past developments in our native animals, making use of the records of our game preserves. In my youth my imagination was caught by the famous description in the *Nibelungenlied* of Siegfried's hunt in the forest of the Vosges."[71] The image of the mighty German hero Siegfried and his ancient hunts and triumphs appealed to Heinz Heck, as well.[72] But within the legends of primeval Germany, something in particular stood out:

> I was interested above all in the two huge wild oxen, which have become almost legendary but are regarded as the most powerful representatives of the primeval German game – the European bison and the aurochs.[73]

Descriptions and renderings of the aurochs from Conrad Gessner, porcelain plates with hunting scenes, cave paintings from thousands of years ago, and preserved skeletons provided the brothers with "a clear mental picture of the aurochs," though comparative analysis of their respective mental pictures demonstrates that they held somewhat different pictures in their minds.[74] Still, to the brothers what they envisioned seemed to still exist right before their eyes. In fact, Lutz argued that they could "find to this day domestic cattle that are quite astonishingly similar to it."[75]

According to the Hecks, the traits that made the aurochs an aurochs had been scattered across its now feral or somewhat domesticated descendants. Recreating, not simply reconstructing, an aurochs was possible in the minds of the brothers. "Breeding back" effectively

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[71] Lutz Heck, *Animals: My Adventure,* trans. E.W. Dickes (London: Methuen & Co. Ltd, 1954)*,* 139.
[72] Driessen and Lorimer, "Back Breeding," 6.
[73] Heck, *Tiere,* 160. Original: "Vor allem aber beschäftigten die zwei riesigsten Wildrinder meine Gedanken, Tiere, deren Namen schon beinah sagenhaft geworden sind, die aber als die gewaltigsten Vertreter deutschen Urwildes gelten: der Wisent und der Auerochs oder Ur!"
[74] Lutz Heck, *Animals: My Adventure*, 140-141. Cis Van Vuure has tabulated the differences in the brother's conceptions of the aurochs. See his *Retracing the Aurochs,* 331.
[75] *Ibid.,* 141.

"put tools into [their] hands for resurrecting extinct species."[76] Underpinning this possibility was the potent philosophy that "no animal…is utterly exterminated as long as some of its hereditary factors remain."[77] Lutz Heck stated it more boldly: "it is inaccurate…to say that the aurochs is extinct."[78] The aurochs was still living on in the physical characteristics of "some primitive races of cattle and in fighting cattle breeds, and its heritable constitution has been essentially preserved in these progeny."[79]

The seeming directness of this process did not go unchallenged during the course of the Hecks' project. One critic described by Lutz Heck as a "well-known breeder, teaching at an agricultural college," allegedly told the brothers "of course you can breed back to the aurochs." The problem, however, rested in the duration of the experiments according to the critic: "it has taken more than six thousand years to breed our present-day cattle from it, and it will take you just as long to breed it back from them."[80] Without six thousand years at hand, the Heck brothers faced insurmountable odds, according to their critic. Another decrier pointed out the conflation of looking like an aurochs, and actually being an aurochs: "Yes, the animal really does look like the aurochs. Good! And with further breeding you will have the complete heritable constitution of the aurochs, but the animal won't be an aurochs!"[81] Still another critiqued the brothers' use of the Ausburg picture as a guide, noting that it in fact was not an aurochs.[82]

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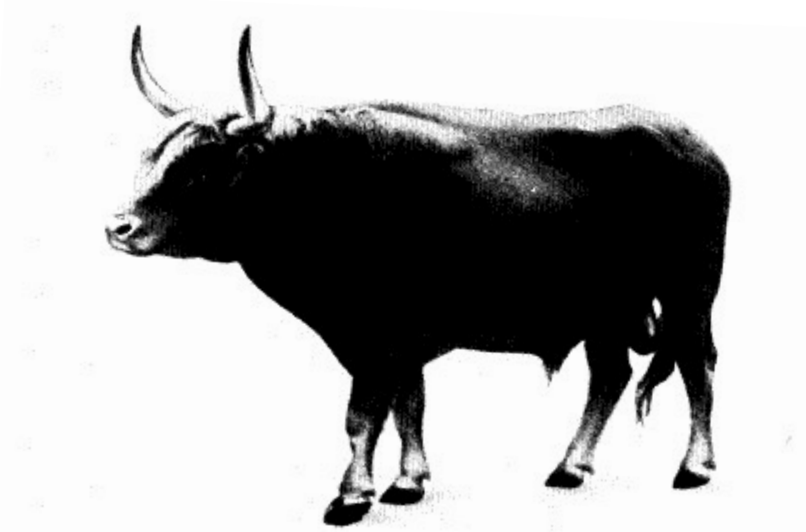
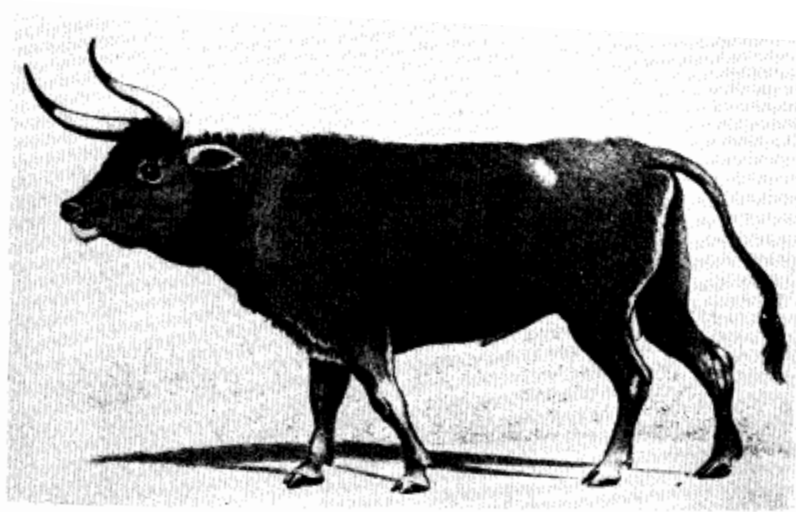
[76] Heck, "Breeding-Back," 117.
[77] *Ibid.*, 119.
[78] Heck, *Tiere,* 163. Original: "Daru mist es falsch, zu sage, dass der Auerochse ausgestorben sei."
[79] *Ibid.* Original: "So lebt in einigen primitive Nutzvieh- und in den Kampfrinderrassen der Auerochse noch fort, und seine Erbmasse ist in diesen seinen Nachkommen im wesentlichen erhalten geblieben."
[80] *Ibid.,* 164. Original, quoted by Lutz Heck: "'Gewiss können Sie den Ur wieder züchten, aber mehr als sechstausend jahre hat es in der Vergangenheit gedauert, bis daraus die heutigen Rinder entstanden, und Sie werden dazu ebenso lange in der Zukunft brauchen."
[81] *Ibid.* Original, quoted by Lutz Heck: "'Ja, das Tier sieht wirklich so aus wie der Auerochs. Gut. Und im Laufe der Weiterzucht wird es auch alle Erbmasse des Auerochsen haben, aber ein Auerochs ist es nicht!'"
[82] F.E. Zeuner, "Domestic Cattle and the Aurochs," *Oryx* 3, no. 6 (1956): 319-322.



AUROCHS BULL BRED-BACK IN TIERPARK HELLABRUN, MUNICH.



THE AUROCHS.
From a painting found in an Augsburg antique shop in 1827.

Figure 32. A Heck bull, above. Below, the "Ausburg Aurochs" copied in early 19th C from 16th C original. [83]

[83] Heck, "Breeding-Back," 118.

The Heck brothers, however, had a different understanding of breeding back. They saw their project as selecting backwards to produce the actual ancestral animal. They did not, however, agree that six thousand years were needed to manipulate the system. Instead, "much as a mosaic picture may be separated into its individual tesserae, the heritable constitution of a living being can be split up in the hereditary process and its elements passed on separately to descendants."[84] One did not need to directly follow the exact path of evolution – down to reversing its causal chain – in order to recreate an aurochs. That seemed an implausible task. Instead, selective breeding and mosaic evolution would produce an animal comprised of the correct mixture of traits, which ultimately added up to an aurochs. To his contemporary critics, Lutz Heck noted that indeed, "it sounds almost incredible, and yet it is fundamentally simple: the aurochs was to be bred back into existence, and all we needed for that was to assemble the right material to start from and then to know how to mix it!"[85]

Both Lutz and Heinz interestingly turned towards cross-breeding to achieve their aims, which to some, directly flew in the face of ideas of "purity" that sat at the heart of much eugenics and degeneration concerns under the National Socialists.[86]The 'mixtures' differed between the two brothers. Heinz admittedly "began crossing all kinds of races of cattle in a way that would have horrified a pedigree breeder."[87] Hungarian and Podolian steppe cattle, Scottish Highland cattle, Alpine breeds from Algau and Werdenfels, piebald Friesians and Corsicans… "all were thrown into the same pot, so to speak."[88] Heinz declared success: "it was like a miracle. The first

[84] Heck, *Animals: My Adventure,* 143.
[85] *Ibid.,* 144.
[86] One such critic was Erna Mohr, the onetime official bookkeeper for the ISPEB. He had criticized Lutz's apparent miscegenation approach to European Bison conservation as well as his aurochs project. E. Mohr, "Von Wisenten und Wisent-Bastarden, *Aus Der Natur* 18, no. 3 (1939): 76-81.
[87] Heck, "Breeding-Back," 120.
[88] *Ibid.*

aurochs for 300 years could be seen alive."[89] Interestingly, he noted that there "has not been one throw-back to any of the domestic breeds used."[90] Despite the fact that the aurochs was more ancient than its domesticated descendants, the reversion of the aurochs traits to the domesticated condition concerned Heinz. This ran counter to standard views of the durability and stability of more ancient and primitive traits – the views that fueled Nazi concern over protecting the younger, 'more sophisticated' Aryan human traits. Ultimately, Heinz's sense of the stability of the wild traits in his newly bred animals quelled any further reflection on the issue.

Heinz's older brother, Lutz claimed success a few years later. Lutz's mix included Spanish and French "fighting breeds" mixed with "other Mediterranean races of cattle."[91] As he reported later:

> For us Heck brothers, the task now arose to unite all of these wild traits, which were still present separately and sporadically, into a single breeding line. For this reason I brought certain breeds of cattle together very laboriously and often from far away, crossed them with each other, purposefully eliminated everything that resembled domestic cattle, and always used something similar to the aurochs for breeding. It has been one of the most exciting experiments of our lives as mammalian zoologists, working step by step, year by year, from one bovine generation to the next, toward this goal: recreate an animal that humans have called extinct.[92]

[89] *Ibid.*
[90] *Ibid.* Today, however, we know that there have been several "throwbacks" in the Heck breed, all of whose current stock are derived from Heinz's population. The variety within the Heck breed is quite great, something encountered in all cattle breeds to a degree. In the case of the Heck cattle, however, on occasional coat pattern that resembles the classic Holstein black-and-white will appear, strikingly refuting Heck's notion of a stabilized breed. [can include image, because it is quite striking]
[91] *Ibid.,* 121.
[92] Heck, *Tiere,* 165. Translation mine. Original: "Für uns Gebrüder Heck ergab sich nun die Aufgabe, diese sämtlichen, getrennt und vereinzelt noch vorhandenen Wildeigenschaften auf einen einzigen Zuchtstamm zu vereinigen. Ich habe aus diesem Grunde gewisse Rinderrassen sehr mühsam und oft von weither zusammengeholt, miteinander gekreuzt, zielbewusst alles ausgemerzt, was nach der Hausrindseite schlug, und stets Auerähnliches wieder zur Zucht benützt. Es war eines der spannendsten Experimente in unserem Leben als Säugtier-Zoologen, Schritt für Schritt, Jahr für Jahr, von einer Rindergeneration zur nächsten auf diese Ziel hinzuarbeiten: ein Tier wider erstehen zu lassen, das die Menschen ausgestorben nennen."

Trips to Camargue, Corsica, and Seville allowed Lutz Heck to witness the strength and ferocity of the animals he ultimately chose to help piece together his aurochs.[93] It is clear from Lutz's writing that the romance of the experience was of great importance to him. His description of the animal – including its "beauty and strength" – as well as his frequent laments that purchasing the breeding stock "was less romantic" than he had wished, conveys the captivation of the distant German past and the adventures that Lutz sought to experience through recreating it.[94]

In Lutz's experiments, aggression was a desired trait. Aggression could not readily be discerned from the "numerous skulls, including whole skeletons of the extinct Aurochs," but might be depicted in the more recent historical records of the animals.[95] Rather, Lutz cited what he called "exact descriptions" and "more or less faithful reproductions in painting and fine arts from the time when both wild cattle, Ur, and wisent lived side by side in Europe."[96] Spanish and French fighting bulls were purchased by Lutz, and primitive breeds were added to the Berlin Zoo's cattle collection; he reported that on January 1, 1933 the Zoo had eighty head of cattle, with eight wild forms and seventeen domestic breeds.[97] His father had taught him that many of domesticated breeds "described as primitive" were disappearing, as those breeds valued for their milk, meat, and work performance spread.[98] In 1933, he and the zoo boasted 8 South French fighting bulls and 4 females (cows or heifers), 2 Corsican bulls, and 4 females, 2 "English Park"

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[93] Heck, *Animals: My Adventure*, 147-149.
[94] *Ibid.,* 146, 153, 154.
[95] Lutz Heck, "Über die Neuzüchtung des Ur oder Auerochs," *Berichte der Internationalen Gesellschaft zur Erhaltung des Wisents* 3, no. 4 (1934): 226. Translation mine. Original: "Zahlreiche Schädel, auch ganze Skelette des ausgestorbenen Auers sind an verschiedenen Orten in fast ganz Europa gefunden und erhalten."
[96] *Ibid.,* 226. Original: "Selbst genaue Beschreibungen und mehr oder weniger getreue Widergaben in der malenden und bildenden Kunst aus der Zeit, als noch beide Wildrinder, Ur und Wisent, nebeneinander in Europa lebten, liegen vor."
[97] *Ibid.,* 228.
[98] *Ibid.,* 227-8.

females, of the type discussed in Chapter 4.[99] Of these, the French fighting cattle, and the Iberian, and in particular Spanish fighting and Corsican breeds, had, according to his own observations "remained similar to the original cattle."[100] The southern French fighting cattle he described as having an angular skull, with a long forehead and curled hair between the horns, "exactly as reported of the aurochs."[101] They were, according to the connoisseur, faster and more agile than the Spanish fighting bull.[102]

These "primitive" and aggressive breeds were noted for their differences to domesticated breeds. Lutz described the Camargue French fighting cattle, for example, as "tirelessly aggressive" though in herds the animals were reportedly often harmless. By contrast, "other breeds of cattle are mentally dulled by being stabled, by being constantly around people as working dairy cattle, and by choosing good-natured, easy-to-handle breeding animals."[103] Their dwindling numbers, in part due to the desalination of salt steppe areas via artificial irrigation turned their usual haunts into productive, arable farming land. "So," he reported, "there is less and less space left for our cattle; the Camargue cattle are increasingly pushed back into poorer areas and breeding suffers."[104] The domesticated cattle were somewhat lamentable to Lutz, who sought to breed away from them, and stave off the depletion of "primitive" herds through competition with farming. As he wrote later:

> The image of the aurochs is alive in our mind's eye, and if we now look around Europe, after some searching we still find forms of domestic cattle that resemble this old image in a downright surprising way. However, we must not search among our highly bred

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[99] *Ibid.,* 229.
[100] *Ibid.,* 229.
[101] *Ibid.,* 231.
[102] *Ibid.,* 232.
[103] *Ibid.,* 232. Original: "Während andere Rinderrassen durch Stallhaltung, durch dauernden Umgang als Arbeits- und Milchvieh mit Menschen und durch Auswahl gutartiger, leicht ze behandeinder Zuchttiere geistig absgestumpft sind, ist das Camargue-Rind auf geistige Fähigkeiten gezüchtet."
[104] *Ibid.,* 235. Original: "Für unsere Rinder bleibt also immer weniger Platz übrig; das Camarguerind wird immer mehr in schlechteres Gbiet zurückgedrängt und die Zucht leidet."

> livestock, which have been bred for milk yield, work capacity or slaughter weight. These domestic cattle have strayed too far from their original form through selected breeding. Characteristics that are dangerous to humans or useless for human purposes, for example aggression, rapid mobility of the original cattle, the long, pointed, dangerous horns, have been eradicated forever in the further breeding of domestic cattle, while other characteristics such as milk yield, abundance of meat, were bred into by selection. As a result, our valuable domestic animal became more and more dissimilar to its progenitor, the Ur, in appearance and behavior, especially in its high breeds.[105]

For his breeding experiments, the Camargue cattle offered much by way of their undomesticated traits: "this breed is particularly suitable for the planned breeding attempt as it is the bearer of many aurochs characteristics. To fight, the selected animals must be aggressive and capable of rapid movements. These are qualities that useful domestic breeds of cattle lack. The peculiarity of the fighting cattle lies in this wildness, which it received from its ancestor, the free-living aurochs."[106] In 1931, Lutz selected five animals from "probably the most famous breeder

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[105] Heck, *Tiere,* 163. Translation mine. Original full quote: "Das Bild des Auerochsen steht lebendig vor unserem inneren Auge, und wenn wir uns nun in Europa umsehen, so finden wir nach einigem Suchen auch heute noch Haurinderformen, die diesem alten Bild in geradezu überraschender Weise Gleichen. Allerdings dürfen wir da nicht unter unserem hochgezüchteten Nutzvieh suchen, das einseitig auf Milchleistrung, Arbeitskraft oder Schlachtgewicht gezüchtet worden ist. Zu weite haben sich durch bewusste züchterische Umformung diese Hausrinder von ihrer eigentlichen Urform entfernt. Die dem Menschen gefährlichen oder für menschliche Zwecke unnützen Eigenschaften, die Bösartigkeit zum Beispiel, die schnelle Beweglichkeit des Urrindes, das lange, spitze, gefährliche Horn, sind bei der Weiterzucht der Haurinder für immer ausgemerzt worden, während andere Eigenschaften, wie Milchergiebigkeit, Fleischreichtum, durch Auslese hineingezüchtet wurden. In Aussehen und Verhalten wurde dadurch unser wertvolles Haustier insbesondere in seinen Hochzuchten seinem Stammvater, dem Ur, immer unähnlicher….Indessen gibt es auch heute noch in Europa weltverlorene Gegenden und Gebirgsländer, wie zum Beispiel die Insel Korsika, wo sich Rinder finded, die von der züchterischen Beeinflussung des Menschen recht unberüht blieben….So lebt in einigen primitive Nutzvieh- und in den Kampfrinderassen der Auerochse noch fort, und seine Erbmasse ist in diesen seinen Nachkommen im wesentlichen erhalten gelieben. Daru mist es falsch, zu sage, dass der Auerochse ausgestorben sei. Kein Lebewesen ist ausgestorben, dessen lebendige Erbmase noch vorhanden ist. Es handelt sich nurd arum, mit der kundigen Hand des Züchters das in diesen letzten Abkömmlingen versteckte und verstreute Erbgut wieder zu vereinigen!"

[106] *Ibid.,* 246. Original: "Dieser genauen Beschreibung des französischen Kamprindes is tzu entnehmen, dass derade diese Rasse als Träger vieler Auereigenschaften besonders geeignet für den geplanten Zuchtversuch ist. Zum Kampf müssen die auserwählten Tiere Angriffslust und Fähigkeit zu schnellster Bewegung besitzen. Das gerade sind Eigenschaften, die den nützlichen Hausrinderrassen fehlen. Die Eigenart des Kampfrindes liegt in dieser Wildheit, die es von seinem Vorfahr, dem in Freiheit lebenden Auerochsen, erhalten hat."

of southern French fighting cattle," the Marquis de Baroncelli's herds, which were transported to Berlin with "great difficulties" via train wagon by the director of the Jardin Zoologique in Nice, Georges de Basilewski.[107] The Camargue bulls were used in crosses with English Park cattle, Corsican, and steppe cattle. On January 18 1933, an English Park cow gave birth to a heifer calf from a Camargue bull, and another calf was born from a Corsican cow the previous day.

Iberian cattle, too, strikingly resembled Lutz's picture of the aurochs. In particular, they resembled depictions of the aurochs from prehistoric Spanish caves. The assumption of true-to-life depictions in the artists' intent impressed Lutz: "the artist at the time possessed such a pronounced talent that his animal pictures hold their own alongside modern works."[108] Hugo Obermaier had provided Lutz with images of the aurochs paintings from the walls and ceilings of the Abrigo de los Toros caves west of Barcelona. Obermaier, a well-known Spanish-German prehistoric archeologist at the University of Madrid, and author of the 1924 *Fossil Man in Spain,* to which Henry Fairfield Osborn wrote the introduction, later received a copy of Lutz's 1934 aurochs back-breeding report, "Uber des Neuzüchtung des Ur oder Auerochs," in the *Berichte der International Geshichte zur Erhaltung des Wisents* (*Reports on the International History of Bison Conservation)* with a handwritten note of thanks for Obermaier's contribution.[109] The cave drawings demonstrated that "in terms of physique," the aurochs were similar to the Spanish fighting cattle.[110] The resemblance of native Spanish cattle to the aurochs in the cave paintings struck Lutz, who reasoned that Spain was still largely covered by grape vines and olive crops,

[107] *Ibid.,* 233-239.
[108] *Ibid.,* 247. Original: "Der damalige Künstler besas seine so ausgesprochene Begabung, dass sich seine Tierbilder neben neuzeitlichen Werken durchaus behaupten."
[109] Obermaier's copy with the handwritten note resides at the Biblioteque Cantonale et Universitaire, in Switzerland. Accession Number 718562346.
[110] Heck, "die Neuzuchtung des Ur," 249. Original: "Im Körperbau Gleichen diese Auer den heutigen spanischen Kampfrindern."

that cattle breeding had only been practiced "incidentally" there, and that only in recent history had highly bred European breeds from elsewhere been introduced in Spain.[111] Thus the Spanish breeds had been able to avoid the encroachment of domesticated forms and retain their primitive characters. As with the French breeds, Lutz purchased several Spanish fighting cattle, shipped in large boxes by sea to Hamburg.[112] They were crossed with Corsican cattle, Scottish highland cattle, and English park cattle.

The Corsican cattle breed provided the color to Lutz's experiment. It was in this breed that he noted "the color of the aurochs was probably preserved best of all," with black bulls donning a lighter stripe along their back, and reddish cows with some black. The breed had, despite its uses as dairy, meat, and work cattle been largely maintained in a primitive state, as those competing breeding interests had prevented "the breeding influence of man" from having an effect "in a single, specific direction, as is usually the case."[113] Overall, Lutz sought in his breeds phenotypic conformation of the animals to some part of the aurochs. Crossing them would reconstitute the aurochs with all the 'parts' reassembled in one animal. The horns were those parts that in domestic breeds were "subjected to the greatest fluctuations" due to early domestication selection for smaller horns to aid control and lessen injury risks in handling animals. The Iberian and French fighting cattle had the closest resemblance to the aurochs depicted in the Ausburg picture and in the cave paintings. The desired smaller udder was best matched by the same Spanish and French breeds, those animals not reared for milk yield.

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[111] *Ibid.,* 250.
[112] *Ibid.,* 265.
[113] *Ibid.,* 273. Original: "…der züchterische Einfluss des Menschen hat sich bein ihnen nicht wie sonst zumeist in einer einzigen, bestimmten richtung ausgewirkt."

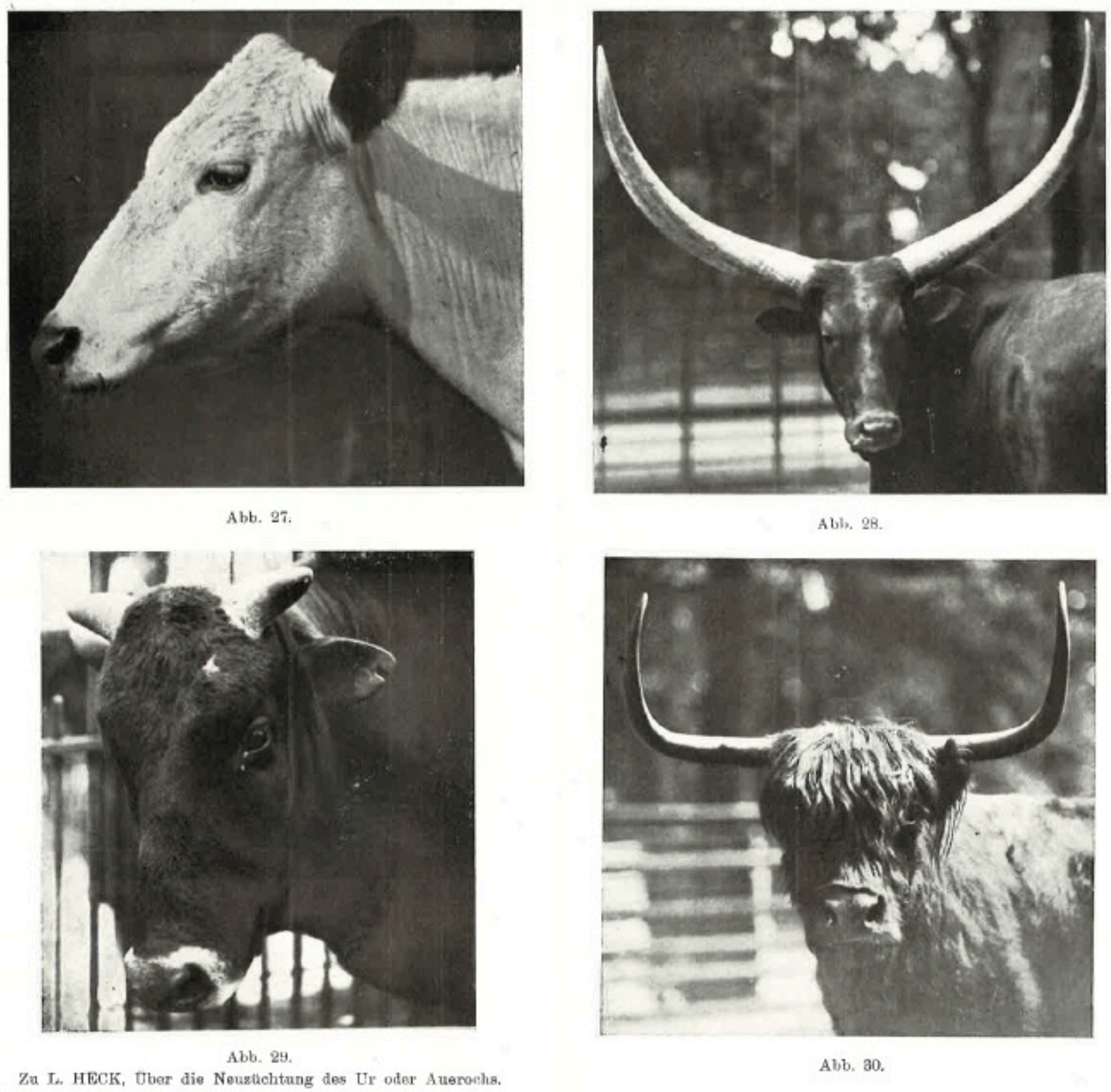

Figure 33. Lutz compiled these photographs to demonstrate the “complete disappearance and variegated growth of bovine horns as a result of breeding influence through domestication.” Clockwise from top left they are of: polled fell cattle from Sweden; Watussi cattle from Rwanda; Egyptian bull; Scottish Highland bull.[114]

[114] *Ibid.,* Plate 25. All except the Egyptian bull were photographed in the Berlin Zoo. The Egyptian bull was photographed by Lutz Heck at the Jardin des Plantes in Paris.

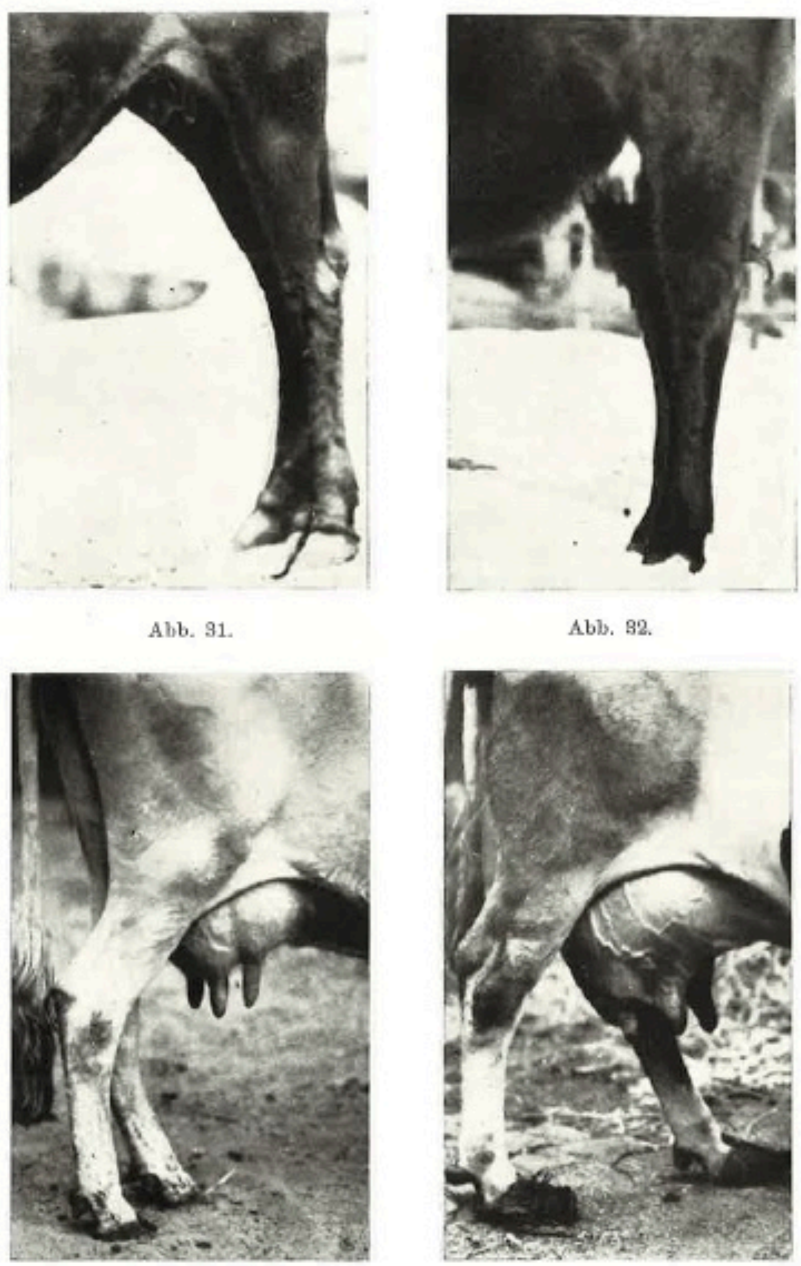

Abb. 31. Abb. 32.

Abb. 33. Abb. 34.

Zu L. HECK, Über die Neuzüchtung des Ur oder Auerochs.

Figure 34. Demonstration of enlarged udders in dairy cattle. Captions provided by Lutz Heck, clockwise from top left: “udder of a suckling fighting cow classified by size and shape still resembled that of wild cattle”; “slightly larger udder of a Scottish highland cattle”; “a still more enlarged udder of a Corsican cow, a primitive breed mainly for meat, but incidentally also brings dairy benefits”; “normal udder of a lowland black and white cow, the most widespread in Northern Germany.”[115]

[115] *Ibid.,* Plate 26.

Abb. 43.

Abb. 44.
Zu L. HECK, Über die Neuzüchtung des Ur oder Auerochs.

Figure 35. Photos by Lutz Heck of "Aurochs-like cattle by accidental crossing" from Finland.[116]

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[116] *Ibid.,* Plate 30.

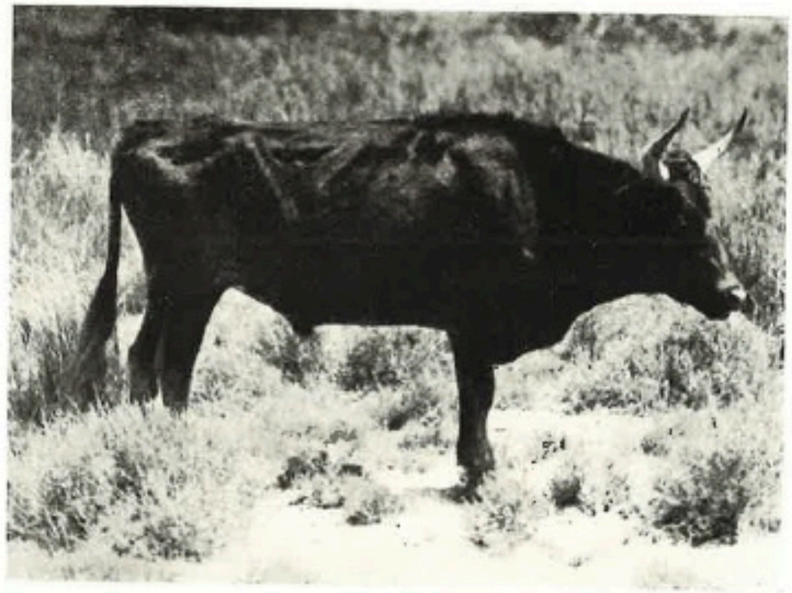

Abb. 10.

Abb. 11.

Zu L. HECK, Über die Neuzüchtung des Ur oder Auerochs.

Figure 36. Lutz Heck's photos of the French fighting cattle in Camargue, France.[117]

[117] *Ibid.,* Plate 18.

Abb. 21.

Abb. 22.

Zu L. HECK, Über die Neuzüchtung des Ur oder Auerochs.

Figure 37. Corsican cattle. The top photo of the cow, taken by Lutz Heck in North Corsica; the three Corsican calves on the bottom were photographed after their arrival at the Berlin Zoo in 1927.[118]

[118] *Ibid.,* Plate 23.

Abb. 8.

Abb. 9.
Zu L. HECK, Über die Neuzüchtung des Auers.

Figure 38. Animal studies by Moritz Pathé, used by Lutz Heck to demonstrate the winter and summer coats (top and bottom images, respectively) expected in the aurochs. The top is of a Korean bull from the Berlin Zoo. The bottom, a Spanish fighting bull from the zoo.[119]

[119] *Ibid.,* Plate 17.

Lutz thus summarized his explorations of the proper breeds for his experiments: “the aim of breeding must be a cow that, as a wild animal, has the body shape of the Spanish fighting cattle, the horn shape of the French fighting cattle, the wildness and agility of the two breeds, the color of the Corsican cattle, has the udder of the Spanish and French fighting cattle and the coat with hair density and shedding of the French, Spanish and Corsican cattle. The aurochs had all these characteristics.”[120] His impressions of the aurochs were informed by cave paintings, the Ausburg picture, and the *Nibelungenlied.* His resulting breed is therefore perhaps best understood as part fighting bull, part Corsican cattle, and part mysticism and romance.

Degeneration and domestication were stated concerns of Lutz Heck; those concerns were part of the stated impetus for his back-breeding project, as well as a threat to ensuring the stability of his new “aurochs” once bred back. Concerns over domestication were promulgated by popular German and Austrian scientists during the 1930s, at the same time that they developed an appreciation for predators and wild animals.[121] Konrad Lorenz, the ethologist and eugenicist, disseminated through his writings and lectures antisemitic discussion of “Aryan” animals which were wild, and what he considered domesticated “Jewish” animals.[122] Through Oskar Heinroth, an early ethologist and mutual acquaintance of Lutz Heck and Lorenz, Lorenz

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[120] *Ibid.,* 294. Original: “Wenn wir daraus die Neuzüchtung des ausgestorbenen Auers planen, muss als Zuchtziel ein Rind vor Augen stehen, welches als Wilditer die Körperform des spanischen Kampfrindes, die Hornform des französischen Kampfrindes, die Wildheit und Wendigkeit der beiden Rassen, die Farbe des korsischen Rindes, das Enter des spanischen und französischen Kampfrindes und das Fell mit Haardichte und Haarwechsel des französischen, spanischen und korsischen Rindes hat. Alle diese Eigenschaften hatte der Auerochse.”

[121] Deichmann *Biologists Under Hitler*; Boria Sax, *Animals in the Third Reich: Pets, Scapegoats, and the Holocaust* (New York: Continuum, 2000); Richard W. Burckhardt, *Patterns of Behavior: Konrad Lorenz, Niko Tinbergen, and the Founding of Ethology* (Chicago: University of Chicago Press, 2005); Lorimer and Driessen, “From ‘Nazi Cows,’” 638.

[122] T.J. Kalikow, “Konrad Lorenz’s ethological theory: explanation and ideology, 1938-1943,” *Journal of the History of Biology* 16, no. 1 (1983): 39-73. For more on the eugenical associations of “domestic” and “wild” with Nazi race policy, see Boria Sax, “What is a ‘Jewish Dog?’ Konrad Lorenz and the Cult of Wildness,” *Society and Animals* 5, no. 1 (1997): 3-21.

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acquired pictures of Lutz's bred-back cattle at the suggestion that he use them in his lectures to show how degenerative domestication could be, though it remains unclear whether they were used by Lorenz.[123] Lutz's aurochs back-breeding drew the attentions of those National Socialists, such as Lorenz, who scorned domestication, as Lutz himself reportedly did, and those whose concerns spurred their support of eugenics and antisemitic ideologies.[124]

Reversing domestication required more than crossbreeding for traits. It necessitated giving the animals a wild life, too. Lutz hypothesized in 1934, "If these breeds are brought together, a cattle that looks similar to the aurochs will probably arise in a very short generation. If these offspring could be brought into the free conditions under which the aurochs used to live, then in the foreseeable future cattle that are completely identical to them, i.e. the wild form, will rise again."[125] With Göring's support, Lutz's animals were able, for a time, to roam free in the Nazi-occupied forests of Poland. Following their experiments, the brothers acknowledged their respective outcomes with astonishment. Heinz claimed, "Professor Lutz Heck bred back the Aurochs in the Berlin Zoological Gardens a few years later from material quite different from

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[123] Lorimer and Driessen, "'From Nazi Cows,'" 638.
[124] There has been some historical disagreement over Lutz's views on the antisemitic ideologies that were prevalent during the time – Lorimer and Driessen note they found little evidence to Lutz subscribing to such a view, though Clemens Driessen and Kai Artinger have pointed to Lutz's SS membership and close personal friendship with Göring as evidence of his views. The Berlin Zoo under his leadership certainly benefitted from aligning itself with state interests and promulgated Nazi propaganda. The Berlin Zoo's Supervisory Board two members resigned after facing pressures regarding their Jewish identity and the vacancies were filled National Socialist members including Eugen Fischer, who helped develop Nazi racial theories. For more, see *Animals as Objects?* A website by the research project "Animals as Objects. Zoological Gardens and Natural History Museum in Berlin, 1810 to 2020," edited by Ina Heumann and Tahani Nadim. Heinz, by contrast, reportedly was imprisoned at Dachau after his marriage to a Jewish woman and membership in the Communist party were exposed through Nazi questioning after his application for a professorship with the Nazi party. See Driessen and Lorimer "Back Breeding," 150-151 for more.
[125] Heck, "die Neuzuchtung des Ur," 294. Original: "Wenn diese Nachkommen in die freiheitlichen Varhältnisse gebracht werden könnten, unter denen der Auer früher lebte, so werden in absehbarer Zeit diesem gänzlich gleiche Rinder, also die Wildorm, neu entstehen."

mine."[126] Yet he called his brother's creation an aurochs as well. In his mind "the result was identical and one could not distinguish between the Auroxen bred in Berlin and those bred in Munich."[127] At the time, and after World War II, there were critics to those claims as well. Still, such results – "that the Aurochs was twice and separately reconstituted" – proved to Heinz Heck that "the principles on which this interesting experiment was based are sound."[128] They prove to historians exactly what the Heck brothers had in mind when they invoked the name 'aurochs.' For them, the aurochs the embodiment of a wild past, achievable through the summing of its non-domesticated parts, survived in its descendants. Their desire to recapture a symbol of German heritage and autochthony, their use of ancient texts and paintings to inform their goal, and their belief in the reversibility of evolution made their project an exercise in looking backwards.

SEEKING A STABLE REVERSION: EVOLVING THE HECK CATTLE

The Heck brother's case can be read as an extreme variation on a much broader set of patterns of thoughts on reversing evolution or domestication. The imagined possibilities for reversing evolution in the Heck case may seem to be a practical extension of the atavisms, reversals, and hypothesized cases of telegony discussed in the previous chapter. As the Heck brothers' case shows, however, reversing evolution scales up both the goal and the program devised to meet it. The Heck brothers developed fairly extensive breeding programs, crossbreeding with a range of animals from around Europe. Their goal, of course, was to do in years what evolution had taken millions of years to turn out. Yet, their project was dedicated to

[126] Heck, "Breeding-Back," 120.
[127] *Ibid.,* 121.
[128] Heck, "Breeding-Back," 121.

reversing the domestication process and to undoing a species extinction. As Lutz Heck had claimed:

> No living being has died out whose living genetic material is still present. It's just a matter of reuniting, with the expert hand of the breeder, the genetic material hidden and scattered in these last offspring![129]

This was more than just the occasional throw-back in domesticated livestock. Still, the brothers' belief in the feasibility of this project was rooted in those long-held observations made by livestock breeders. Traits still clearly existed in some form in the descendants of the aurochs, that, when pieced together could reform the extinct organism. The goal of these efforts was, in no small part, to transport Germany to a mythologized primeval state, literally seeking to bring the so-called *Volk* back to their natural and geographic roots.[130] In other words, through the budding offshoots of evolution and domestication, they might achieve a form of time travel.

The notion of evolutionary reversal or biological time travel received its first full expression in the late nineteenth century. In fact, an early time traveler himself, the unnamed protagonist of H.G. Wells' *The Time Machine,* can be seen as the embodiment of what time travel could reveal about the biological forecast of humans: degenerative dystopias or fragile, refined futures. Wells provides a nice microcosm, if a bit of a detour, to unpack historical views of the direction of evolution, the feared threat of degeneration back down the line of progress across Victorian and National Socialist thought, and how those frameworks informed the breeding of the Heck cattle.

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[129] Heck, *Tiere,* 163. Translation mine. Original: "Kein Lebewesen ist ausgestorben, dessen lebendige Erbmase noch vorhanden ist. Es handelt sich nurd arum, mit der kundigen Hand des Züchters das in diesen letzten Abkömmlingen versteckte und verstreute Erbgut wieder zu vereinigen!"
[130] Lacoue-Labarthe, Nancy, and Holmes, "Nazi Myth," and Giaccaria and Mica, eds., *Hitler's Geographies.*

In H.G. Wells' 1895 tale of a man who travels forwards in time, the future is bleak. Two races of mankind have evolved and survived, each one degenerate in its own way: the effete Eloi, descended from elite society, and the cannibalistic Morlocks descended from the subterranean working classes. Human society, limping along as two caricatures, has regressed in Wells' story.[131] Such a future represented the seemingly real threat of societal relapse that worried late nineteenth-century British advocates of a progressive march in history.[132] Taken to the extreme, those concerns over degeneration eventually fueled the eugenics movement, and contributed to cross-cultural comparisons of relative cultural attributes using physical measures such as cranial sizes.[133] In late nineteenth-century and early twentieth-century biology, degeneration was a concern for early conservationists, eugenicists, and breeders alike. 'Atavism,' or the reappearance of a once lost ancestral trait, became at once proof of the interconnectedness of species, and also a source of concern over slipping backwards down the evolutionary tree.

The essential idea underpinning such atavism was that traits themselves never disappeared. The potency of the past suggested to some that there was a different propensity for expression between traits depending on how entrenched, or rather primal, they were.[134] The more primitive the trait, the more stable it was. Observation from breeders had born this out: when two breeds with different traits interbred, the older trait would often be preferentially expressed over the younger, more delicate traits. Thus, in the nineteenth century, stabilizing a breed and its

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[131] H. G. Wells, *The Time Machine* (New York: Henry Holt and Company, 1895), and Bowler, *Invention of Progress,* 196-7.
[132] Bowler, *Invention of Progress*, 194-201.
[133] George W. Stocking Jr. *Victorian Anthropology.* For more on physical anthropology, see George W. Stocking Jr., *Delimiting Anthropology: Occasional Essays and Reflections* (Madison, WI: University of Wisconsin Press, 2001).
[134] Donald K. Pickens, *Eugenics and the Progressives* (Nashville, Tenn.: Vanderbilt University Press, 1968), 42. Many of the ideas can be seen expressed in the eugenicist writings of the early twentieth century including the rather representative writings of conservationist zoologist and eugenicist Madison Grant. See, for example, Grant, The Physical Basis of Race," (1917).

desired characteristics was of great concern to those working with domesticated livestock and pedigreed sporting animals.[135] In other words, the past contained a power. That power for many eugenicists was extremely problematic. They extrapolated the differential of traits onto human populations, warning against the interbreeding of races, lest the younger – and in their eyes more refined and specialized – traits of the European ancestral races be overwhelmed by "primitive" characteristics.[136] The past, to them, was something from which to move away firmly and carefully. But to do so successfully required insurance against slipping backwards. For the proponents of eugenics, that insurance came in the form of extreme social policies designed to prevent "racial mixing" and to cull those "primitive" traits from the population entirely. The Heck brothers instead sought the past and its potent retention in living breeds. "Primitive" was often a moniker deployed with delight to refer to a breed they sought in their aurochs back-breeding work. Concerns over degeneration took the form of concerns over domestication in such projects under the Nazi Socialists. This, as discussed above, was typified in the work of Konrad Lorenz.

While eugenicists and breeders worried themselves about degeneration, the mechanism and possibility for a true reversal of an evolutionary pathway was considered in the context of paleontology and genetics from the late nineteenth century on. While some forms seemed as if they had never and might never progress (living fossils, for example), others bore vestigial structures as markers of their specialization through loss of adaptations. With a longer narrative of the history of life on earth presented by paleontological findings, however, the trajectory of

[135] For more see Derry, *Bred for Perfection.*
[136] It is worth noting that concern grew in the opposite direction as well, primarily in anthropology where the extinction of "primitive races" sparked efforts to mostly record and study, though sometimes to protect and revitalize. See Patrick Brantlinger, *Dark Vanishings: Discourse on the Extinction of Primitive Races, 1800-1930* (Ithaca, NY: Cornell University Press, 2003), and Sepkoski, *Catastrophic Thinking.*

evolution still seemed quite unidirectional. One paleontologist stipulated succinctly that an evolutionary path, once traversed, could not be undone within a lineage. Louis Dollo, a Belgian paleontologist operating in the late nineteenth century, understood evolution as discontinuous, irreversible, and limited.[137] His particular contribution to the ever-evolving theory of evolution is still cited today as a starting point for scrutiny in biological research: that evolution is irreversible.

Dollo's first formulation of what would become known as Dollo's Law dictated, "an organism cannot return even in part to a previous condition already passed through in the series of its ancestors."[138] He emphasized that even if "it finds itself placed in an environment identical with one through which it has passed," the organism "never exactly renews a previous condition."[139] Lutz Heck's belief that the back-bred aurochs would completely be reformed once released into the wild would, therefore, have seemed a superficial read on the results of the back-breeding. Biologists today, largely following Branislav Petronievics' work from 1920 and Stephen Jay Gould's reinterpretation of the law in 1970, define irreversibility as "the function of the complexity of a number of a series of independent events" – essentially conceding that reversing evolution is less probable as the number of evolutionary elements increases.[140] This notion of Dollo's Law deemphasizes Dollo's original distinction between reversible environments and reversible organisms. According to Dollo, even if an organism evolves to a seemingly similar state as an ancestor in order to fit a reversed environment, "by virtue of the

[137] Stephen Jay Gould, "Dollo on Dollo's law: Irreversibility and the Status of Evolutionary Laws," *Journal of the History of Biology* 3:2 (1970): 189-212.
[138] Louis Dollo, "Les lois de l'évolution," *Bulletin de la soc. Belge de Géol.* 7 (1893), 4.
[139] Branislav Petronievics, *On the Law of Irreversible Evolution* (Washington D.C.: Government Printing Office, 1920).
[140] Gould, "Dollo," 200.

indestructibility of the past, it always retains some trace of the intermediate stages which it has traversed."[141] Such a law had significant bearing on taxonomic formulations.[142]

Hardly feeling the same threat of the past that concerned early eugenicists, zoologists following Dollo's lead recognized that the past was not so easy to revisit – certainly not to the degree that it required safeguarding against biological time travel. Any evolutionary development would leave its mark on an organism, keeping evidence of past traits visible to a degree. But this also suggested that a true reversal, or rewinding of all the previous evolutionary steps, could never occur. Even an animal that evolved to resemble an ancestral state in many ways, when examined, would show signs of the new evolutionary path it carved to occupy a similar morphology. The past was at once inescapable in parts and unobtainable in the full. For scientists in the German milieu of the early twentieth century, Dollo's law would draw interest as what botanist Walter Max Zimmermann called "phylogenetic-historical laws," that held implications for systematists.[143] Interestingly, to the Heck brothers, evolution was like the eugenicists' view – pregnant with the potential for reversal at any moment. Far from being a threat, however, the brothers used that potential in their attempts to create "the living picture of primeval strength."[144] In the 1930s, that beast – "wild-eyed, with head high, and with menacing horns whose points shone in the green forest" – got its first taste of the 'wild.'[145]

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[141] Dollo, "l'évolution," 32.
[142] For example, Petronievics building on Dollo described the case of the Stegosaurus dinosaur. It was a quadrupedal beast, yet its direct ancestor was bipedal, and the ancestor prior to that was quadrupedal. If evolution were *truly* reversible, there would be no way to distinguish the secondary quadrupedal existence from the first, yet paleontologists could make such distinctions, as the form was slightly different in both cases. In other words, it found a different route to becoming quadrupedal. Petronievics, *Irreversible Evolution*, 433.
[143] In Walter Zimmermann, *Die Phylogenie der Plfanzen* (Jena: G. Fischer, 1930). For a discussion of Zimmermann's work, including his most notable contribution of telome theory of plant development, see Laubichler and Niklas, "Morphological Tradition."
[144] Heck, *Animals: My Adventure,* 154.
[145] *Ibid.*

Today, Dollo's law raises several interesting questions for biologists who hold together a menagerie of supposed violations of the law to better understand evolutionary processes like development, heterochrony, heterotopic shifts, meristic characters (that is, serially-repeated structures), and pleitropy (two or more effects of a single gene). In particular, studies on feral animals, such as pigs, are especially helpful to interrogating the biological meaning and reality or unreality of Dollo's law.[146] Domestication, in those studies, has left an evolutionary mark on the animals, and once feral, those formerly domesticated animals can be studied for the wild traits that are re-expressed, and the domesticated ones that are harder to shake. Dollo's law, therefore, uses temporality in the role of explanation to the explanandum of how disappeared traits might reappear, and especially so in the context of domesticated and feral or "rewilded" animals – a subject to which the next chapter turns.

CONCLUSION: TO HECK WITH DOLLO

Whether true aurochs or not, the fate of Lutz's Heck cattle was largely a crispy one. On 23 November 1943, Allied bombings of Berlin set the zoo on fire. During the bombings, thirty percent of the animals still in the zoo were killed.[147] Lutz Heck's cattle population in Berlin and the annexed Eastern European reserve were reportedly destroyed.[148] In 1944, the Red Army

[146] Maselli et al. investigated smell in feral pigs, and found that though the pigs demonstrated a structural recovery of olfactory sense, based on neuron density in olfactory regions of the brain, their sense of smell was worse than their truly wild compatriots. The authors concluded that on the basis of unrecovered function (heightened smell), the once-domesticated pigs were evidence in support of Dollo's Law. Valeria Maselli, Gianluca Polese, Greger Larson, et al., "A Dysfunctional Sense of Smell: The Irreversibility of Olfactory Evolution in Free-Living Pigs," *Evolutionary Biology* 41 (2014): 229–239, https://doi.org/10.1007/s11692-013-9262-3

[147] According to a list digitized by the "Animals as Objects. Zoological Gardens and Natural History Museum Berlin, 1820 to 2020" research project. In "The Zoo and National Socialism" at https://animalsasobjects.org/story.the-zoo-and-national-socialism/ Accessed April 21, 2023.

[148] An account of the destruction of the Berlin Zoo is given in Heck, *Tiere.*

retook Białowieża. Göring was captured and famously committed suicide while in jail; but not before he allegedly shot the last of the back-bred "aurochs" in his reserve, to keep them from Russian hands.[149] Lutz's herds did not survive the war.[150] Heinz's herds survived in Munich, and made their way to England and the Netherlands.[151] In 2009, Derek Gow imported Heck cattle into his farm in Devon, England, leading to the media frenzy around the aggressive "Nazi cows." Heck cattle would be deployed in the 1980s in a Netherlands ecological rewilding project – a story treated in the next chapter. As for the fate of the Heck brothers themselves, Lutz fled and lost directorship of Berlin Zoo; he was banned from international organizations.[152]

Figure 39. From 2009 article "The Herd Reich" in *The Sun,* reminiscent of WWII troop diagrams[153]

[149] de Bont, *Nature's Diplomats*, 131, and Bruce, *Through the Lion Gate,* 217.
[150] Douglas Campbell and Patrick Whittle, *Resurrecting Extinct Species: Ethics and Authenticity* (London: Palgrave Macmillan, 2017), 32.
[151] Driessen and Lorimer, "From 'Nazi Cows,'" 632.
[152] de Bont, "Extinct in the Wild," 131.
[153] J. Coles, "The Herd Reich," *The Sun,* April 22, 2009.

The aurochs under the Nazis became a symbol of several intertwined ideas. It suggested a primeval and ancestral Germany, one that could take part in grounding a national vision rooted in the past. It was also an antithesis to domestication and a symbol of things that were wild; this extended to its affect in human engagement with the animal, as hunting the aurochs could also re-wild, or de-domesticate, German men too. It thereby not only firmly associated the past with wildness, but demonstrated the value judgment about the wild under the National Socialists: identity, vitality, and connection could be found in a reconnection to the German "primitive" past. This "Aryan" aurochs could help facilitate that, at least for those close enough to Göring to partake in his hunting parties. The Heck brothers saw potential in the domesticated descendants of the aurochs, and with their views on chromosome theory, reconstituting the animal was perhaps within their grasp. If the reversions discussed in Chapter 4 suggested the aurochs was a synchronic ghost, haunting the improvement of living breeds, the Heck brothers sought to revive that ghost in corporeal form.

It should be no surprise in this part of the aurochs narrative, that the Heck brothers approached their ambitions with a hearty mix of cave paintings, Medieval and Ancient descriptions of the aurochs, and observance of living feral of semi-wild living cattle breeds, such as the Corsican cattle. The different prehistoric, historic, and synchronic records of the aurochs, and their associated testimonials of it at different timescales, had become so engrained by the time of the Heck brothers, that one need not simply defer to the Nazi proclivity towards myth to explain why something like the *Nibelungenlied* would have informed their work. Of course, texts such as the *Nibelungenlied* helped conjure the aurochs as a specifically "German" or "Aryan" animal, and led Lutz Heck at least towards prioritization of aggression and behaviors that would make for an enjoyable hunt. Still, the many timescales of the aurochs continued to bear their full weight on the attentions of those who studied it. With a belief in the staggeringly fast genetic reconstitution of the animals through back breeding, the Heck brothers envisioned an additional temporal assertion for the aurochs: a future.

Chapter 6: Rewilding with an Anthropocene Aurochs

Figure 40. Photograph by Frans Schepers of bull rewilding in the Lika Plains of the Velebit Mountains, Croatia. Schepers' caption: "The last bull took its time before stepping out to join the herd."[1]

In 2011, the first artificial insemination cross-bred bull of the Tauros Programme based in the Netherlands was born: his name was Manolo Uno after the last Iberian cowboy.[2] Manolo was a cross between two breeds considered to be 'original' to Europe: a Maremmana primtivo cow from Italy and a Pajuna bull from Spain. The Heck cattle were nowhere near this breeding program. Though the program does orient toward breeding back an aurochs, or as close as possible. The reason at the heart of this current project is ecological: "The Aurochs," they have noted, "is one of the missing keystone species, a species that had and has a key ecological role to

[1] From "Second Generation of Tauros Now Grazing in the Lika Plains," accessed April 22 2023, rewildingeurope.com/news/second-generation-of-tauros-now-grazing-in-lika-plains/.
[2] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

play, but that most of us seem to have forgotten about."[3] The crossing, according to the head of the Tauros Programme, Dr. Ronald Goderie, produced surprisingly ideal phenotypic results: dark fur with a white "eel stripe" down the spine. The horns were not as big as desired, but according to Goderie, for a first deliberate cross Manolo embodied "a perfect example of what we had in mind." What they had in mind was breeding something just like the aurochs. The biggest surprise with Manolo was that what they had hoped for was happening with "very fast results."[4]

Those fast results were exciting to the team, and maintaining such accelerated breeding results that resemble a phenotypic aurochs has become a main component of the work that Stitching Taurus, the group responsible for the Tauros breeding program, is now performing with their partners, including Dr. Richard Crooijmaans, a geneticist at Wageningen University. They seek to breed their aurochs 2.0 to perform its function as a "keystone" grazer that could revitalize abandoned farmlands into biodiverse ecosystems that resemble a past baseline. The tensions between the timescales of the endeavor are familiar to those attuned to the ways and rates at which the environment is being changed in the Anthropocene: how to evolve an organism over roughly five decades that took millions of years to evolve via natural selection; or rather, how to de-domesticate an organism that took thousands of years to domesticate?

On the one hand, these rewilders are aiming for a self-sustaining population of wild cattle, which means natural reproduction without human intervention is one goal of their work. On the other hand, natural reproduction and natural selection within their herds would take much longer than artificially selecting the desired animals with the desired traits. Use of artificial insemination helps accelerate that process even further. And what would expedite that artificial

[3] Frans Schepers, managing director of Rewilding Europe. Quoted in "The Comeback of the European Icon," November 8, 2012, at rewildingeurope.com/news/the-comeback-of-the-european-icon/ Accessed April 22 2023.
[4] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

selection process even more would be knowing which calves will have the adult traits that the breeders desire before they reach maturity and display those traits, so that breeders could identify the parents of their next crosses even earlier. That goal is still hypothetical but it informs much of the genetics work at the heart of the Tauros Programme, and was emphasized by Crooijmaans when I interviewed him. "Biomarkers" for the wild traits – phenotypic and behavioral – could be made for the genes of their mixed cattle herds, correlating desired traits to alleles on parts of the genome for which they could test via samples taken early in the individual's life. Why waste time with a calf that will ultimately develop with the wrong traits? The practice is already done in agricultural cattle raising, to test for protein-encoding sequences that have been tied to milk production and body-fat.[5] So-called "wild" traits desired by the Tauros Programme, however, have not yet been 'biomarked.'

Such tensions between the desired natural breeding rhythms of the animals and the pressures to deliver an "aurochs 2.0" in a timely manner, along with many other temporal frictions involved in this and other case studies of rewilding, are not tucked away in some corner of the breeding practice. They bring together competing interests between the animals' own internal timescales (those biological processes such as reproductive cycles), with external timescales measured in fiscal years, and broad ecological change in the direction of landscapes from geological times past. They sit at the center of the breeding work as well as a longstanding discursive tradition about where human interference ought to begin and end in conservation practices – and by extension, rewilding. Below, I draw upon the published material of Stitching Taurus and its partners, as well as interviews I conducted on-site at Stitching Taurus and Wageningen University in the Netherlands in November 2022, which demonstrate how

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[5] Barbara Orland, "Turbo-Cows: Producing a Competetive Animal in 19th and Early 20th Century Switzerland," in *Industrializing Organisms,* eds. Schrepfer and Scranton (New York: Routledge, 2004).

engrained these temporal tensions are within the aims, functioning, and underpinning logics of what they are calling the "aurochs 2.0."[6]

Adding to the mesh of timescales and directions that rewilding breeding practices navigate, the contemporary rewilding projects that make use of the descendants of the aurochs to bring back a form of wild taurine cattle draw on the holistic record of the aurochs that has been treated in this thesis. They compare and consider evidence from cave paintings, fossils, historical depictions, and the results of the Heck brothers' experiments to create something that fulfills the ecological and cultural functions of the extinct aurochs as closely as possible. The chapter contains references to the material discussed from the nineteenth-century paleontological concerns of aurochs' temporal classifications, to the early agricultural and genetical explorations of primitive breed reversions, and the Heck brothers' own back-breeding. Those references continue to be relevant to rewilding work that centers the aurochs. Cis Van Vuure, whose own early-2000s work *Retracing the Aurochs,* compiled an impressive array of scientific and historical sources to provide a fuller picture of the aurochs that might aid the current rewilding work, is a member of the board at Stitching Taurus.[7] The wide scope of cultural myth, paleontology, and breeding potential, are evident everywhere in the aims, practices, and public media appearances of those at Stitching Taurus. Their work uses the layered methodologies and records considered throughout the chapters in this thesis, while introducing another: the aurochs genome.

This chapter aims to demonstrate the desirability of the layered temporality of the aurochs for those seeking rewilding. It is, through the lens of time, a perfect pairing with the

[6] Ronald Goderie, Wouter Helmer, Henri Kerkdijk-Otten and Staffan Widstrand, *The Aurochs: Born to be Wild: The Comeback of a European Icon* (Zutphen, Netherlands: Roodbont, 2013).
[7] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022. Van Vuure, *Retracing the Aurochs.*

multiple entangled temporalities in rewilding work, and in Anthropocene discourse more broadly.[8] In the presence of a wealth of rewilding temporalities that bring internal timescales into direct relation with external timescales – baselines, targets, deadlines, reproductive realities, expedited selection possibilities – the organism has become a stand-in biotechnology for the desired wilderness. The goal, in effect, is for the organism to function as both producer and product of the rewilding process.[9] The seemingly expansive temporal stickiness the organism has when taken holistically – those anthropocentric associations to some notion of pre-human, domesticated by humans, made extinct by humans, etc. – are enough to allow it to function as a contributor to the process of rewilding for any desired temporal baseline.

To some, that abundance of temporal possibilities within the world of rewilding might be called an absence of a coherent temporal baseline for the rewilding goals.[10] The observation is a salient one: the temporal baselines used as goalposts for rewilding are often themselves inconsistent across different projects or internally incoherent within one. In the case of the Tauros Programme, the aim is to create a self-sustaining 'wild', or 'de-domesticated' organism, which they have called the Tauros breed. What temporal goalpost does that program prioritize? Or does it prioritize any specific past over any others? This chapter will examine what the temporal targets are for the Tauros Programme, but whether or not that project aims for a Pleistocene, Holocene, pre-human, or post-human landscape does not change the suitability of the aurochs to serve as a stand-in for any permutation of wilderness that these ecologists could imagine; in fact, imagining novel future ecosystems is in many cases the goal of rewilding, and

[8] See Huebener, *Nature's Broken Clocks* for a discussion of ecocritical time studies. And Barbara Adam on environmental damage spurred by industrialization, and its debts to Western views of time in general in Adam, *Timescapes.*
[9] Edmund Russell "The Garden in the Machine: Toward an Evolutionary History of Technology," in *Industrializing Organisms,* eds. Schrepfer and Scranton (New York: Routledge, 2004).
[10] Dolly Jørgensen, "Rethinking Rewilding," *Geoforum* 65 (2015): 482-88.

an organism known over centuries through its temporal stickiness is an excellent candidate for such experiments.[11] This chapter explores tensions in temporalities and logics at the heart of rewilding programs like Stitching Taurus, bringing together my case study interviews with Ronald Goderie, the founder of the Tauros Programme, and Richard Crooijmaans, the lead geneticist on the project, and primary material on this “aurochs 2.0” program, alongside established frictions within ecology about the place of nature within shifting temporalities. It suggests that in the case of rewilding, the expectation for simplicity was never part of the project, and the aurochs’ messy mesh of timescales suits that just fine.

Figure 41. Stitching Taurus program site in Keent Nature Reserve, Netherlands.[12]

[11] Jonathan Prior and Kim J. Ward, “Rethinking Rewilding – a Response to Jørgensen,” *Geoforum* 69 (2016): 132-5.
[12] Photo by author.

When I visited the Keent Nature Reserve just outside of Nijmegen, Netherlands on November 9, 2022, the visitor house was being set up for an event. Stitching Taurus, whose flag flies high on a pole to welcome you to the otherwise unassuming open landscape nestled amongst farms, has been hosting and participating in many events centered around the promise and practical production of rewilding projects. The site, formerly farmland and donated to the Tauros Programme by ARK Nature, a founding partner of Rewilding Europe, covers around 400 hectares of public space. It is at Keent that the Tauros breed – the so-called "aurochs 2.0" – is being bred, steered by Dr. Ronald Goderie.

Goderie, a Dutch ecologist, got his start in the 1980s, when according to him it was much harder to get a job as an ecologist. Now, as he says, "it's completely different – they can't get enough ecologists."[13] Ecology is at the base of Stiching Taurus's work. In 2012, the Tauros Programme affiliated its work with Rewilding Europe, a not-for-profit foundation registered in the Netherlands in 2011 that sees rewilding as a key catalyst in climate solutions.[14] Initiatives such as Rewilding Europe, whose own headquarters resides in Nijmegen, near the roaming herds of Tauros in Keent, emphasize the restorative force of reintroducing or breeding-back keystone organisms for landscapes, global climate, and local economies.

The Tauros Foundation was founded in the Netherlands in 2008 by Ronald Goderie and its breeding initiative, the Tauros Programme started in 2011 in cooperation with Rewilding Europe. Through its three registered LLCs, Rewilding Europe provides loans to rewilding enterprises, owns land to be rewilded, and connects that land with initiatives such as Stitching Taurus who provide the animals with which they rewild. At the end of 2022 Rewilding Europe

[13] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.
[14] As stated on the "Public Disclosures" page of Rewilding Europe, Accessed February 2023, https://rewildingeurope.com/public-disclosures/.

was working with ten rewilding landscapes across Europe, including seeding Tauros animals along the Danube Delta system in Ukraine, Romania, and Moldova, in the Velebit Mountain range connected to Slovenia and Dalmatia, and in the Netherlands.[15] Boasting membership from 77 groups across 27 countries, Rewilding Europe has grown as a facilitator of smaller, local initiatives, as well as a major presence in public media about rewilding practices.[16] This self-described "Pan-European" operation received early capital from the Dutch Postcode lottery, which has since 2015 become a regular benefactor of the group.[17] The Tauros breed developed in close cooperation with Rewilding Europe, and ARK Nature. In 2013, Rewilding Europe awarded the Tauros Programme 20,000 EUR supplied by the Dutch Liberty Wildlife Fund to conduct DNA research into the aurochs and its nearest relatives.[18] Since then, Goderie and his team have worked closely with geneticists at Wageningen University in the Netherlands to chart a path forward to breeding a wild ecological grazer that approximates the aurochs enough to be monikered "aurochs 2.0."

Stitching Taurus' initial work, prior to their "aurochs 2.0" breeding program that began around 2009, used the grazing power of imported Scottish highland cattle as a cheap and effective way to manage open landscapes. Over time, the animals that had once been considered as mere "grazing machines" were increasingly seen as transformative parts of the ecosystem; the work of Dutch ecologist Frans Vera who used the Heck cattle breed in a Netherlands rewilding

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[15] Rewilding Europe, *Annual Review* (2021), 89-91. https://www.rewildingeurope.com/wp-content/uploads/publications/rewilding-europe-annual-review-2021/.

[16] These numbers taken from Rewilding Europe "Public Disclosures," accessed February 2023, https://rewildingeurope.com/public-disclosures/a.

[17] The funding is noted in Rewilding Europe's *Annual Review* (2021), and an overview can be found at rewildingeurope.com/about/achievements. Accessed February 2023.

[18] Ronald Goderie, Johannes A. Lenstra, Maulik Upadhyay, Richard Crooijmans, and Leo Linnartz, Stitching Taurus "Summary of: Aurochs genetics, a cornerstone of European biodiversity" Report (2015), https://www.rewildingeurope.com/wp-content/uploads/publications/aurochs-genetics-summary/html5/index.html?page=1&noflash.

experiment begun in the 1980s was a catalyst in thinking about the role of large grazers in contemporary ecological systems and nature preserves. Around 2008, Stitching Taurus turned their attentions to the aurochs as the best candidate for natural grazing landscape management – they had, after all, done the job for thousands of years while fending off natural predators such as wolves. Their hardiness in the face of predators was part of their appeal.[19] There was only one problem: they no longer exist. Faced with possible substitutes such as the Heck cattle, Stitching Taurus made a more radical choice: to create their own breed that is constantly circling in as closely as possible to the aurochs in form, function, and genetics.

Goderie was clear that he did not want to use Heck cattle in his own work, as Vera had, for three reasons. He "didn't want anything to do with a poisonous heritage of the Heck brothers;" furthermore, the horns were all wrong. Additionally, the specific crossings that had been used to produce the Heck animals – Spanish fighting bulls, for example – made the animals "more aggressive than they normally would be as a vegetarian [herbivore]."[20] Having witnessed one of the roundups of the Heck cattle that were being used as grazers elsewhere in the Netherlands, Goderie described the process as "like a military operation, because they were afraid of the animals, and what you put in you get out, and the animals were in fact dangerous."[21] Aggression is still a concern for the breeding program's own herds, as the public has open access to the park in Keent in which the herds roam, and incidents gain negative attention.[22] Aggression

[19] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.
[20] *Ibid.*
[21] *Ibid.*
[22] The reserve in Keent is a public park – people go through all the time. When visiting the reserve, I saw someone passing through and Goderie watched to make sure the individual did not get too close to the herds, just to be safe. Their goal is a coexistence within the park between park-goers and animals like the Tauros, but such a goal still requires public education about the wildness of the animals.

is also one of two conditions that allows the group to shoot one of their herd; the other is "undue suffering."[23]

Public interaction is just one front which Stitching Taurus has to manage as they continue their breeding program and populate rewilding spaces across Europe with the Tauros breed. They also contend with the legacy of not just the Heck brothers' experiments, but also that of Vera's Netherlands rewilding experiment that had used the Heck cattle. They must mediate internal conflicts within their goals and practices and the deeper history of rewilding as it is deployed as a possible solution to some of the ecological deterioration being faced in the Anthropocene.

A REVIEW OF REWILDING

The work of Goderie, Crooijmaans, and the herds being put to work as breeders of a wilder future, step rather neatly into the historical trends of rewilding.[24] Contemporary rewilding emerged as a recent term at the end of the twentieth century, but many of its concerns were born out of the early-twentieth century's international conservation efforts. In the Netherlands in particular, the deeper regional history of both agrarian industry and nature preservation and creation partially informs why it has become a central site for the rewilding of the aurochs.

Rewilding is generally considered a quite recent phenomenon in the history of conservation, though its contours can be found in the conservationist policies developed around

[23] An incident occurred in April 2021 in which an article with video was posted in the De Gelderlander, depicting the shooting of two Tauros bulls which had badly injured each other – the shooting unfortunately had been botched. Stitching Taurus addressed the incident on their website and clarified the strict conditions under which they would shoot cattle, and the unfortunate botching of the shooting in that case. The post addressing the incident could still be found at stitchingtaurus.nl/berichten/ as of April 2023.

[24] Jørgensen, "Rethinking Rewilding," has taken a genealogical approach to understanding 'rewilding,' following Foucault's lead. The results of her method, however, demonstrate a capacious and plastic term which in her mind renders it useless. The research she presents gives a helpful picture of the multifaceted nature of rewilding, but is maybe too quick to deem that plurality unproductive.

1900. A tiny portion of the variety of conservation practices appeared in the previous two chapters, but conservation practices themselves have an incredibly mixed origin and diverse methods in their longer history, especially during imperial knowledge exchanges from the seventeenth to the nineteenth centuries. Still, the distinct initiatives undertaken around 1900 influenced global environmental strategies along Western ideals, and are sufficient as a starting place for understanding the overt conservation intentions that remain implicitly to this day.[25]

During the decades spanning 1870s-1910s, internationalist concerns and congresses developed alongside a conceptual alignment of nature with national identity, and a closing in of the global map in which nature was less awaiting discovery as it was needing protection at home.[26] The resulting preservationist tendencies that emerged during these global trends emphasized preservation of landscapes that were seen as a manifestation of the nation, as well as preserving large animals for hunting.[27] These impulses mostly occurred in Europe, and European colonies, respectively.[28] The back-breeding project of the Heck brothers recounted in the previous chapter existed within this cultural lineage, emerging out of an extreme prioritization of both heritage and reinstatement of alleged original nature, as well as an elite and largely masculine practice of game hunting. The concerns of the contemporary rewilders in this chapter

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[25] de Bont, *Nature's Diplomants,* 24. For more on the earlier history of the imperial strand of environmentalism, see Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600-1860* (Cambridge, UK: Cambridge University Press, 1995).
[26] de Bont, *Nature's Diplomats,* 24-25.
[27] Preservation for hunting purposes has one of the longest historical lineages from ancient Persia to Qing China. See Thomas T. Allsen, *Royal Hunt in Eurasian History* (Philadelphia, PA: University of Pennsylvania Press, 2006).
[28] de Bont, *Nature's Diplomats,* 25. For more on heritage concepts of nineteenth-century Europe, such as *Heimat,* that combined natural and cultural objects, giving value to both through their associations across such a divide, see Astrid Swenson, *The Rise of Heritage: Preserving the Past in France, Germany, and England, 1789-1914* (Cambridge, UK: Cambridge University Press, 2013),. de Bont argues that big game preservationists presented the animals of interest as part of an imperial heritage, rather than as part of a global commons. de Bont, *Nature's Diplomats,* 31.

appear less nationalistic in their aims and motivations, and are certainly disinterested in preservation for hunting purposes. Yet, the same focus on charismatic animals and some sense of a lost national landscape underpins their work. That is especially the case in the Netherlands.

In the late twentieth century, the Netherlands became one of the most publicly discussed sites of rewilding practices, due to the initial promise and eventual unfortunate results of a long-term experiment in the Oostvaarderplassen (OVP) reserve. But the history of the country before the OVP "fiasco" underscores the particularities that have kept the Netherlands as a foremost site investing in rewilding practices, and currently spearheading the creation of an "aurochs 2.0." As Clemens Driessen has noted in his scholarship on the deeply cultural elements of nature, the Dutch have a particular experience of nature and nation that is mediated through the concept of the "cultivated landscape."[29] Indeed, he even cites a Dutch saying: "God created the world, but the Dutch created the Netherlands."[30]

From Dutch cultivated landscapes to its heavily agricultural history, there has developed a vested interest in what wild spaces mean and how to achieve them in the Netherlands.[31] The industrialized agricultural trends are in many ways what rewilding has been reacting against. The development of methodical agricultural breeding and its intensification beginning in the eighteenth century and accelerating into the twentieth and twenty-first centuries has changed the landscape of Europe, as well as the organisms bred to such ends.[32] Rather than only preserving a

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[29] Quoted in Steph Yin, "The Netherlands Rewilding experiment, gone haywire," August 23, 2019, *WHYY PBS,* Accessed December 2022.
[30] *Ibid.*
[31] For more on the cultural history of cultivated landscape in the Netherlands, see Simon Schama, *The Embarrassment of Riches: An Interpretation of Dutch Culture in the Golden Age* (Berkeley, CA: University of California Press, 1988), which in part shows the cultural imprint of reclaimed land in the Netherlands and the threat of the sea that was its cultural foil.
[32] For a broad account of the market-pressures of livestock and their effects on animal and plant biology, see Schrepfer and Scranton, eds., *Industrializing Organisms*; see also Otter, *Diet.*

sense of nature – i.e. spaces with biodiversity that lay largely unmanaged by humans – a series of public experiments have been used to restore ecological systems. They can require quite intimate and intensive interventions to breed wild animals, manage their lives, and through that work change landscapes over time.[33] Rewilding has become one such form of public ecological experiment, and has taken hold across Europe, with the pan-European trend of former farmland abandonment raising discussion about how best to use land, promote biodiversity, and facilitate quality of life and standards of living for people.[34] Some of the key programs leading the way are based in the Netherlands, including Rewilding Europe. The region's deep history of engaging in agricultural work and animal husbandry provides it with the institutions, knowledge, and resources developed through intense industrialized agriculture to inform the intimate breeding-based strategies of rewilding work that centers extirpated or globally extinct animals such as the aurochs. In these ways, the contemporary rewilding methods of groups like Stitching Taurus are quite different than the forms of self-described rewilding that had come before.

Rewilding is generally seen to have begun as a scientific term in the 1980s, most closely in association with The Wildlands Project in North America founded in 1991, through a collaboration between conservation biologist Michael Soulé and activist David Foreman which sought to create wilderness areas in North America separate from human activity.[35] The project's definition of wilderness was predicated upon the presence of wild predators, including the wolf, which had been glaringly absent from North American ecosystems since the extirpation of

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[33] For more on the experimental roots of ecological restoration in North America, see Matthias Gross, *Inventing Nature: Ecological Restoration by Public Experiments* (Lanham, MD: Lexington Books, 2001).
[34] Laetitia M. Navarro and Henrique M. Pereira, "Rewilding Abandoned Landscapes in Europe," *Ecosystems* 15 (2012): 900-12.
[35] Credited to Michael Soulé and Reed Noss, "Rewilding and Biodiversity: Complementary Goals for Continental Conservation," *Wild Earth* 8 (1998): 19-28.

wolves from Yellowstone National Park, when the last was killed in 1926.[36] In Soulé's use, rewilding was driven by the aims of prioritizing wilderness spaces separate from human activity, in which reintroduced predators could resume their role in the ecosystem and thus restore wilderness spaces.[37] The early American provenance of rewilding has not globally been retained, as today most associate rewilding with its European flavor: landscape rewilding through species reintroduction, including using taxon conspecifics for Pleistocene or Holocene megafauna. Here the concern was a depletion of biodiversity in abandoned farmlands, without a focus on predators as a driver of ecological restoration.

Rewilding today is quite an expansive umbrella, embodying various historical baselines of past "wilds" which ecologists aim to restore, and different means to bring about such restorations, including the use of fire maintenance, modified flood patterns, assisted migration, and reintroduction of species now missing, or at the extreme, extinct. In the face of this bewildering range of rewildings, the term itself has drawn criticism. Dolly Jørgensen's critiques were succinctly summed up by her in a 2015 article: "Just as Shakespeare's Macbeth laments about life, rewilding becomes a word 'full of sound and fury, signifying nothing'—or perhaps, signifying everything."[38] Others have pushed back on Jørgensen's criticisms, citing the common core at the heart of the disparate projects given the moniker 'rewilding.' To them, rewilding is united by an aim of non-human autonomy, and according to Jonathan Prior and Kim J. Ward writing in response to Jørgensen, case studies of rewilding demonstrate the dynamics of "human-

[36] For more on the use and history of "rewilding" see Jørgensen, "Rethinking Rewilding," Prior and Ward, "Response," and Jamie Lorimer, Chris Sandom, Paul Jepson, Chris Doughty, Maan Barua, and Keith J. Kirby, "Rewilding: Science, Practice, and Politics," *Annual Review of Environment and Resources* 40 (2015): 39-62.
[37] Jørgensen, "Rethinking Rewilding," provides a taxonomy of six different types of rewilding, of which this earliest "3-Cs" model of the Wildlands Project (cores, corridors, and carnivores) is just one.
[38] Jørgensen, "Rethinking Rewilding," 486.

non-human entanglements" present in the experiments of rewilding.[39] At the heart of this discourse is a familiar question about humanity's place in nature, which is here given a temporal and experimental dressing. Temporal, as Jørgensen points out, because of the many benchmarks of rewilding projects that set desired pasts as either pre-human, or pre-human-land-cultivation, or pre-human-driven extirpation as their baselines for rewilding.[40]

Detaching humans from nature becomes a temporal project, as rewilders seek to create spaces in the world that evoke a pre-human-*something* ecosystem. This purported detachment, however, is challenged by the experimental setting of much rewilding work. Experimental, as Prior and Ward demonstrate, because humans will inevitably be involved in wildlife rewilding, as the premise of the work is often an experiment in/of nature.[41] The experiment of it all, much like other scientific experiments conducted in the 'field,' reminds us of the balance between controlled and naturalized: instigated and maintained with human direction, but seeking to see nature in action to test a hypothesis.[42] Considering re-wilding as an experiment, therefore, collapses Jørgensen's critique that it seeks a human separation from nature; on the contrary, as Prior and Ward would argue, it necessitates humanity's involvement. The story of the aurochs itself directly pushes back against Jørgensen's claim that "the rewilding concept has been deployed in a myriad of ways to exclude humans in time and space from nature."[43] Indeed, the story of an infamous predecessor to Stitching Taurus, which made use of the Heck cattle breed discussed in the previous chapter, has been cited as an "experimental site unashamedly created

[39] Prior and Ward, "Response," 134.
[40] These different baselines are discussed in relation to the aurochs rewilding efforts in more detail below. A helpful summary of the range of baselines in rewilding work can be found in Lorimer, Sandom, Jepson, Doughty, Barua, and Kirby, "Rewilding."
[41] Prior and Ward, "Response," 134.
[42] See Gross, *Inventing Nature* for more on blurring boundaries between lab and field, and on public experiments in and of nature.
[43] Jørgensen, "Rethinking Rewilding," 487.

through human and non-human entanglements."[44] That is the Dutch Oostvaardersplassen experiment, conceived of by ecologist Frans Vera. In the interest of suspenseful foreshadowing, it has also colloquially become known as the OVP fiasco.[45]

In the 1980s, Dutch ecologist Frans Vera began introducing the Heck 'back-bred' cattle herds into Netherlands polders "rewild" them. As scholars Jamie Lorimer and Clemens Driessen have characterized it, when Vera began introducing 'back-bred' cattle herds into the polders, it was arguably to '"rewild' themselves and the landscape they inhabit."[46] Vera, in direct contrast to the Heck cattle's creators, was not primarily concerned with the cattle being a true aurochs in form.[47] Instead, his experimental herds were, in Driessen and Lorimer's words "valued for the missing ethological and ecological processes they *could* initiate."[48] His goals for the Heck cattle transcended the Heck brothers' original vision, and operate in the realm of rewilding of landscapes based on an ecological, not mythological, framework. More than that, however, he viewed the cattle as experimental material, and open to whatever the cattle or the landscape they occupy should become.[49]

The difference in temporal postures was reinforced by, and in some ways rooted in, the difference in their conception of the cattle themselves. The Hecks were retrospective, and believed their cattle to be true aurochs. Rewilding experimenters such as Vera are forward facing, working with experimental material that is guided by past organisms, but is valued for the unpredictable future it has. In that sense it matches present concerns with the unpredictable

[44] Prior and Ward, "Response," 134.
[45] Dubbed "fiasco" in Bert Theunissen, "The Oostvaardersplassen Fiasco," *Isis* 110, no. 2 (2019): 341-5.
[46] Jamie Lorimer and Clemens Driessen, "Bovine biopolitics and the promise of monsters in the rewilding of Heck cattle," Geoforum 48 (2013): 249. Lorimer and Driessen treat this within their discussion of rewilding vs. conservation.
[47] *Ibid*., 255.
[48] Emphasis my own. *Ibid*.
[49] *Ibid*.

future of landscape and climate. Those research goals, and the cattle themselves, are viewed as novel, potentially unpredictable, and future oriented, attributes that align them with holistic, as opposed to reductionist, approaches to the organisms and their ecologies.[50]

In the 1980s, Vera's experiment was able to meet a moment in Dutch concerns over their natural spaces. According to Goderie, "ideas evolved on the lack of naturalness of our Dutch nature."[51] Certainly the Netherlands is known as a country of cultivated spaces – with canals winding through, and managed and maintained nature spaces kept accessible to the public. Initially, the OVP polder – land which was itself reclaimed from the sea – was to be an industrial development site, but after some Greylag geese colonized it, humans lobbied to officially make it a nature reserve, creating what has been called an "accidental ecology."[52] In 1983, 35 Heck cattle were brought in, and in 1992 Vera and his team added Red Deer to the polders. The aim for the project in Vera's eyes was to leave nature to its own devices, let it "rewild itself," and in the process demonstrate what European landscapes had been like before they were so heavily changed by human civilization.[53] The hope, as Goderie told me, was to reinstate the kinds of large animal dynamics that had been missing, but had once been a part of European nature. Importation of Scottish Highland cattle had occurred in the 1980s in the Netherlands for "natural grazing purposes," but those animals were, according to Goderie, "seen more as a mowing machine than the animal being part of the ecosystem."[54] For Vera and his reintroductions and

[50] The criteria to denote different forms of rewilding, from their historical baselines, or interest in future-oriented novelty, to their spatialities and associated politics have been loosely taxonomized by Lorimer and Driessen, "From 'Nazi Cows.'" They provide a short-hand chart demonstrating the various postures in time, space, method, ontology, and politics that rewilding can take. See Figure 5, Lorimer and Driessen,v "From 'Nazi Cows,'" 647 for a chart of their rewilding breakdown.
[51] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.
[52] Lorimer and Driessen, "Bovine Biopolitics."
[53] Frans W.M. Vera, "Large-scale Nature Development: the Oostvaardersplassen," *British Wildlife* 29 (2009): 28-36.
[54] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

importations, the ecosystem was the entire point. Exactly what that ecosystem should be was informed in large part by what ecologists and paleoecologists thought the ecosystems of Europe used to be.

In the early twentieth century, British ecologists Arthur George Tansley and Charles Edward Moss had created a picture of past European ecosystems covered by closed-canopy forest that would dominate ecological reconstructions of Europe's pre-civilization past. As part of their reasoning, Tansley and Moss leaned on the ecological effects of large ungulate grazers, which they believed had only been present in affecting numbers following their domesticated introduction by humans. They argued that large ungulates could thwart tree regeneration in a forest, slowly changing it to grassland or heath in a process of retrogressive succession.[55] Such ecological roles of large grazers and their general effects on a web of organism interactions had already been noted and memorably described by Charles Darwin in a section of Chapter 3 of *Origin,* on the "Struggle for existence" in which he described the effects of cattle grazing in heaths as thwarting the growth of Scotch fir trees.[56]

Tansley and Moss believed that with the introduction of domesticated livestock to Europe by mankind, the landscape had been changed, removed of forest coverage.[57] Dense forest, they

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[55] Arthur G. Tansley, ed., *The Types of British Vegetation* (Cambridge, UK: University of Cambridge Press, 1911); Charles E. Moss, W.M Rankin, and A.G. Tansley, "The Woodlands of England," *New Phytologist* 9 (1910): 113-149.
[56] Charles Darwin, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (London: John Murray, 1859), Chapter 3, 70-72 for his discussion of cattle and trees in relation to the population checks that species put on one another. Following his example he notes: "Here we see that the cattle absolutely determine the existence of the Scotch fir."
[57] A.C. Forbes, "On the regeneration and formation of woods from seed naturally or artificially sown," *Transactions of the English Arbori-cultural Society* 5 (1902): 239-70. Charles E. Moss, *Vegetation of the Peak District* (Cambridge, UK: Cambridge University Press, 1913). Moss, Rankin, and Tansley, "Woodlands." Tansley, *British Vegetation.*
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reasoned, must have once covered mainland Europe and Britain but had been destroyed by grazing and ploughing. This baseline of a closed-canopy forest as the undisturbed, natural vegetation of Europe held sway for ecologists for decades.[58] According to Frans Vera, founding figures of ecology such as Tansley and Eugenius Warming viewed livestock as "exotic species introduced by man, and therefore not belonging to nature. Grasslands were considered to be artificial product, 'stolen' from the forest."[59] The confident establishment of the forest-baseline for the "natural vegetation" of Europe informed reconstructions of the environments in which natural wild fauna, including the aurochs, must have lived. With support of this forested European past coming from early palynological work, the aurochs was interpreted as a forest-dwelling animal following its official scientific recognition as the wild ancestor to cattle in 1927. The aurochs was thus cemented as the wild ancestral cattle as it was imagined within the past environments which were then understood to have been a closed-canopy forest. As such, Tansley had suggested that the aurochs likely lived in low densities such that it would not have disturbed that forested ecosystem revealed by the paleo-ecologists.[60] Afterall, the aurochs in any great density, like its domesticated descendants, likely would have contributed to a patchwork landscape of open grassland, groves, and heaths through its eating and other behaviors destructive to trees and their saplings.[61]

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[58] Tansley *British Vegetation*. Vera, "Large-scale."
[59] Vera, "Large-scale," 29-30. He references E. Warming, *Oecology of Plants: an Introduction to the Study of Plant Communities* (Oxford, UK: Clarendon Press, 1909).
[60] Arthur G. Tansley, *The British Islands and their Vegetation*, 3rd edition (Cambridge, UK: Cambridge University Press, 1953).
[61] In Vera, *Grazing Ecology,* Vera discusses his views on the cyclical modules of nature facilitated by the presence of wild grazers, based on his dissertation in 1997. Vera cites Gould in the book when outlining his historical method and the null hypothesis he ultimately rejects, and when describing his non-linear modular system of "cyclical turnover of vegetation." He even opens his book with a quote from Gould's *Wonderful Life:* "'The most important message taught by the history of science is the subtle and inevitable hold that theory exerts upon data and observations.' 'The greatest impediment to scientific innovation is usually a conceptual lack, not a factual lack.'" It is clear that Vera sought to critically

The population size of past wild grazers, therefore, was critical to maintaining their picture of dense forest. With the uncovering and interest in greater and greater numbers of aurochs and wild tarpan horse remains that dated back to a time before agriculture by archeozoologists in the 1990s, skepticism about the 'naturally' forested past state of Europe before agriculture followed.[62] Their very presence encouraged ecologists such as Vera to suggest that perhaps the European landscape had been more open than was previously understood before agriculture developed.[63] For Vera, the reclaimed polders of the OVP, recently colonized by geese and subsequently protected as a nature reserve was an ideal site to test this hypothesis: that the post-glacial landscape of the area had not been dense forest, but rather was kept more like a mosaic of grassland and groves through the presence of large populations of sizable grazers such as the aurochs, tarpan, and red deer.[64]

Vera's experiment to push back against the forested picture of natural, pre-cultivation Europe established by Tansley and Moss and maintained over decades would have consequences for nature policy. As Vera noted, "this image influences the policy which determines the future appearance of our (i.e. European) living environment. For example, everywhere in the Netherlands forests are planted, because this supposedly meets the growing need for urban dwellers to have nature close to home."[65] While biodiversity advocates in Europe had argued that farming itself had introduced biotopes and diversity in landscapes, Vera's thesis indicated that the natural baseline for European biodiversity ought to be neither dense closed-canopy forest, nor

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reexamine what he saw as circular reasoning underpinning the forested view of European natural baseline in the late and post-glacial environments. The forested view had gained its own momentum that was leading to an interpretation of evidence that could be better explained by other hypotheses.

[62] Jørgen Tiemen Zeiler, "Hunting, fowling and stock-breeding at neolithic sites in the western and central Netherlands" (PhD diss., University of Groningen, 1997); Vera, *Grazing Ecology*.

[63] Vera, "Large-scale," 30.

[64] Theunissen, "OVP," 1.

[65] Vera, *Grazing Ecology*, xiii.

agricultural plots.[66] His experiment in the OVP provided a very public opportunity to make the case that a biodiverse European nature might look very different than the powerful synonymous formulation of "forest equals nature."[67] The aurochs, as part of that picture, was not just an inhabitant of a mosaic landscape of grasslands, in Vera's historical reconstruction. It was crucial evidence, through its own biological functions as an ecological grazer, of the world it must have inhabited.

Beginning in the 1980s, Vera and his colleagues seeded the OVP with large grazers such as Konik ponies and Heck cattle, which would suit as "aurochs-like grazers." Thirty-five Heck cattle were introduced in 1983, to function in the role that the aurochs might have had in the past.[68] The Heck cattle had made their way from herds that remained from Heinz Heck's stock, following the demise of Lutz's entire stock during World War II. They and the Konik ponies were considered stand-ins for their wild ancestors, because, as Vera put it: "they have undergone very little selective breeding and may therefore have many of the characteristics of their wild ancestors."[69] Those natural characteristics, he hoped, could be "redeveloped" once the animals became truly feral whilst living in the wild.[70] It is curious that the Heck cattle might be considered to have had minimal selective breeding, given, as Chapter 5 described, that they had been bred from a range of selected cattle that the Heck brothers thought contained important aurochs traits. Vera, however, was operating in a rewilding framework that was set against the highly industrialized dairy cattle industry in the Netherlands – those overbred rectangles with fast maturation, and of which 80-90% were, at the time of the experiment in 1996, derived from

[66] Vera, *Grazing Ecology*, 379.
[67] *Ibid.*, xiv. He takes aim at this prevailing notion in his 1997 doctoral thesis and later book, as being both culturally and scientifically rooted, though inaccurate.
[68] Vera, "Large-scale," 32.
[69] *Ibid.,* 33.
[70] *Ibid.* He builds this argument in Vera 1988 as well.

no more than 80 bulls.[71] The Heck cattle, by contrast had maintained some diversity, given their mixed origin. And, while a true population bottleneck appears to have occurred during the firebombings of World War II, no dedicated selection by those managing the herds appears to have taken place on the survivors or their descendants following that period. In essence then, the Heck cattle seemed a viable option to stand-in as an aurochs understood as its ecological grazing ecological function.

The project did not only rely on the World War II relics, but also made use of Konik ponies, and in 1992, Red deer were introduced to mix grazing strategies, preventing the domination of any single type of flora.[72] Overtime, if a park-like landscape of wood pasture with a biodiversity of specific bird species emerged, Vera would consider declaring the experiment a success. Unfortunately for Vera, the project began attracting negative attention when the large grazers starved after some unusually severe winters. In the face of the public scrutiny that erupted during those bouts of starvation, the use of the Heck cattle themselves came under fire and their "Nazi" origins were touted as evidence that the entire experiment had been careless.

In retrospect, much has been made of the inconsistency in logic that underpinned the experiment. In order to ascertain the true wild nature of Europe, Vera was already starting from a place of intervention: the very land in the OVP that he seeded with large grazers was entirely reclaimed, and had been submerged under water during the Holocene period he sought to rekindle. Beyond that, the management of the system was very involved, despite a public strategy of non-intervention. Reporting on the eventual fiasco by PBS recounted constant managing of the water levels to keep optimal grazing for the Greylag geese; in one case, when a

[71] Vera, *Grazing Ecology*, 381.
[72] Vera, "Large-scale," 33.

wild boar appeared the rangers shot it.[73] The incompatibility of non-intervention strategies designed to let nature fully take over, and the meticulous curation and maintenance of the reserve would ultimately stoke a fire in the case of fencing and feeding.

Following some harsh winters in 2005 and 2010 that led to some of the cattle's demise and drew scrutiny to the project, in the winter of 2017-2018 the grazers suffered a particularly severe cold spell. Their populations had been climbing in the absence of natural predators, and without food during the winter, or anywhere else to go, their numbers plummeted. Soon photographs taken by animal activists circulated, depicting the once-promising reserve as a "cemetery, without burying."[74] Over 3,000 (60%) of the large grazers had died in the winter, their corpses reportedly visible from the trains that passed by the area. Animal welfare groups had tried to throw food over the fence during a second unusually harsh winter, but police ushered them away. While protests erupted and more online images of the corpses circulated, a commission was called to investigate the policies of the reserve that had led to the fiasco.[75]

At the heart of the issue was the technical legal status of the animals. In the case of the large grazers at the OVP, the animals had been considered wild, meaning the public could not intervene and feed them. Still, they were fenced in.[76] For the OVP grazers in the Netherlands, the

[73] Frank Berendse, "The Netherlands Rewilding experiment, gone haywire," interview by Steph Yin, *WHYY,* PBS, August 23, 2019. Berendse, an ecologist, was Vera's former mentor at Wageningen University.
[74] Karen Schulting, animal activist in Netherlands; quoted in Steph Yin, "The Netherlands Rewilding experiment, gone haywire," *WHYY,* PBS, August 23, 2019.
[75] Reconciling Nature and Human Interests: Report of the International Committee on the Management of the Oostvaardersplassen (ICMO), Wing rapport 018 (The Hague: Wageningen UR, 2006). And: ICMO2, Natural Processes, Animal Welfare, Moral Aspects, and Management of the Oostvaardersplassen: Report of the Second International Commission on Management of the Oostvaardersplassen (ICMO2), Wing rapport 039 (The Hague: Wageningen UR, 2010).
[76]There is precedent for feral cattle that are culturally and legally considered wild despite protections that keep them isolated and from freely roaming. Ritvo has explored this dynamic in the historical context of the Chillingham cattle.

commission determined that the animals were still considered wild, despite the fence, but asked the managing rewilders to intervene in cases in which the animals were otherwise going to simply starve; with the new policy, rangers would shoot those on the brink of death so to avoid undue suffering, but also not interfere with those that would have died "naturally."[77]

In 2018, the OVP experiment came to an end, succumbing to the public outcry. Vera had been excluded from decision making in the project towards the end. Subsequent scholarship has scrutinized both public reaction and logical flaws in the project itself. Bert Theunissen has critiqued the role of preconceived expectations for 'equilibrium' in nature in public understanding as contributing to the public fiasco.[78] Social scientist Koen Arts has argued that the experiment was a great and so-far successful one that is still ongoing – only, the experiment has been a social one. At the heart of the experiment, according to Arts, is an exploration of the entangled human values within nature conservation, and all taking place within a densely populated European country.[79] Still others see the ecological management lessons learned, as well as the realized importance of public communication as deeply valuable; the role of predators, the scale of rewilding and its ecosystems, and the technical management skills needed to rewild have all been underscored by the OVP experiment.

Vera, for his part, was disappointed by the reaction to the experiment. As he argued, the experiment fell victim to a sense of a shifting baseline in care standards – the public applied the same standards of care they would to domesticated livestock, but these were not domesticated livestock, he argued. He also noted that the experiment had been cut too short for results to have been attained. For its part, the government had expected success measured by population

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[77] This mirrors the approaches taken today by Stitching Taurus in their herd management.
[78] Theunissen, "OVP."
[79] Reported in Steph Yin, "The Netherlands Rewilding experiment, gone haywire," *WHYY,* PBS, August 23, 2019.

stability within just ten years.[80] Ultimately, if given more time, Vera thought the experiment could have stabilized. Comparing the time scales of nature and humanity, Vera described the inadequacy of measuring success on the scale of human agendas in an interview following the experiment's conclusion: "You know how old the area is? It's only from 1968…So it's like saying to a baby, you have to walk and you have to get a job. The area is still a baby, and now we expect the area to behave as an adult."[81] For the Tauros Programme, the OVP experiment has become a counterpoint from which they set themselves apart in interviews.[82] And yet, many of the tensions which were publicly laid bare in the course of that experiment are present in the operations and aims of the Tauros breeding program and its rewilding partner, Rewilding Europe. Many of those are temporal in nature and are proving to be entrenched in the practice of rewilding ecosystems through breeding programs.

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[80] Theunissen, "OVP," 344.
[81] Reported in Steph Yin, "The Netherlands Rewilding experiment, gone haywire," August 23, 2019, *WHYY PBS,* Accessed December 2022.
[82] For more on the OVP, see: Theunissen, "OVP"; Vera, "Large-scale"; Vera 1988; Vulink and Van Eerden 2001; Reconciling Nature and Human Interests: Report of the International Committee on the Management of the Oostvaardersplassen (ICMO), Wing rapport 018 (The Hague: Wageningen UR, 2006). And: ICMO2, Natural Processes, Animal Welfare, Moral Aspects, and Management of the Oostvaardersplassen: Report of the Second International Commission on Management of the Oostvaardersplassen (ICMO2), Wing rapport 039 (The Hague: Wageningen UR, 2010).

	Startup phase	Active breeding phase	Passive breeding phase	Natural breeding and natural selection
Period	2008–2013	2014–2018	2018–2025	After 2025
Nature Reserve	Small	Small	Medium	Large
Animal status	Domestic	Domestic/Feral	Feral	Wild
Breeding strategy	Active natural breeding Artificial insemination Embryo transplantation Mild selection	Active natural breeding Less artificial insemination Less embryo transplantation Selection	Natural breeding Strong selection	Natural selection
Human action	Strongly hands-on	Hands-on/Guidelines	Guidelines	Hands-off

Figure 42. "Phases of the Tauros Programme" from Rewilding Europe website.[83]

In the wake of OVP, Stitching Taurus works to set itself apart from the public relations fiasco, and emphasizes the differences in their methods, and in particular, their animals. Stitching Taurus has been working since 2009 to create its "aurochs 2.0" Tauros breed. They have

[83] From rewildingeurope.com/rewilding-in-action/wildlife-comeback/tauros/. Accessed on April 22 2023. Also in Stitching Taurus' print book, Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs.* They have been enlarged and split in two for visibility here.

centered the animal as their north star. Since they are not using the Heck cattle, they are instead crafting their own breed, what they call the "Tauros breed" – something "fit for purpose," using the aurochs as their guide. The aurochs, then, is the blueprint for their desired product, and, once it can propagate on its own and improve its fit in the wild through natural selection, it will also be its own producer. When I asked Goderie how they will know when they have had success, he pointed me towards the many benefits, from insect diversity to vegetation changes, that can come to the landscape ecology from the project. A huge measure of a successful Tauros Programme, though, is the successful breeding of an aurochs-like animal. So, what, to the Stitching Taurus group constitutes an aurochs? How have they generated their ideal target for their breeding program?

The breeding program itself began with selections that utilized desirable phenotypes and semi-self-sufficient behaviors. Genetics studies of fifty cattle breeds were compared to the genetic data from a single aurochs specimen suggesting that the most important hotspots for "original genetic material" preservation were in Iberia, Poland, Croatia, and Italy. They ranked the top breeds based on their genetic similarity to the aurochs and found several of the breeds they now use were in that list. Other breeds in the top ten may have been genetically close, but were phenotypically small. In balancing the mix desired by their scientific committee, of Iberian breeds and Podolic Italian breeds, with phenotypic traits deemed most important, they set out collecting. They began with breeding Mahamana, Pahuna and Marunese breeds from Portugal. They got, as Goderie said "quite a mix." In 2009, Goderie and his team travelled to Spain, Portugal, Italy, across Southern Europe, meeting with farmers to buy animals. Wherever they went they "were given all the regards." Goderie recalled a stop in their travels when they saw farmers in Málaga, Spain herding the last groups of a local, endangered breed being replaced by beef breeds. The farmers in Spain and elsewhere told the group that they were mad to be breeding anything other than Limousin beef cattle, which reliably produces coveted kilos and beef. However, having travelled from the Netherlands with an interest in their specific animals, and "moreover, with a bag of money with us," changed most minds. Through their collection trip they sought to collect ten individuals, genetically diverse, with more females than males for production. Only one breed escaped their designs, Goderie's "bucket list" Maltese bull.

Everywhere they went, the owners would claim their animals were "direct descendants from the aurochs." Goderie told me "that's good – they're proud of their breeds." Individuals of the Maremmana breed from Italy, another large and tough breed hailed as a direct aurochs descendant, were sent by an Italian professor and inseminated using artificial insemination with Pahuna bull semen. When the first calf was born, the professor announced the birth to the media, bringing the first major news attention to the program.[84]

Due to space constraints, there was no practical way to keep the initial breeds they collected separate as a seed stock; they made an exception for the Maremmana, keeping "pure Maremmana" animals in their own area, because they are quite primitive and there are not many in the world. Aside from their exception to help conserve the Maremmana, the breeds they began with have "blended now into what we all call for practical reasons Tauros," but technically are a mixture of different animals, with first to six generation cross breeds living together.[85] Initially they attempted deliberate crossing and backcrossing, reintegrating an older generation or "pure" animal of a particular breed into their crosses. That did not last long: "sooner or later we had to

[84] Goderie noted that this was when the first bit of confusion about their program started circulating. While they use "old fashioned breeding techniques," their use of ancient DNA as an informative breeding guide was misconstrued as something akin to the Mammoth cloning research that embodies de-extinction work. "They had the idea that we were doing kind of Jurassic farm," which was not the case, as Goderie explained.
[85] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

give up control in different areas; it's one thing to have quite a nice scheme on paper, but the bull doesn't want to get catched [sic]. So he doesn't just produce for one season but he produces three, four seasons."[86] The first bull born in 2010 through a crossing, Manolo, was the product of just such an accident, and yet he was "a perfect example of what we had in mind."

What made Manolo such a successful, if accidental, result? What have been the goals, methods, and measures of success of the program? To begin, the goal of this breeding project comes down to the understood ecological role of the aurochs as a keystone organism. They seek to breed something as close to the aurochs in its ecological functions and self-sustaining wild behaviors, such as fending off predators, in order to rewild landscapes to an *a priori* ideal. In this way, Goderie and his team are less concerned with the technoscientific aims of de-extinction work, the likes of which can be found in George Church, Ben J. Novak, and Beth Shapiro's ancient DNA labs and the popular tizzy over "cloning" mammoths and de-extincting passenger pigeons. As Goderie said "we want to get as close as can be to aurochs, but it's not like we want to make a copy."[87] Breeding the Tauros breed, then, is only an exercise in de-extinction in so far as it values an extinct wilderness, and draws on the lost wild aurochs as a blueprint for bringing back a wild bovine. As Goderie says, it is a very different case than, say, the mammoth, which has truly gone extinct: "cattle hasn't [sic] gone extinct!"[88] The press that Stiching Taurus has received has often labeled their work as "de-extinction"; this misnomer has its function, though. In Goderie's words it helped "give a kickstart – we got a lot of publicity."

When I asked him directly whether that term is appropriate to describe what they are doing, he replied: "others call it de-extinction. It's a matter of definition. If you say de-extinction

[86] *Ibid.*
[87] *Ibid.*
[88] *Ibid.*

is about extinct species, then we're not talking de-extinction. If you're talking de-extinction about extinct wild, wild animals, okay, then we might be talking about de-extinction. Because the wild animal's gone, and we're trying to bring it back."[89] Given the assessment that the species itself is not truly extinct, as "cattle breeds have retained a lot of the original aurochs characteristics," Stitching Taurus publicly asserts that "all cattle today are simply domestic aurochs in different shapes and forms. If we recognise that fact, then the conclusion is inevitable: Although some animals might be more equal than others, the aurochs never really died out. It just simply adapted and changed."[90]

Rather than "cloning" an aurochs, the program centers two priorities to drive its vision: "fit for purpose" and "all good things are wild and free."[91] The first, "fit for purpose," and its addendum "in the Darwinian sense," was repeated several times in our conversation and is central to the Tauros Programme's published book on their work, *The Aurochs: Born to Be Wild.*[92] To Goderie, fit for purpose means "that if you're as close as can be [to the aurochs] this helps."[93] In other words, their goal is to create a breed that is largely wild, self-sustaining, and functioning in the ecological role of a large grazer and the aurochs is, to them, an ideal blueprint. The Chillingham cattle were brought up as an illuminating counterexample by Goderie, highly inbred and strikingly white. As he noted, "the moment you let Darwin do the job, they will disappear." The second idea, "all good things are wild and free," he told me, comes from a Henry David Thoreau quote that he read in the Matt Haig novel *The Midnight Library.* To him, it summarizes what they want to achieve: "we look at the way animals, especially in the highly

[89] *Ibid.*
[90] Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs,* 71, in a chapter called "Extinct, but still kicking!"
[91] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.
[92] Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs*, 123.
[93] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

intensive farming industry are being kept, well that's not good, that's not free, and that's not wild." To truly get to a stage wherein the animals are considered "wild" would necessitate, in Goderie's eyes, legal recognition of their status, as well as their ecological role. They would need unfenced, large areas; ideally tens of thousands of hectares; and they would need predators such as wolves. Space is a constraint currently at the Keent reserve. This past year was a "breakout year" in population size for the herds in the Netherlands, but they don't have enough room for the surplus animals. One solution is Tauros beef: they send the surplus to the butcher, and sell the wild beef in deep frozen packages. Apparently it has a nice, wild taste, even if the animals are still on their way to becoming truly wild.

Figure 43. You can also order Tauros beef from online to be shipped in the Netherlands.[94]

Their blueprint for this rewilding Tauros breed is many layered. As a good modern project, genetics plays a role, but so too do general phenotypic goals, modern artistic renderings, cave paintings, historical descriptions, and videos of Temple Grandin cross-referenced with

[94] Photo by author, November 2022. Stitching Taurus visitor center, Keent, Netherlands.

Caesar. Genetics, however, catches the most media attention, and helped inform the initial breeds they brought in for the program. In close partnership with Wageningen University geneticist Richard Crooijmaans, Stitching Taurus identified which breeds in Europe would let them get "as close as possible" to the aurochs, not just phenotypically, but based on the entire genome. Crooijmaans had already been working on biodiversity and genomics research for traditional cattle, pigs, and chicken breeds.[95] His research had focused on identifying DNA segments that encode for desirable traits in certain breeds, such as resistance to insect transmittable diseases, that could be selected for in commercial animals. The goal of this research is to help commercial animal breeders breed animals that can better meet the instability of changing future environments, because, as Crooijmaans stated clearly "ecosystems are changing, insects are migrating, temperature changes – nothing is stable, and things are going very fast." With the help of a PhD student working on the research to identify resistance-encoding DNA segments, Crooijmaans and his team aid animals with the challenge of adapting "very fast." This technical expertise and experience made him a desirable addition to the ambitions of Stitching Taurus, who themselves were seeking to breed an animal with a particular resilience and impact on the ecosystem not seen since the true aurochs had gone extinct.

In order to make genetic comparisons between living breeds and the aurochs, genetic sequencing of the extinct animal was needed. While its first breedings were done without aurochs genomic information, Stitching Taurus turned its attention to a series of attempts to provide a genomic picture of the aurochs and cattle evolution. With advances in ancient DNA (aDNA), researchers at Trinity College, Dublin first attempted to sequence aurochs skeletal material from museums across Europe in 2001, to be compared with 30 living European cattle

[95] Interview with Richard Crooijmaans by author, Wageningen University, Netherlands, November 11 2022.

breeds deemed "primitive."[96] Genetic variation at 770,000 sites (or SNPs) was measured across the samples, yielding information on the existing breeds and enabling the first genealogical tree construction that made use of mtDNA (mitochrondrial DNA) between the aurochs and the living breeds.[97] mtDNA, inherited through the maternal line and found in the mitochondria of cells, was chosen because it is abundant in a cell and relatively easy to analyze. Significant differences between the mtDNA of the aurochs specimens and the living domesticated taurine breeds were found. Comparison between autosomal DNA of the aurochs and the taurine breeds, found in the nucleus of a cell, was initially impossible, because the DNA extracted from the aurochs bones was too degraded, and unsuitable to genetically analyze. In 2012, the research group of Beth Shapiro, a well-known de-extinction innovator and ancient DNA researcher at the University of California, Santa Cruz attempted to sequence skin from a medieval Polish aurochs specimen, but in that case too, the DNA was too degraded.[98]

The full genetical picture of the aurochs is, for now, still not entirely clear, though much progress has been made. The picture is always undergoing revision. In 2012, David MacHugh at University College, Dublin, granted the Tauros Programme access to his own sequenced aurochs genome. From those results, the Tauros Programme built a broader picture of the genetic pathway to achieving an aurochs-like breed; but, as Crooijmaans is quick to point out, "we will need multiple animals from a breed to see what kind of variation is there."[99] The sequence from MacHugh, published in 2015, was from a single aurochs humerus bone specimen 6,700 years old

[96] Ronald Goderie, Johannes A. Lenstra, Maulik Upadhyay, Richard Crooijmans, and Leo Linnartz, Stitching Taurus "Summary of: Aurochs genetics, a cornerstone of European biodiversity" Report (2015), https://www.rewildingeurope.com/wp-content/uploads/publications/aurochs-genetics-summary/html5/index.html?page=1&noflash, 7.
[97] *Ibid.*
[98] *Ibid.*
[99] Interview with Richard Crooijmaans by author, Wageningen University, Netherlands November 11 2022.

found in 1998 in Derbyshire, England.[100] In 2010, the specimen underwent a complete mtDNA sequence; those results, combined with Y-chromosome studies of aurochs specimens provided an informative, though highly limited picture of the evolutionary history of cattle and its relation to the aurochs. Autosomal DNA, by contrast, is derived from the non-sex chromosomes and can offer a picture of evolutionary history that is not limited to a uniparental genetic lineage (ie inherited via the mother, for mitochondria, or through the father for Y-chromosome DNA). In 2015, the whole genome sequenced from that single British humerus specimen was published, providing a fuller genetic picture of aurochs evolution than just the mtDNA or Y-chromosome DNA could alone.[101] Still, the data was from a single individual. This, of course, does not give a full glimpse at the variety and genetic diversity of the millions of animals that "likely roamed for several hundred thousands [sic] years around Europe, Asia, and Northern Africa." Put simply, there is still a lot of information missing.[102] For now, however, the breeding program has moved forward with the roadmap provided by those results, generating a breed of "aurochs 2.0" for a pan-European rewilding initiative by making use of the only available genome to serve a guide: that of a single British individual.

For Crooijmaans, however, additional data that could change our evolutionary understanding is an expected part of genomics research. In 2013, the Tauros Programme reported using the results of those early DNA studies as a guide, suggesting which breeds were most closely genetically aligned to the aurochs. With that information, they continue their breeding

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[100] Park et al., "Genome Sequencing," 234.
[101] *Ibid.*
[102] Ronald Goderie, Johannes A. Lenstra, Maulik Upadhyay, Richard Crooijmans, and Leo Linnartz, Stitching Taurus "Summary of: Aurochs genetics, a cornerstone of European biodiversity" Report (2015), https://www.rewildingeurope.com/wp-content/uploads/publications/aurochs-genetics-summary/html5/index.html?page=1&noflash, 6.

program, making use of Iberian and Podolican breeds.[103] Recently, however, a group of researchers at Dublin, Trinity College drew from archeological specimens in museums to once again construct a clearer picture of aurochs genetical diversity and history. Drawing on drinking horns from the National Museum of Denmark, they took shavings from the inside of the horns to extract mtDNA, including of the horn that was allegedly of the "last aurochs" bull in the Jaktorów forest.[104] Additional, more resolute DNA data will continue to refine the picture of aurochs kinship to domesticated breeds, but already it is clear that the aurochs was not simply a linear progenitor, but rather a constant cross-breeding entity with various domesticated breeds at various times, in various places.[105]

What might retain that British humerus specimen as a helpful guide for the Tauros Programme in the face of such a messy relationship picture, is the fact that its radiocarbon dating to 6700 BP places it comfortably before the Neolithic in Britain, as well as the appearance of domesticated cattle in Britain.[106] This has led some genomics researchers to claim that the specimen can be "confidently assumed to represent a 'pure' sample, free from possible genomic contamination through later cross-breeding with domestic cattle."[107] It serves, therefore, as a temporal token of a truly wild target for programs like that of Goderie and Crooijmaans. Still, Goderie pointed out to me that while they aimed to "get as close as can be to aurochs, it's not

[103] Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs,* 138.
[104] Their findings indicated some domesticated admixture in that famous horn, suggesting that the last aurochs population was mixed with domesticated cattle by the time of their extinction. Maiken Hemme Bro-Jørgensen, Christian Carøe, Filipe G. Vieira, Sofia Nestor, Ann Hallström, Kirstian M. Gregersen, Vivian Etting, M. Thomas P. Gilbert, and Mikkel-Holger S. Sinding, "Ancient DNA analysis of Scandinavian medieval drinking horns and the horn of the last aurochs bull," *Journal of Archaeological Science* 99 (November 2018): 47-54.
[105] M.R. Upadhay, et al, "Genetic origin, admixture and population history of aurochs (*Bos primigenius)* and primitive European cattle," *Heredity* 118 (2017): 169-76.
[106] Park et al., "Genome Sequencing," 2.
[107] Sinding ad Gilbert, "The Draft Genome."

like we want to make a copy." This is in part because at a population level it is still unclear what the variation was like: "we've got now maybe like ten animal samples, it's still a very very tiny fraction of probably the millions of animals that must have herded, roamed around Europe and Asia and Northern Africa."[108]

What, then, provides the guide for their Tauros breed work? As Goderie said several times in our conversation, "animals should be fit for purpose. We think fit for purpose means that if you're as close as can be [to the aurochs] this helps." The aurochs, then, whether genetically, behaviorally, anecdotally, phenotypically, or ecologically, forms their proven guide of a large grazer that is "fit for purpose." With genetics offering constant revision to which breeds they use in their program, they stabilize the aims of their work through a by now familiar medley of evidence to inform their breeding goals and mate pairing selections. Cave paintings inform form and coloring; artist renderings based on skeletons such as those in Lund and Jena inform physique; behavioral observations of other feral cattle breeds set ethological expectations; historical written records inform and complicate the picture of form, function, and behavior; ecological goals for large ungulate grazers are derived from ecology and paleoecology; and finally, new genetics data continually challenges their previous breeding pairings, while also offering hope of a way to identify and mark anything that domestication has touched in order to expedite selection away from domesticated and towards "fit for purpose."

Stitching Taurus follows the aurochs model very closely, and where disagreement abounds (for example a genetically-close breed not resembling its recorded phenotype closely enough), the program might take the historical path. Goderie pointed me towards an image in Stitching Taurus's book *The Aurochs: Born to be Wild* when I asked what their phenotypic goals

[108] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

were. Size was the first trait he pointed out, 180cm tall for a bull, athletic; next, a large, long head and big horns (the image in the book forced a smaller horn depiction because the page was too short to accommodate the full spread of an aurochs' horns, he told me); then pronounced muscles forming a hump to hold that large head up. The paintings of Lascaux were, he thinks, "quite accurate." They even displayed what might be sexual dimorphic coloration of the coat, with reddish cows and smaller horns. Otherwise, one might expect the mature bulls to boast dark coats with a white "eel stripe" running down the spine. The coat color is a lower priority than phenotypic traits that allow the animals to defend themselves, such as size and horn shape. Still, they can be a measure of some success. When breeding for defensive traits, "you get the coat for free – the wild phenotype is quite easily dominant."[109]

Lascaux was one source in their efforts; but then, as he told me, "we have genetics, and of course all the historical material from Julius Caesar," as well as "later medieval sources, written sources, Polish guys [presumably referring to the nineteenth-century reconstructions of Schneeberger and Herberstein, discussed in Chapter 2]." To make use of those sources, Stitching Taurus worked closely with Cis Van Vuure's extensive research; he himself is on the scientific committee for the group. As Caesar, Herberstein, and other sources about the aurochs sometimes disagree about the animals' temperament, Goderie brings in Temple Grandin: in a film about her work on YouTube, Goderie told me, you can see her enter a cattle corral with dozens of young bulls, lie down, and nothing happens. Schneeberger had described a similar tendency in the

[109] To demonstrate this, Goderie relayed a story about his "bucket list" bull, the Maltese. The region considers them as part of their heritage and would not sell to Stitching Taurus; however, in the 1990s a movie was filming that needed animals, and they discovered they only had cows of the breed. No bulls remained. They began backbreeding with the breed to create a stock they could use for the film, using the completely white Chianina, the largest Italian breed. By the third generation, not much white was visible at all. The story is quite reminiscent of the Chillingham cattle experiments and interpretations.

aurochs, in that they may ignore you until you keep provoking them, but laying flat on the ground, they will leave you be.[110]

Stitching Taurus readily draws on quite varied records, bringing them into conversation with each other and ultimately choosing the elements that might best suit their image of what the aurochs was and what the “aurochs 2.0” should be. A more aurochs-appropriate method could hardly be imagined. Through this method, the group seeks to achieve some measure of success in the next few years. Their official timeline, shown above, has already passed them by, however. Based on the description of their breeding efforts, including selecting animals to inform DNA research into their biomarkers to mate the best animals, they are still in a somewhat hands-on phase for breeding. Still, Goderie, Crooijmaans and their team readily offered me numerous examples of observed behaviors, social structures, and traits that exemplified the kind of “wildness” they hope to see from their keystone rewilding bovines. In one particularly interesting site, the Lika Plains in Croatia, the Tauros herds had accidentally gotten free from the confined areas and are naturally breeding already. Goderie noted that the situation there is “beyond control,” which in some ways makes it the only case that is actually ahead of schedule. The animals are evidently developing behaviors to defend themselves from wolves, to survive harsh winters, and are breeding freely on their own. As with the OVP, the timescale of the project is multiple: ecological restoration can be expected to take some time, but breeding practices are aiming to expedite what they can.

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[110] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

FUZZY TEMPORALITIES

The Tauros herds, though not true aurochs, are nonetheless just as temporally loaded as their ancestors. The case of Stitching Taurus and Rewilding Europe is evocative for the discussions about temporality and human involvement in nature raised by the OVP episode. In the discussion that follows, the case study of the Tauros Programme will be put into conversation with the broader ecological discourse around time in the Anthropocene: rhythms and rates, proxies, and shifting baselines. Doing so demonstrates the fascinating temporal tensions within contemporary rewilding practices, and also how uniquely the aurochs is positioned to draw those out and meet them.

The environmental reconstructions involved in rewilding work are the products of many temporal layers – those that have been traced in this thesis. The evidence used in the case of Stitching Taurus is quite holistic, seeking references to guide their Tauros herd creation from the paleontological, archaeological, genetic and genomic, artistic, behavioral, and ecological. In many ways, then, these projects form a microcosm of the instability of the multi-scalar and multi-directional temporalities seen in this dissertation.

There are several key temporal tensions within rewilding in general, and seen in this case study of the Stitching Taurus back-breeding work. Tensions seems the most fitting word here, as these temporalities are not illogical, mutually destructive, or congenial. They, either conceptually or practically, exist in relation to one another in ways that are not quite settled, demanding further scrutiny and suggesting their promise as sites for even more scholarly attention. The first, are the tensions between what are seen as natural timelines, rhythms or rates involved in the life cycles and generative reproduction of the animals, and the desire for an expedited breeding process to make the herds usable within a couple decades. I'll call this temporal tension the breeding rewilding "rates." The tension of rates echoes not only discourse going back to Darwin and Wallace about the rapidity of results in purposeful artificial selection compared to natural selection, but is also evocative of the philosophical discourse around time in the Anthropocene, in which changes in systems long thought to be relatively stable or slow (which is often read as "natural") have been occurring at an alarming pace.

The second tension is the "temporal-proxy" status of the bovines and their fossilized progenitors that closely links specific organisms, taxonomic conspecifics, or morphological parts, to specific environments in the past, present, and future. Using the aurochs as a proxy to stand in for a specific period in the past was explored in previous chapters. Here, the aurochs has become a proxy for specific ecosystems, or keystone functions within ecosystems.

The third tension is the question of to when in the past rewilders want to rewild – the answer across the board is inconsistent, and indeed even within the same school of thought shifts occur over generations. The general phenomenon of changing temporal targets has been referred to as a "shifting baseline" for rewilding and conservation of nature. This shifting baseline is a persistent thorn in rewilders' sides, as critics tout the changing benchmarks for rewilding success as evidence of its unclear goals. By bringing together details from the case study of the Tauros breed as well as the current rewilding discursive fruits that have implicitly or explicitly considered these temporal tensions, we can provide a fuller appraisal of the fuzzy temporal picture inherent in rewilding projects focusing on the aurochs or other such organisms. That fuzzy temporality, it will be shown, is perhaps not something to avoid, but something that renders the aurochs an ideal focus for ecologists with an eye to a shifting past.

1) Breeding Rewilding Rates

The goal of the Tauros Programme is in large measure to meet a level of rewilding success within a particular timeline. As the OVP experiment showed, however, the measures of success articulated on the scale of decades by funders, managers, and publicity for such projects are often much too short to demonstrate observable changes in an ecosystem. Nature, as Darwin argued in 1859, just operates on a much larger time scale than do humans and their interventions and observations. Of course, humans can and have expedited nature in its changes – again, artificial selection, as Darwin demonstrated, can achieve drastic results in a much shorter time than might evolution by natural selection.[111] To expedite programs like the Tauros Programme, selection is utilized, as are breeding strategies such as artificial insemination. These practices benefit from their measurable success in the agricultural industries.

Breeding cattle for their product outputs including beef and dairy had what Chris Otter summarizes as "evolutionary consequences."[112] Before the growing interest in breed maintenance and the development of the livestock industry in the eighteenth and nineteenth centuries, domestication itself had already resulted in measurable changes to the animal's form and biological processes. Some were perhaps unintentional products of "domestication syndrome," which had been studied by biologists Dmitri Belyaev and Lyudmila Trut in foxes in the USSR.[113] Through domestication syndrome, selections for docility and other desirable domesticated behavioral traits would be linked to formal transformations, including droopy ears and white coat. Animal sizes decreased during domestication processes, evidenced in cattle by

[111] Darwin, *Origin*.
[112] Otter, *Diet,* 31.
[113] Lee Alan Dugatkin and Lyudmila Trut, *How to Tame a Fox (and Build a Dog): Visionary Scientists and a Siberian Tale of Jump-Started Evolution* (Chicago: University of Chicago Press, 2017).

the decrease in bone size of those found in archaeological sites.[114] Reproductive timing, including time to reproductive maturity, seasonal breeding cues, and time between pregnancies have all altered as a result of domestication as well. Still, with the application of statistical genetics to the agricultural industry in the early twentieth century, and its increased power through computers in the mid-twentieth, the "evolutionary consequences" have only grown. As Otter says, "individual animals had their shapes manipulated, their flesh restructured, their biology altered, and their life spans telescoped," in the early twentieth century.[115] Animals were earlier to maturity, and in dairy farming, were impregnated more often to produce milk. And with an increasing technological mediation between livestock and their "natural" biological processes even today, when animals breed has continued to change: former signals for mating based on seasonal changes have been replaced by the rhythms of the market and the need for births in order to produce milk, facilitated by artificial insemination and frozen embryos.[116] Stitching Taurus uses several of those same processes for the early phases of their breeding work.

When I arrived as Stitching Taurus, Goderie had a small, sealed plastic bag that was to be delivered to geneticist Crooijmaans. The bag contained hair samples and ear punches from a Tauros animal who fit the only criteria Crooijmaans had asked: the "the most beautiful" Tauros bull, which at the time represented the population. When I saw the same bag at Crooijmaan's lab in Wageningen a few days later, he informed me that with it, they will conduct molecular

[114] Gabriela F. Mastromonaco and Antolio L. Gonzalez-Grajales, "Reproduction in female wild cattle: Influence of seasonality on ARTS," *Theriogenology* 150 (2020): 396-404.
[115] Otter, *Diet*, 31. For more on the effects of domestication on cattle behavior, see Rebecca Doyle and John Moran, Chapter 3 "The implications of Cattle domestication," in *Cow Talk: Understanding Dairy Cow Behavior to Improve their Welfare on Asian Farms* (Clayton, Australia: CSIRO Publishing, 2015).
[116] *Technology and Culture* is publishing a forthcoming special issue covering this topic, led by historian Tamar Novick. See also Otter, *Diet,* 34.

analysis to confirm the parents of the animal, and to create a reference for the Tauros breed.[117] One of the goals of the analysis is to map the genome, locating segments of the DNA that encode for horn formation, coloring, and more desirable phenotypic traits. With that biomarker, the group can screen offspring early, to determine before it develops full horns or mature coat color whether or not it will fit the desired type. "So then," as Crooijmaans said, "you can speed things up."[118] For now, however, the biomarkers are still being determined, so behavior, performance, and traits developed in maturity are still used as the selection criteria for the breeding animals. In time, however, Crooijmaans hopes they will have a better sense of the biomarkers for desired traits, though through the domestication process, he suspects the changing genome of the animals has left some traits lost.[119] The group also used artificial insemination, because again, as Crooijmaans said, with it you can "speed things up," but the ultimate goal is still to complete the project with "natural breeding," but that takes many more generations to see results.

That the same breeding strategies seen in agriculture – namely, artificial insemination and selection based on blood work taken early in a calf's life – are being deployed in the Tauros Programme is no surprise. The project seeks to create a breed that is returned to its natural temporalities and behaviors, but it makes use of domesticated breeds, and has partnered with Crooijmaans, a geneticist who worked on agricultural variation studies, based at an esteemed and

[117] Interview with Richard Crooijmaans by author, Wageningen University, Netherlands November 11 2022.
[118] In his words: "And how do you know if you have a calf? Only one year? If the calf is there? Do you know if it has big horns or not? Or doesn't have the right color? If you have the wrong color? Then you say, Oh, that's not the one which I need to go for continuing? Then you have to make the same cross again, and hopefully 50% chance if you have the right things coming in. So that takes time. you also want to have phenotypes in early stage, what kind of prediction we'll be, of course you have phenotypes. Ah yeah the coloring and the horns you don't know, right, so if you have other phenotypes, again, hey, this is quite interesting. Maybe this animal will grow and grow up and will have bigger horns, if you can have these phenotypes already. You can't select if you don't have any molecular markers yet."
[119] Methylation, however, might be one path forward.

influential agricultural university, Wageningen.[120] The efficiency of those modern technology-mediated means of reproduction is unavoidable: even when seeking to return cattle to a "wild" state, the project seeks to expedite that process through intimate interventions that are mainstay in agricultural practice.

The tensions within expediting a natural breeding process are evident in the case of the Tauros breed, and require a consideration of the temporality of animals at the individual and inter-generational level. The reproductive timing of the animals used in the Tauros Programme initially greatly resembled the reproductive timing of its other domesticated counterparts: fast. One of the goals of the rewilding project is to leave the animals ultimately to their own devices, which for reproductive timing, would mean a timeline to reproductive maturity, gestation period, and time between pregnancies that might overall be quite different than reproductive times found in their highly selected industrialized kin.[121] As a shorthand, breeders can colloquially think of it as this: the wilder the animal the slower the reproductive rate. If the goal of this program is to create a wild breed that can sustain itself, that breed will ultimately re-develop its wild reproductive rates – to achieve those within the aims of the program, however, necessitates the use of the expedited breeding rates found in its domesticated counterparts, and accelerating those further using artificial insemination. Beyond this, the program seeks to make informed decisions about which animals will be selected in mating pairs even earlier in the animals' lives using those biomarkers that Crooijmaans and his team are working on developing. The practical consequence of the tensions within this process is evidenced in the Croatia rewilding site. Here, the Tauros herd got loose from their confined space and began breeding on their own, fending

[120] Interview with Richard Crooijmaans by author, Wageningen University, Netherlands, November 11 2022.
[121] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.

themselves off, or not, from wolves, and even demonstrating behaviors that, to the managers' eyes, seemed to be long-lost wild social behaviors. The animals were, in effect, re-wilding themselves, with the help of natural selection. Whether they were fit for purpose enough to do so successfully remains to be seen, as several have fallen prey to wolves. Still, as Goderie told me, this might be the only part of their program that is not only on schedule, but ahead of it.[122]

These differing rates (the accelerated rates of the domesticated and the more protracted of the wild), convey an important thread within environmental discourse. The Tauros herds are not demonstrating natural breeding timing as one might expect (in which getting thinner in winter, and fattening up in Spring trigger elements of their reproductive cycle), in part because of climatic effects with less severe winters, but also, as Goderie told me, because of the lasting impact of the OVP fiasco on public sentiment that keeps the program from letting the animals grow thin in the winter.[123] Their wild status is therefore stuck in limbo, which is creating a standstill for the program's aims of a fully naturalized population whose reproduction is self-sustained along expected natural rhythms and is otherwise self-sufficient.

2) Temporal Proxies

The aurochs and its drove of domesticated and de-domesticated descendants have functioned as proxies for different times in the past in both cultural and scientific spaces. Its two most prevalent proxy roles in contemporary science come in very different forms: disarticulated parts used to retrodict past environments, and the whole organism functioning as a proxy for a past process that can bring back a past ecosystem. In both of these, the link of the aurochs to its

[122] *Ibid.*
[123] *Ibid.*

environment is taken to be so tight that its very presence can help reconstruct its former environment, while its fossils are increasingly revealing of past environments.

While customs of casting the knucklebones of cows to predict the future had been a favored practice of oracles across cultures, contemporary paleoecologists and scientists under the name "ecomorphologists" use cow bones for their retrodictive powers – that is, predicting what the past was like in cases in which it is underdetermined. Functional morphologists in the nineteenth century used similar correlative powers, in which living organisms and their behaviors, biological functions, and relation to their environs would stand in as suitable proxies for reconstructing the form, behaviors, functions, and environs of their fossilized kin. Cuvier made this practice the basis of modern paleontology and showed how present organisms could provide insights into those confined to the past. Within this process of ecological extrapolation to the past, however, some assumptions existed – it expected nature to exist perfectly in balance, rather than a messy evolutionary process of achieving moments in which form and function seemed designed, or at the very least recognizably resembled modern equivalents. Inherent in the inference leaps from present to past was a lack of consideration of different forms adapted to the same environment and convergence in evolution; thorny issues that continually demand the attention of scientists and philosophers of evolution. In general, this view of evolution left little room for the process, as it was upon the evolutionary results that reconstructions were built.

The modern analogue of this older intellectual endeavor can be found in the recent field of ecomorphology. In ecomorphology, the aurochs and its fossilized bovine brethren have become model cases for 'retrodicting' – or predicting backwards – past environments. Researchers use data sets of bovid toe bones and astragali of ruminants (those 'knucklebones' bones that were often used in divination) to test what degree of fidelity there is between the characteristics of toe and limb joints – which engage closely with an animal's environment – and its habitat. From there, when a fossil astragalus is unearthed, they can retrodict the substrate and environment of the animal. Beginning with David DeGusta and Elisabeth Vrba in 2005, the bovid postcranial skeleton became, in essence, a model species for much ecomorphological work.[124]

The link between the aurochs and its environment transcends even this retrodictive power; indeed, as the rewilding case shows, it is now also valued as a means to bring back entire ecosystems. The animal stands in as a temporal and ecological proxy through its role as a large grazer. As seen in Vera's work, and the continuing efforts of Stitching Taurus, the contemporary breed-back herds are taxon-proxies or conspecifics for the aurochs, which itself is now understood as a keystone species in a postglacial ecosystem. The current value of the "aurochs 2.0" to programs like Rewilding Europe, is as a proxy of the aurochs in its own ecosystem – a large grazer that can maintain a mosaic landscape with natural biodiversity levels believed to have been present in the Holocene. This expectation is derived from the ecological concept of the keystone element of an ecosystem: that species, or other biological unit, that performs a critical function for maintaining the ecosystem and its diversity.[125]

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[124] David DeGusta and Elisabeth Vrba, "Methods for Inferring Paleohabitats from Discrete Traits of the Bovid Postcranial Skeleton," *Journal of Archeological Science* 32 (2005): 1115-1123 and David DeGusta and Elisabeth Vrba, "Methods for Inferring Paleohabitats from the Functional Morphology of Bovid Phalanges," *Journal of Archeological* Science 32 (2005): 1099-1113. See also Plummer "Habitat preference of extant African bovids based on astragalus morphology: operationalizing ecomorphology for paleoenvironmental reconstruction," 2008; Barr, "Functional morphology of the bovid astragalus in relation to habitat: controlling phylogenetic signal in ecomorphology," 2014.

[125] For more on how the "keystone" perspective is operating in rewilding see Vera, "Large-scale." C. Josh Donlan, et al., "Pleistocene Rewilding: An Optimistic Agenda for Twenty-First Century Conservation," *The American Naturalist* 168, no. 5 (November 2006): 660-81. See also *Goderie, Helmer, Kerkdijk-Otten, and Widstrand, The Aurochs* for an account of how the "aurochs 2.0" might fulfill the duties of a good keystone organism.

Vera's work advocated for a more active view of ecological agents such as the aurochs – the aurochs itself was seen to impact the landscape and ecosystem, driving the changes of its own environment.[126] For historical sciences, the possibility of keystone species and niche construction complicates the conclusions that could be drawn from consideration of just the animal. The broader ecosystem and its keystone species both could impact each other to the point of mutually constituting each other. The result is a picture of systems in change and frequent instability. That potential for mutual influence and change is exactly what Vera was counting on for the OVP rewilding experiment: the Heck cattle and Konik ponies would, when in a wilded environment, reattain their wilder attributes, and over time come to shape their landscape into a pre-cultivation European nature. In turn, the keystone large grazers would continue to rewild themselves.

3) Shifting Baselines

One of the most prevalent complaints about the rewilding experiments is exactly to what or when they are rewilding is unclear. The complaint reveals a fundamental philosophical conceit that has emerged from several separate discourses: history of science, philosophy of biology, sociology, and materialist philosophy.[127] The conceit is that fixed entities, or perceived termima, or any sense of an optimal solution is untenable when nonlinearity is present in a system. If feedback can be found in a system, for example, niche construction or cultural reappraisal of scientific objects, nonlinearity is present. Non-linearity, then, signifies the lack of a fixed or

[126] Niche construction is a popular offshoot of these ideas. For a summary of the idea see F. John Odling-Smee, Kevin Laland, and Marcus Feldman, *Niche Construction: The Neglected Process in Evolution*, (Princeton: Princeton University Press, 2003); Kevin Laland, Blake Matthews, and Marcus W. Feldman, "An Introduction to Niche Construction Theory," *Evolutionary Ecology* 30(2016): 191-202.
[127] For example, Latour, "Textbook Case," and Manuel De Landa, *A Thousand Years of Nonlinear History* (New York: Zone Books, 1997).

stable entity.[128] In the case of rewilding using aurochs-like herds, several instabilities can be found. Epistemologically, the target picture of the aurochs is changing with better genomic data, and our knowledge about what constitutes a natural, desirable landscape changes too. Materially, the animals themselves are evolving, constantly in response to their own biology, their ecosystems, and as part of their ecosystems, the aims of their human managers. Equilibrium is hard to envision here, and the idea of "fit for purpose" only just covers up these interesting instabilities still at work.[129] In the face of an incredibly unstable climate system, the desired landscape of rewilders seeking to generate a steady-state is itself in flux.

Here the lack of stability is dubbed "Shifting Baseline Syndrome" in which, in the absence of a fixed and agreed upon past 'wild' to rewild to, I argue some have chosen organisms that themselves can be shorthand over time for a whole host of motivations and goals.[130] Rather than picking a very specific moment of the past (pre-industrialized? pre-human? post-glacial?), the baseline of the desired natural landscape shifts, and the targets become biotechnologies to help the process of wilding a landscape, rather than achieving a specific wild landscape itself. Those living biotechnologies, such as the Tauros, contain within them all the heritage and natural attributes that will enable a wilding process. In this way, the Tauros breed can be described as a "macro-biotechnology," to borrow from Edmund Russell's helpful prompt.[131] Its "macro" status stems from its technological functions operating at the scale and process-level of an individual

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[128] De Landa, *Thousand Years,* 13-14.
[129] The public expectation for a natural equilibrium of grazing populations was detrimental, Theunissen argued, to the OVP experiment, and not in line with the nuances of ecological and biological thought. Theunissen, "OVP."
[130] The concept under the term "shifting baseline syndrome" is credited to Daniel Pauly, a marine biologist, in 1995. Daniel Pauly, "Anecdotes and the Shifting Baseline Syndrome," *Trends in Ecology and Environment* 10 (1995).
[131] Russell, "Garden in the Machine," 6-11 on his full range of suggestions for those studying evolutionary history.

animal, including digesting, fending off predators, and perpetuating itself. The animal is both producer and product for the process of rewilding, impacting its external timescales (the ecological changes rewilders hope to see) through its own internal timescales (those biological functions from digestion to reproduction).[132]

Figure 44. Image depicting the impact of the "keystone" aurochs, from Stitching Taurus's book, *The Aurochs: Born to Be Wild.*[133]

The term "Shifting Baseline Syndrome" has a more pervasive meaning beyond rewilding. It has been credited to Daniel Pauly, a marine biologist, in a 1995 paper, and is said to arise when

[132] Schrepfer and Scranton, *Industrializing Animals*; and Luis A. Campos, Michael R. Dietrich, Tiago Saraiva, and Christian C. Young, eds., *Nature Remade: Engineering Life, Envisioning Worlds* (Chicago: University of Chicago Press, 2021).

[133] Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs,* 23. Image caption in book: "Herds of aurochs had a great impact on the vegetation, and in turn on other wildlife as well." Image by Jeroen Helmer/ARK Nature.

"each new generation does not know what nature may have looked like before mankind started to cultivate; the cultivated landscape and the wildlife within it changes almost imperceptibly for each generation; each new generation defines what is 'natural' according to its own experience of the (changed) cultural landscape it has encountered, and uses this as a baseline against which to measure changes in the environment. …"[134] In this colloquial sense, shifting baseline syndrome refers to the acceptance of a new standard for the environment based upon imperceptible changes, and each new generation only knowing its own version of nature. Over time, the result of what "nature" should look like becomes drastically different. Adding to this natural falling off in the expectations for nature, is the changing scientific knowledge of what environments used to be like. The change in historical views on the aurochs' European environment from a closed-canopy forest to a mosaic, park like landscape is a helpful example of this kind of change.[135] The benchmark for a successfully rewilded nature may look quite different to rewilders two generations from now for both reasons: shifts in scientific knowledge, and cultural memory loss of previous standards for nature.

Rewilders today have leaned on the deeper history of the aurochs to make use of the animal to meet competing targets: biodiversity targets and climate targets. Pleistocene rewilders tend to prioritize rectifying past losses by "reinstituting ecological and evolutionary processes that were transformed or eliminated by megafaunal extinctions."[136] They center Pleistocene taxon substitutions for their benchmarks of restoration in nature, "defined not only by the presence or absence of species but also by the presence or absence of species interactions — the

[134] Vera, "Large-scale," 29 for full list.
[135] Vera, "Large-scale," 30. This episode, readers will recall, also demonstrated a fascinating circular reasoning: when they thought Europe was forested, they thought aurochs was a forest animal and therefore had low numbers so as to maintain the forests and not dimmish them in the way grazers were expected too. It also affected whether they considered the aurochs indigenous to Europe.
[136] Donlan, et al., "Pleistocene Rewilding," 662.

true functional fabric of nature."[137] Pleistocene rewilding also has a fringe, in which the ideas of a furry "Jurassic Park" percolate most readily in news coverage: here, cloning mammoths and Sergey Zimov's "Pleistocene Park" in northern Siberia are not science fiction. They are geared towards restoring a steppe ecosystem through keystone Pleistocene animals such as mammoths, revived through de-extinction technologies. Not all rewilders use a generically Pleistocene benchmark, however. In North America, some prioritize pre-Columbian Landfall ecosystems; others aim for a late-Pleistocene arrival of the first Americans.[138] Others consider times prior to extirpations at varying intervals, from thousands of years ago, to those in the nineteenth century as appropriate benchmarks for their work.[139] Advocates of Pleistocene Rewilding have lamented that the history of that period has "largely been ignored as both conservation biologists and the public, seemingly hampered by an implicit post-Columbian bias, struggle with our biodiversity crisis."[140] In their view, making our decisions based upon a "deeper history offers a new vista, one with widespread implications for how humans might perceive and manage nature."[141]

The Holocene – that period of stable climate which followed the on-off ice ages of the Pleistocene, and in which humanity domesticated livestock, grew agricultural crops, and developed its societies – is another favored benchmark. As Deborah Coen and Fredrik Albritton Jonsson have argued, however, the adoption of the Holocene ideal by the new discipline of Earth Systems Science is an exercise in "Holocene nostalgia," which can trace its roots back to nineteenth-century Victorian views in which the Holocene marked a providential new,

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[137] *Ibid.* This concept is credited to Estes 2002.
[138] Paul Robbins and Sarah A. Moore, "Ecological Anxiety Disorder: Diagnosing the Politics of the Anthropocene," *Cultural Geographies* 20, no. 1 (2012): 3-19.
[139] Donlan, et al., "Pleistocene Rewilding," 664 for a list of 'restoration baselines.' Additional breakdowns of the baselines for various rewilding projects can be found in Lorimer, Sandom, Jepson, Doughty, Barua, and Kirby, "Rewilding," and Jørgensen," Rethinking Rewilding."
[140] Donlan et al., "Pleistocene Rewilding," 661.
[141] *Ibid.*

climatically stable geologic period facilitating the beginning of human history, and consequently, its triumphant flourishing.[142] The Holocene and its climate has been touted as creating a "safe operating space" for humanity in the past.[143] The goal to some is therefore obvious: return to safety in the face of Anthropocene instability and use the Holocene as a baseline.

The answer to the question of which benchmark or baseline ought we to use for nature protection, restoration, and rewilding changes depending on what image of a secular 'eden' the scientists conjure. These sciences that have a "commitment to evaluating ecological relationships with regard to an a priori baseline," can be considered 'edenic sciences.' The problem can thus be reframed as Paul Robbins and Sarah A. Moore do into this simple formulation: what is the 'eden' of these 'edenic sciences.'[144] There is no one single answer. Foregrounding the shifting baselines can perhaps decenter past targets that attract their adherents, and instead draw focus to the interwoven environmental and social processes as we rethink what our planet looks like, and what we want it to.[145]

CONCLUSION: LESSONS FOR A MULTI-SCALAR ECOLOGY APPROACH

The temporal tensions discussed above offer one lens through which to look at the mess of rewilding. Others are pertinent, too, including the trade-offs in land use policies that have geopolitical ramifications. If rewilding occurs in Europe, land use must intensify elsewhere on the globe to meet agricultural demand. The trend so far has been to intensify land use in the

[142] Coen and Albritton Jonsson, "Between History," 412-413.
[143] *Ibid.* They cite Jan Zalaciewicz and Mark Williams for this view.
[144] Robbins and Moore, "Ecological Anxiety," 4.
[145] Coen and Albritton Jonsson suggest that overcoming this 'Holocene nostalgia,' for example, will enable us to break out of the Victorian geology that linked human flourishing to the Holocene and to generate our own ethics for the current climate crisis and how we can meet it. Coen and Albritton Jonsson, "Between History and Earth Systems Science."

global south and tropics.[146] I asked Goderie whether the Indian aurochs would ever be rewilded. He replied that there is no need for that work in India as there is already a wild cattle culture that works well enough, and wilderness there is not as lacking as it is in Europe.[147] This picture is a familiar one in the Anthropocene, where tradeoffs abound, and solutions also beget consequences. Still, a promising development of reckoning with the Anthropocene is the robust language developing to describe existing entanglements. Time and process provide a helpful analytical framework to understand the multiscalar concerns of not just the Anthropocene, but also the entanglements of nature studied in evolutionary biology, as the Extended Evolutionary Synthesis suggests.

As for the Tauros Programme, the tensions exposed by such rewilding practices are not new in kind or degree. Over the past few decades a growing slate of scientific 'anxieties' stemming from observations of biological crises and pushback against calling them crises have been noted. The Anthropocene concept has spurred deeper consideration of the entanglements of these debates. Concern over invasive non-native species, concern over devoid urban ecology, or underappreciation of plentiful urban ecology, human involvement, lack of human involvement, have centered in many of these debates.[148] Bruno Latour, and Paul Robbins and Sarah A. Moore have characterized these concerns as part of a set, though they give their sets different names and different prognoses. From Robbins and Moore, who characterize these ecological concerns as an "Ecological Anxiety Disorder" scholars are encouraged to articulate the stakes and commitments

[146] Kay, "Europeanization through biodiversity conservation"; Collard, "Putting animals back together, taking commodities apart."
[147] Interview with Ronald Goderie by author, Stitching Taurus, Keent, Netherlands, November 9, 2022.
[148] Robbins and Moore, "Ecological Anxiety."

in the ensuing political struggles, and thereby "mobilize[] alliances between various at-risk polities and scientific researchers."[149]

That mobilization necessitates a resolution of the disorder by, according to Emma Marris, Latour, Robbins, and Moore, embracing the ecological entanglements and their Anthropocene consequences, or rather "the monsters created in a world where humans exert strong influence."[150] Marris, for her part, advocates a reconceptualization of wild spaces in the face of these human-nature entanglements, recognizing that preserving nature can no longer be a practice of just setting it aside – there must be engaged facilitation and maintenance of it. What both Latour and Robbins suggest is that there are challenges at the root of several scientific and cultural understandings of nature, wilderness, and human involvement in either. Those challenges, however, are not new. What is new is seeing them as true crises. Bruno Latour writes that this is because we have bought into the myth that science would neatly separate and tame the myth from the fact.[151] Of course, things are more entangled than that, so we should not be surprised by the consequences and ramifications that remind us of those entanglements. As the aurochs shows, science has only ever worked to layer and embed them deeper into problem spaces that are retained holistically, in a rational reflection of nature's own entanglements.

In many ways it is astounding that within rewilding so many scientific perspectives, techniques, methods, and specialties come together. From within rewilding there are interesting problem spaces that reveal themselves, as discoveries and new agendas emerge in ecology, climate change, paleontology, ancient DNA studies, agricultural breeding, cloning, and evo-

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149 *Ibid.,* 5.
150 *Ibid.,* 5. And Bruno Latour, "Love Your Monsters" in *Love Your Monsters: Postenvironmentalism and the Anthropocene,* edited by Michael Shellenberger and Ted Nordhaus (Berkeley, CA: Breakthrough Institute, 2011). Emma Marris, *Rambunctious Garden: Saving Nature in a Post-Wild World* (New York: Bloomsbury, 2011).
151 Latour, "Love Your Monsters."

devo. Their enmeshed plurality of temporalities is perhaps one of the most interesting and possibly quietly innovative elements of this Frankensteinien field of work. But it is by no means the only ways in which rewilding and breeding-back practices are taking a holistic approach to their scientific work; work which has explicitly made porous the boundaries that we imagine between scientific disciplines and cultural crises, and their different temporal postures. Placing their aspirations and methods within specific charismatic organisms, such as the aurochs, retains those entanglements of temporal modes, scientific methods, and cultural priorities. In a way, it allows the rewilders to have actionable agendas, and tangible work with some measurable aims by smuggling into its biotechnology the same conceptual mess it is looking to experiment with, and not necessarily resolve.

Conclusion

Whether the threads of this thesis are applicable elsewhere in the history of science may be a matter of the charisma of the object.[1] The aurochs and its living descendant cattle held a fascination for scientists and the public, which perhaps helped keep them separate from the generalizable methods of study used with organisms like *Drosophila*. Fascination with the aurochs in part emanated from its scattered temporal record, enabling it to factor in broad periodizing attempts, and the most intimate scales of biological temporality such as reversions. As Jacob Wilson concluded in his own 1899 essay:

> It is no small thing to have been written of by the historians of Greece and Rome, to have formed a theme for Scott, a text for Darwin, a subject for Landseer, or to be able to trace the line of one's family in unbroken sequence to the earliest dawn of modern life.[2]

The approaches of recent rewilders are no exception to the list of scientists who have succumbed to the holistic charms of the aurochs. The development of current scientific knowledge on the aurochs, demonstrated most clearly in the Derbyshire specimen genome which opened this dissertation, are indeed impressive. Celebration of the accomplishment of science as it has learned more about the aurochs is warranted. But a remarkable intervention of those scientific pursuits needs recognition as well. They have turned time and again to integration of their records of study, taking as their scope all that a study of the aurochs might encompass. They have, in other words, treated the aurochs as a processual entity, foregrounding its temporality, and demanding that any biography of it does the same.

Stitching Taurus notes in its book, *The Aurochs: Born to Be Wild,* that greater knowledge of the aurochs came with time:

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[1] Lorimer, "Nonhuman Charisma."
[2] Wilson, "Chillingham White Cattle," 28.

> During the first half of the 1900s, things became clearer. Much more bone material and even some complete aurochs skeletons were found. For the first time in three centuries, scientists could now really start to understand what the aurochs had been. Indeed, it turned out that the aurochs had been a formidable animal with large horns, as Caesar had described, but as always when science takes over, the myths disappeared. Aurochs turned into a real wildlife species and basically turned out not to be all that different from the cattle of the time. It was larger in every aspect, but still resembled the cows and bulls in the barns of any farmer in the neighborhood.[3]

True, some of the "myth" of the aurochs has dissipated; for example, its once exclusive status as a linear ancestor to all cattle has been complicated by genomic evidence of its continued interbreeding with its domesticated descendants. But, as this thesis argues, the aurochs is no more static today than it was before, and sometimes science does not simplify, or dissipate all the myth.[4]

Even setting aside the most mythical manifestation of the aurochs story in this thesis – the Nazis' desire to bring it back as an 'Aryan' animal worth populating the *Lebensraum* and performing the masculine ritual of the hunt – the aurochs is today still presented as a special cultural emblem. That same Stitching Taurus book opens with a foreword, contextualizing the importance of the aurochs, "Europe's defining animal," in nature, and in culture:

> The aurochs was an extraordinary animal. Not only was it a keystone species in the natural surroundings where it lived and which it helped to shape, but it also became crucially important for the history of modern mankind. The aurochs turned into man's most valuable animal, the ancestor of all cattle, of every domestic cow and bull in the whole world.
>
> The taming of the aurochs lead [sic] to prosperity, the founding of civilisations, the rise of empires, nations and religions. It meant milk to the children, cheese and yoghurt to the people and draught power for the plough. It meant survival and population growth, wealth and capital.
>
> Europe's first higher civilization, the Minoans, had a bull monster, the Minotaur, at the centre of its cult. In Greek mythology the god Zeus once

[3] Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs,* 80.
[4] Bruno Latour has argued this case before. "It's Development, Stupid!" published as Latour, "Love Your Monsters."

took the shape of a bull, when he swam over from Crete to present day Lebanon and snatched away a beautiful Phoenician princess.

> Her name was Europa.
>
> The aurochs has always been at the very root of the whole idea of a continent called Europe. It is in fact our continent's defining animal.
>
> It was driven to extinction by the actions of man, but could actually also be brought back by the actions of man. We mean that this amazing animal simply deserves not just this book, but also a comeback plan.[5]

Despite scientific scrutiny and genuine accrual of knowledge about objects, myths do not readily subside. In the case of rewilding nature under a sentiment of a continental, or in some cases, planetary environmental concern, more regional geopolitical identities still emerge – something which social sciences and humanities scholars of the Anthropocene have pointed out. The processes and identities forged along the timescale of human history do not dissipate simply because the Anthropocene seeks to capture something about a longer time scale of geological and planetary change.

As this thesis has sought to expose, time itself is a deeply revealing analytical lens. Our external timescales, those demarcations of time we use to measure everything else, have in some cases become naturalized in our thinking over time. But, as history is best poised to do, a narrative of the formation of those various periods, scales, and demarcations in time reveals how they were created, negotiated against one another, or subsumed. The Anthropocene concept has drawn scholarly attention to telling the stories of how we have studied and demarcated our temporality, in order to shed an uncritical assumption of temporality's "natural-ness," and to question what "natural" even means. In this thesis, the geological periods, historical records, comparative histories of societal development, reversions, de-extinctions, and rewilding

[5] Frans Schepers and Ronald Goderie, "Foreword: Europe's Defining Animal," in Goderie, Helmer, Kerkdijk-Otten, and Widstrand, *The Aurochs*.

temporalities engage one another: they do not stand alone, but have to continually be justified by the practioners of the fields that use them. As the narrative in this thesis argues, those temporalities were often brought together in the holistic study of the aurochs by those who formed this defacto “aurochs network.” Through their integrative practice, those interlocutors can be read as time theorists themselves, and offer a case in which holism, interdisciplinarity, and multi-scalar temporalities have been preserved in the study and bodily remaking of a particular entity.

While the foreword from Stitching Taurus above is designed most obviously to garner enthusiasm and support for their work of breeding an aurochs-like breed to the benefit of European rewilding projects, it is also revealing of an approach to the study of this animal that has been quite common since its rediscovery as a fossil in the nineteenth century. The aurochs breeds its own cult of enthusiasm, and retains an expansive array of associations that scientists and amateurs who have studied it incorporate into their own scope of study. Its relation to time, those internal changes and external attempts to measure it, is multifaceted but that helpfully demonstrates how timescales and disciplines integrate when the object of study is interesting enough to court that, and with further study, might provide lessons for the biologists, philosophers, and Anthropocene-minded scholars who seek to navigate rich temporal tensions and differing timescales in their own work. It is, put simply, charismatic.

Bibliography

Adam, Barbara. *Timescapes of Modernity: The Environment and Invisible Hazards*. Global Environmental Change Series. New York: Routledge, 1998.

Albritton Jonsson, Fredrik. *Enlightenment's Frontier: The Scottish Highlands and the Origins of Environmentalism.* New Haven, CT: Yale University Press, 2013.

Allsen, Thomas T. *Royal Hunt in Eurasian History.* Philadelphia, PA: University of Pennsylvania Press, 2006.

Anthony, Patrick. "Making Historicity: Paleontology and the Proximity of the Past in Germany, 1770-1820." *Journal of the History of Ideas* 82, no. 2 (April 2021): 231-56.

Anonymous. "Review of *The Antiquity of Man.' The Times,* April 9, 1863. In "Scientific Pamphlets," Library and Archives, Natural History Museum, London.

Arnold, David. *Science, Technology and Medicine in Colonial India.* Cambridge, UK: Cambridge University Press, 2000.

Artinger, Kai. "Lutz Heck, Der 'Vater er Rominter Ure.' Einige Bemerkungen zum wissenschaftlichen Leiter des Berliner Zoos im Nationalsozialismus." *Der Bär von Berlin: Jahrbuch des Vereins für die Geschichte Berlins* 42 (1994): 125-138.

Auld, R.C. "The Wild Cattle of Great Britain." *The American Naturalist* 22, no. 258 (June 1888): 498-509.

Bagchee, Monie. *The Asiatic Society: A Brief History*. New Dehli: People's Publishing House, 1984.

Baron, Samuel H. "Herberstein and the English "Discovery" of Muscovy." *Terrae Incognitae, XVIII* (1987): 43-54.

Bapteste, Eric, and John Dupré. "Towards a Processual Microbial Ontology." *Biology & Philosophy* 28, no. 2 (March 2013): 379–404. https://doi.org/10.1007/s10539-012-9350-2.

Barrow, Jr., Mark V. *Nature's Ghosts: Confronting Extinction from the Age of Jefferson to the Age of Ecology* Chicago: University of Chicago Press, 2009.

Bashford, Alison, Pratik Chakrabarti, and Jarrod Hore. "Towards a Modern History of Gondwanaland." *Journal of the British Academy* 9s6 (2021): 5–26. https://doi.org/10.5871/jba/009s6.005.

Bawden, Tom. "Nazi super cows: British Farmer Forced to Destroy Half his Murderous Herd of Bio-engineered Heck Cows After They Try to Kill Staff." *The Independent,* January 5, 2015.

Berendse, Frank. “The Netherlands Rewilding experiment, gone haywire.” Interview by Steph Yin. *WHYY,* PBS, August 23, 2019.

Beurton, Peter J., Raphael Falk, and Hans-Jörg Rheinberger, eds. *The Concept of the Gene in Development and Evolution: Historical and Epistemological Perspectives*. Cambridge Studies in Philosophy and Biology. Cambridge, UK: Cambridge University Press, 2000.

Bidwell, E., William Boyd Dawkins, et al. “Report on the Herds of Wild Cattle in Chartley Park, and other Parks in Great Britain.” *Report of the Fifty-Seventh Meeting of the British Association for the Advancement of Science,* 135-45. London: John Murray, 1887.

Blake, C. Carter. “Bos longifrons.” *Geological Magazine* 5, no. 44 (1868): 100-102.

Bojanus, Ludwig Heinrich. *De uro nostrate eiusque sceleto commentatio* Vol 13. Bonn: Verhandlungen der Kaiserlichen Leopoldinisch-Carolinischen Akademie der Naturforscher, 1827.

de Bont, Raf. *Nature’s Diplomats: Science, Internationalism, and Preservation, 1920-1960*. Pittsburgh, PA: University of Pittsburgh Press, 2021.

Bowler, Peter J. *Fossils and Progress: Paleontology and the Idea of Progressive Evolution in the Nineteenth Century*. New York: Science History Publications, 1976.

Bowler, Peter J. *The Invention of Progress: The Victorians and the Past.* Oxford: Basil Blackwell, 1989.

Boyd Dawkins, William. *Cave Hunting: Researches on the Evidence of Caves Respecting the Early Inhabitants of Europe.* London: MacMillan and Co., 1874.

Boyd Dawkins, William. *Early Man in Britain and His Place in the Tertiary Period.* London: MacMillan and Co., 1880.

Boyd Dawkins, William. “On the Classification of the Tertiary Period by Means of the Mammalia.” *Quarterly Journal of the Geological Society of London* 36 (1880).

Boyd Dawkins, William. “On the British fossil oxen. Part II. Bos longifrons, Owen.” *Quarterly Journal of the Geological Society* 23 (1867).

Boyd Dawkins, William. “On the Fossil British Oxen. Part I. *Bos Urus,* Caesar,” *Quarterly Journal of the Geological Society* 22 (1866).

Boyd Dawkins, William and Sidney H. Reynolds. *A Monograph of British Pleistocene Mammalia* Vol 3. London: Palaeontographical Society, 1872.

Brandt, J.F. “On the Geographical and Geological Distribution of the Reindeer, the Bison, and the Aurochs.” *Quarterly Journal of the Geological Society of London* 23 (1867).

Brantlinger, Patrick. *Dark Vanishings: Discourse on the Extinction of Primitive Races, 1800-1930.* Ithaca, NY: Cornell University Press, 2003.

Bro-Jørgensen, Maiken Hemme, Christian Carøe, Filipe G. Vieira, Sofia Nestor, Ann Hallström, Kirstian M. Gregersen, Vivian Etting, M. Thomas P. Gilbert, and Mikkel-Holger S. Sinding. "Ancient DNA analysis of Scandinavian medieval drinking horns and the horn of the last aurochs bull." *Journal of Archaeological Science* 99 (November 2018): 47-54.

Brookfield, J.F.Y. "Evolution: The Evolvability Enigma." *Current Biology* 11, no. 3 (February 2001): R106–8. https://doi.org/10.1016/S0960-9822(01)00041-0.

Brown, George Andrew. *Studies in Stock Breeding.* Melbourne: Walker, May, and Co., 1902.

Browne, Janet. *The Secular Ark: Studies in the History of Biogeography.* New Haven, CT: Yale University Press, 1983.

Bruce, Gary. *Through the Lion Gate: A History of the Berlin Zoo.* Oxford, UK: Oxford University Press, 2017.

Buckland, William. *Reliquiae Diluvianae: Or, Observations on the Organic Remains Contained in Caves, Fissures and Diluvial Gravel, and on Other Geological Phenomena Attesting the Action of an Universal Deluge.* London: John Murray, 1823.

Burkhardt, Richard W. "Closing the Door on Lord Morton's Mare: The Rise and Fall of Telegony." *Studies in History of Biology* 2 (1979).

Burckhardt, Richard W. *Patterns of Behavior: Konrad Lorenz, Niko Tinbergen, and the Founding of Ethology.* Chicago: University of Chicago Press, 2005.

Burnett, Linda Andersson. "Northern Noble Savages?: Edward Daniel Clarke and British Primitivist Narratives on Scotland and Scandinavia, c. 1760-1822." PhD diss., University of Edinburgh, 2012.

Burrow, John W. "Images of Time: From Carlylean Vulcanism to Sedimentary Gradualism." In *History, Religion and Culture: British Intellectual History, 1750-1950,* edited by Stefan Collini, Richard Whatmore, and Brian Young. Cambridge: Cambridge University Press, 2000.

Button, Clare. "James Cossar Ewart and the Origins of the Animal Breeding Research Department in Edinburgh, 1895-1920." *Journal of the History of Biology* 51 (2018): 445-47.

Caesar, Julius. *Commentarii de Bello Gallico.* Translated by Carolyn Hammond. Oxford: Oxford University Press, 1996.

Campbell, Douglas and Patrick Whittle. *Resurrecting Extinct Species: Ethics and Authenticity.* London: Palgrave Macmillan, 2017.

Campos, Luis A., Michael R. Dietrich, Tiago Saraiva, and Christian C. Young, eds. *Nature Remade: Engineering Life, Envisioning Worlds.* Chicago: University of Chicago Press, 2021.

Canales, Jimena. *A Tenth of a Second: A History.* Chicago: University of Chicago Press, 2009.

Carrano, Matthew T., Jeffrey A. Wilson and Paul M. Barrett. "The History of Dinosaur Collecting in Central India, 1828-1947." In *Dinosaurs and Other Extinct Saurians: A Historical Perspective*, edited by R.T.J. Moody, E. Buffetaut, D. Naish and D.M. Martill. London: Geological Society of London, 2010.

Chakrabarti, Pratik. *Inscriptions of Nature: Geology and the Naturalization of Antiquity.* Baltimore: Johns Hopkins University Press, 2020.

Chakrabarty, Dipesh. "The Climate of History, Four Theses." *Critical Inquiry* 35 (2009): 197-222.

Chakrabarty, Dipesh. *Provincializing Europe: Postcolonial Thought and Historical Difference*. Princeton, NJ: Princeton University Press, 2000.

Clendinnen, Inga. *Ambivalent Conquests: Maya and Spaniard in Yucatan, 1517-1570.* Cambridge, UK: Cambridge University Press, 2003.

Coen, Deborah R. and Fredrik Albritton Jonsson. "Between History and Earth System Science." *ISIS* 113, no. 2 (June 2022): 407-416. https://doi.org/10.1086/719648.

Cohen, Claudine. *The Fate of the Mammoth.* Chicago: University of Chicago Press, 2002.
Coleman, William. *Biology in the Nineteenth Century: Problems of Form, Function, and Transformation.* Cambridge, UK: Cambridge University Press, 1977.

Coles, J. "The Herd Reich." *The Sun,* April 22, 2009.

Crutzen, P.J. and E.F. Stoermer. "The Anthropocene." *Global Change Newsletter* 41 (2000): 17-18.

Darbishire, Arthur D. *An Introduction to a Biology: And Other Papers.* New York: Funk and Wagnalls, 1917.

Darwin, Charles. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.* London: John Murray, 1859.

Darwin, Charles. *The Variation of Animals and Plants under Domestication* I. London: John Murray, 1868.

Daston, Lorraine, ed. *Biographies of Scientific Objects*. Chicago: University of Chicago Press, 2000.

Daston, Lorraine. "The History of Science and the History of Knowledge." *KNOW* 1, no. 1 (March 2017): 131-54. https://doi.org/10.1086/691678.

Daston, Lorraine ed., *Things that Talk: Object Lessons from Art and Science*. New York: Zone Books, 2004.

Daszkiewicz, Piotr and Tomasz Samojlik. "Corrected date of the first description of aurochs *Bos primigenius* (Bojanus, 1827) and steppe bison *Bison priscus* (Bojanus, 1827)." *Mammal Research* 64 (2019), 299-300.

De Landa, Manuel. *A Thousand Years of Nonlinear History.* New York: Zone Books, 1997.
Degerbol, Magnus and Bent Fredskild. "The urus (Bos primigenius Bojanus) and neolithic domesticated cattle (Bos taurus domesticus Linné) in Denmark. With a revision of Bos remains from the kitchen middens." *Det kongelige Danske Videnskabernes Selskab, Biologiske Skrifter* 17(1): 1-234.

DeGusta, David and Elisabeth Vrba. "Methods for Inferring Paleohabitats from Discrete Traits of the Bovid Postcranial Skeleton." *Journal of Archeological Science* 32 (2005): 1115-1123.

DeGusta, David and Elisabeth Vrba. "Methods for Inferring Paleohabitats from the Functional Morphology of Bovid Phalanges." *Journal of Archeological* Science 32 (2005): 1099-1113.

Derry, Margaret. *Bred for Perfection: Shorthorn Cattle, Collies, and Arabian Horses Since 1800*. Baltimore: Johns Hopkins University Press, 2003.

Derry, Margaret. *Made to Order: The Designing of Animals.* Toronto: University of Toronto Press, 2022.

Derry, Margaret. *Masterminding Nature: The Breeding of Animals, 1750-2010.* Toronto: University of Toronto Press, 2015.

Deichmann, Ute. *Biologists Under Hitler.* Translated by Thomas Dunlap. Cambridge, MA: Harvard University Press, 1996.

Dollo, Louis. "Les lois de l'évolution." *Bulletin de la soc. Belge de Géol.* 7 (1893).

Donlan, C. Josh, et al. "Pleistocene Rewilding: An Optimistic Agenda for Twenty-First Century Conservation." *The American Naturalist* 168, no. 5 (November 2006): 660-81.

Douglas, George (Earl of Morton). "A communication of a singular fact in natural history." *Philosophical Transactions of the Royal Society* (1821).

Doyle Rebecca, and John Moran. *Cow Talk: Understanding Dairy Cow Behavior to Improve their Welfare on Asian Farms.* Clayton, Australia: CSIRO Publishing, 2015.

Dresow, Max. “Measuring Time with Fossils: A Start-Up Problem in Scientific Practice.” *Philosophy of Science* 88, no. 5 (December 2021): 940–50. https://doi.org/10.1086/714855.

Dresow, Max. “Time, Life and Environment: Practices of Geohistory at the Intersection of the Earth and Life Sciences.” PhD diss., University of Minnesota, 2021.

Driessen, Clemens and Jamie Lorimer. “Back Breeding the Aurochs: The Heck Brothers, National Socialism, and Imagined Geographies for Non-Human Lebensraum.” In *Hitler’s Geographies: The Spatialities of the Third Reich,* edited by Paolo Giaccaria and Claudio Minca, 138-157. Chicago: University of Chicago Press, 2016.

Dugatkin, Lee Alan and Lyudmila Trut. *How to Tame a Fox (and Build a Dog): Visionary Scientists and a Siberian Tale of Jump-Started Evolution.* Chicago: University of Chicago Press, 2017.

Dunlop, Andrew. “On Raised Beaches and Rolled Stones at High Levels in Jersey.” *Quarterly Journal of the Geological Society* 49 (1893): 523-530.

Emerson, Ralph Waldo. “History.” In *The Essential Writings of Ralph Waldo Emerson,* edited Brooks Atkinson, 113-131. New York: Modern Library, 2000.

Ewart, James Cossar. “Experimental Contributions to the Theory of Heredity.” *Trans. High. Agr. Soc. Scot.* 14 (1902): 243-251.

Ewart, James Cossar. *The Penycuik Experiments.* London: Adam and Charles Black, 1899.
Falconer, Hugh. *Descriptive Catalogue of the Fossil Remains of Vertebrata: From the Sewalik Hills, the Nerbudda, Perim Island, &c. In the Museum of the Asiatic Society of Bengal.* CB Lewis, Baptist Mission Press, 1859.

Falconer, Hugh and Proby Cautley. “Prospectus for publication, under the auspices of Her Majesty’s government, and of the Honourable the Court of Directors of the East India Company: A Work to be Entitled, Fauna Antiqua Sivalensis.” *Journal of the Asiatic Society of Bengal* XIV (1845).

Felius, Marleen, Peter A. Koolmees, Bert Theunissen, European Cattle Genetic Diversity Consortium, and Johannes A. Lenstra. "On the Breeds of Cattle—Historic and Current Classifications." *Diversity* 3, no. 4 (2011): 660-692. https://doi.org/10.3390/d3040660.

Forbes, A.C. “On the regeneration and formation of woods from seed naturally or artificially sown.” *Transactions of the English Arbori-cultural Society* 5 (1902): 239-70.

Fream, William and James Richard Ainsworth Davis. *Elements of Agriculture: A Text-Book,* 6th ed. London: John Murray, 1897.

Fuller, Errol. *Lost Animals: Extinction and the Photographic Record.* London: Bloomsbury Publishing, 2013.

Futuyma, Douglas J. “Evolutionary Biology Today and the Call for an Extended Synthesis.” *Interface Focus* 7, no. 5 (October 6, 2017): 20160145. https://doi.org/10.1098/rsfs.2016.0145.

Gayon, Jean. “Natural Selection, Regression, and Heredity in Darwinism and Post-Darwinian Evolutionary Theory.” In *Heredity Explored: Between Public Domain and Experimental Science, 1850-1930,* edited by Staffan Müller-Wille and Christina Brandt. Cambridge, MA: MIT Press, 2016

Geikie, James. *The Great Ice Age and its Relation to the Antiquity of Man.* London: W. Isbister, 1874.

Gentry, Anthea, Juliet Clutton-Brock, and Colin P Groves. “The Naming of Wild Animal Species and Their Domestic Derivatives.” *Journal of Archaeological Science* 31, no. 5 (May 2004): 645–51. https://doi.org/10.1016/j.jas.2003.10.006.

Ginzburg, Carlo. *Clues, Myth, and the Historical Method*. Translated by John and Anne C. Tedeschi. Baltimore: Johns Hopkins University Press, 2013.

Goderie, Ronald, Wouter Helmer, Henri Kerkdijk-Otten and Staffan Widstrand. *The Aurochs: Born to be Wild: The Comeback of a European Icon*. Zutphen, Netherlands: Roodbont, 2013.

Goderie, Ronald, Johannes A. Lenstra, Maulik Upadhyay, Richard Crooijmans, and Leo Linnartz. Stitching Taurus “Summary of: Aurochs genetics, a cornerstone of European biodiversity” Report (2015). https://www.rewildingeurope.com/wp-content/uploads/publications/aurochs-genetics-summary/html5/index.html?page=1&noflash.

Gould, Stephen Jay. “Dollo on Dollo’s law: Irreversibility and the Status of Evolutionary Laws.” *Journal of the History of Biology* 3:2 (1970): 189-212.

Gould, Stephen Jay. *An Urchin in the Storm: Essays about Books and Ideas*. 1st ed. New York: W.W. Norton, 1987.

Gould, Stephen Jay. *Time’s Arrow, Time’s Cycle: Myth and Metaphor in the Discovery of Geological Time*. The Jerusalem-Harvard Lectures. Cambridge, Mass: Harvard University Press, 1987

Greenaway, Frank. *Science International. A History of the International Council of Scientific Unions*. Cambridge, Cambridge University Press, 1996.

Gross, Matthias. *Inventing Nature: Ecological Restoration by Public Experiments.* Lanham, MD: Lexington Books, 2001.

Grove, Richard. *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600-1860.* Cambridge, UK: Cambridge University Press, 1995.

Hall, Edward T. *The Dance of Life: The Other Dimension of Time.* Garden City, NY: Anchor/Doubleday, 1983.

Hall, Stephen J.G. "Caring for the Legend of the Wild Bull: An Interpretation of the Georgian Landscape of Chillingham Park, Northumberland." *Garden History* 38, no. 2 (Winter 2020): 213-30.

Haraway, Donna. "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century." In *Simians, Cyborgs and Women: The Reinvention of Nature,* 149-181. New York: Routledge, 1991.

Haraway, Donna. *The Companion Species Manifesto: Dogs, People, and Significant Otherness*. Paradigm 8. Chicago: Prickly Paradigm Press, 2003.

Haraway, Donna. "Teddy Bear Patriarchy: Taxidermy in the Garden of Eden, New York City 1908-1936." *Social Text* 11 (1984): 20-64.

Harrington, Anne. *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler.* Princeton, NJ: Princeton University Press, 1996.

Harrison, Thomas. "The Culture of Time and Space: 1880-1918 by S. Kern." *The Review of Metaphysics,* 39, no. 1 (September 1985): 162-163.

Harwood, Jonathan. "Linkage Before Mendalism? Plant-breeding research in Central Europe, c. 1880-1910." In *Classical Genetic Research and its Legacy,* 1st edition, edited by Jean-Paul Gaudillière and Hans-Jörg Rheinberger. London: Routledge, 2004.

Harwood, Jonathan. *Styles of Scientific Thought: The German Genetics Community, 1900-1933,* Science and its Conceptual Foundations series. Chicago: University of Chicago Press, 1993.

Heck, Heinz. "The Breeding-Back of the Aurochs." *Oryx* 1:3 (1941): 117-122.

Heck, Lutz. *Animals: My Adventure*. Translated by E.W. Dickes. London: Methuen & Co. Ltd, 1954.

Heck, Lutz. *Tiere - mein Abenteuer: Erlebnisse in Wildnis und Zoo.* Berlin: Verlag Ullstein, 1952.

Heck, Lutz. "Über die Neuzüchtung des Ur oder Auerochs." *Berichte der Internationalen Gesellschaft zur Erhaltung des Wisents* 3, no. 4 (1934): 225-294.

Heim, Susanne. *Plant Breeding and Agrarian Research in the Kaiser-Wilhelm-Institutes, 1933-1945*. Dordrecht: Springer, 2008.

von Herberstein, Sigismund. *Rerum Moscovitarum Commentarii.* In aedibus Joann Steelsii, 1556.

Herf, Jeffrey. *Reactionary Modernism: Technology, Culture, and Politics in Weimar and the Third Reich.* Cambridge, UK: Cambridge University Press, 1984.

Heymanowski, K. "The last mainstay of aurochs and the organization of their protection in the light of contemporary documents." *Sylwan* 116, no. 9 (1972): 9-28.

Hopwood, Nick Staffan Müller-Wille, Janet Browne, et al. "Cycles and circulation: a theme in the history of biology and medicine." *HPLS* 43, no. 89 (2021). https://doi.org/10.1007/s40656-021-00425-3.

Housman, William. *Cattle: Breeds and Management.* London: Vinton and Company, 1897.

Huebener, Paul. *Nature's Broken Clocks: Reimagining Time in the Face of the Environmental Crisis*. Regina, Saskatchewan: University of Regina Press, 2020.

Huebener, Paul. *Timing Canada: The Shifting Politics of Time in Canadian Literary Culture*. Montreal: McGill-Queen's University Press, 2016.

Hughes, Diane Owen, and Thomas R. Trautmann, eds. *Time: Histories and Ethnologies*. Comparative Studies in Society and History Book Series. Ann Arbor: University of Michigan Press, 1995.

Huxley, Julian. *Evolution: The Modern Synthesis.* London: Allen and Unwin, 1942.

Ingold, Tim. "Culture and Perception of the Environment." In *Bush Base: Forest Farm, Culture, Environment, and Development,* edited by Elisabeth Croll and David Parkin. New York: Routledge, 1992.

Irving-Stonebraker, Sarah. "Nature, Knowledge, and Civilisation. Connecting the Atlantic and Pacific Worlds in the Enlightenment." *Itinerario* 41, no. 1 (April 2017): 93–107. https://doi.org/10.1017/S0165115317000092.

Jørgensen, Dolly. "Rethinking Rewilding." *Geoforum* 65 (2015): 482-88.

Jurkowlaniec, Grażyna, and Magdalena Herman, eds. *The Reception of the Printed Image in the Fifteenth and Sixteenth Centuries: Multiplied and Modified*. Routledge Research in Art History. New York: Routledge, Taylor & Francis Group, 2021.

Kabir, Ananya Jahanara. "An Enchanted Mirror for the Capitalist Self: The Germania in British India." In *Medievalisms in the Postcolonial World: The Idea of 'the Middle Ages' Outside Europe,* edited by Kathleen Davis and Nadia Altschul, 51-79. Baltimore: Johns Hopkins University Press, 2009.

Kalikow, T.J. "Konrad Lorenz's ethological theory: explanation and ideology, 1938-1943." *Journal of the History of Biology* 16, no. 1 (1983): 39-73.

Kater, Michael Hans. *Das "Ahnenerbe" der SS, 1935-1945: Ein Beitrag zur Kulturpolitik des Dritten Reichs* [*The "Ahnenerbe" of the SS 1933-1945: A contribution on cultural policy of the Third Reich].* Munich: R. Oldenbourg, 2006.

Kaufmann, Doris. "Dreams and self-consciousness: mapping the mind in the late eighteenth and early nineteenth centuries." In *Biographies of Scientific Objects,* edited by Lorraine Daston, 67-85. Chicago: University of Chicago Press, 2000.

Keel, Terence. *Divine Variations: How Christian Thought Became Racial Science.* Stanford, CA: Stanford University Press, 2018.

Kern, Emily. "Out of Asia: A Global History of the Scientific Search for the Origins of Humankind, 1800-1965." PhD diss., Princeton University, 2018.

Kern, Stephen. *The Culture of Time and Space, 1880-1918.* Cambridge, MA: Harvard University Press, 2003.

Kingstone, Helen. "The Comparative Method in 'Shallow Time': Walter Scott, Thomas Carlyle, and Francis Galton." In *Historicizing Humans: Deep Time, Evolution, and Race in Nineteenth-Century British Sciences*, edited by Efram Sera-Shriar, and Theodore Koditschek, 172-192, Pittsburgh, Pa: University of Pittsburgh Press, 2018.

Kitchener, Andrew C. and John Doune. "A Record of the aurochs, *Bos primigenius,* from Morayshire." *The Glasgow Naturalist* 25 (2012).

Knox, Robert. "The Anatomical Examination of the Wild Ox." *Quarterly Journal of Agriculture* 9 (1838).

Knox, Robert. *The Races of Men: A Fragment.* Philadelphia: Lea and Blanchard, 1850.

Kohler, Robert E. *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology.* Chicago: University of Chicago, 2002.

Kohler, Robert E. *Lords of the Fly: Drosophila genetics and the Experimental Life.* Chicago: University of Chicago, 1994.

Koselleck, Reinhart. *Futures Past: On the Semantics of Historical Time.* Translated by Keith Tribe. New York: Columbia University Press, 2004.

Krebs, Christoph B. *A Most Dangerous Book: Tacitus's Germania from the Roman Empire to the Third Reich.* New York: W.W. Norton and Co, 2011.

Krüger, Tobias. *Discovering the Ice Ages.* Leiden: Brill, 2013.

Lacoue-Labarthe, Philippe, Jean-Luc Nancy, and Brian Holmes. “The Nazi Myth.” *Critical Inquiry* 16, no. 2 (1990): 291-312.

Laland, Kevin, Blake Matthews, and Marcus W. Feldman. “An Introduction to Niche Construction Theory.” *Evolutionary Ecology* 30 (2016): 191-202.

Lartêt, Édouard. “Nouvelles Recherches sur la Coexistence de l’Homme avec des Grands Mammifères Fossiles Réputés Caractéristiques de la Dernière Période Géologique.*’’Annales des Sciences Naturelles, Quatrième Série: Zoologie* 15 (1861): 176–253.

Latour, Bruno. “Love Your Monsters.” In *Love Your Monsters: Postenvironmentalism and the Anthropocene,* edited by Michael Shellenberger and Ted Nordhaus. Berkeley, CA: Breakthrough Institute, 2011.

Latour, Bruno. “A Textbook Case Revisited – Knowledge as a Mode of Existence.” In *The Handbook of Science and Technology Studies* 3rd Edition, edited by E. Hackett, O. Amsterdamska, M. Lynch and J. Wacjman, 83-112. Cambridge, Mass, MIT Press, 2006.

Latour, Bruno. *We Have Never Been Modern*. Translated by Catherine Porter. Cambridge, MA: Harvard University Press, 1993.

Laubichler, Manfred D. and Karl F. Niklas. “The Morphological Tradition in German Paleontology: Otto Jaekel, Walter Zimmermann, and Otto Schindewolf.” In *The Paleobiological Revolution: Essays on the Growth of Modern Paleontology,* edited by David Sepkoski and Michael Ruse. Chicago: University of Chicago, 2009.

Le Goff, Jacques. *Time, Work and Culture in the Middle Ages.* Translated by Arthur Goldhammer. Chicago: University of Chicago Press, 1980.

Leitch, J. “Notes on the geological formation and fossils of the Silloth New Dock.” *Transactions of the Cumberland and Westmoreland Association for the Advancement of Science and Literature* 9 (1885): 169-174.

Lewis, Charlton T. and Charles Short. *A Latin Dictionary.* Oxford: Clarendon Press, 1879.

Lincoln, Bruce. *Theorizing Myth: Narrative, Ideology, and Scholarship.* Chicago: University of Chicago Press, 1999.

Linné, Carl. *Systema naturae: per regna tria naturae. I. Regnum animale. Editio decima.* Holmiae: Impensis Direct. Laurentii Salvii, 1758.

Lorimer, Jamie. “Nonhuman Charisma.” *Environment and Planning D: Society and Space* 25, no. 5 (October 2007): 911–32. https://doi.org/10.1068/d71j.

Lorimer, Jamie and Clemens Driessen. “Bovine biopolitics and the promise of monsters in the rewilding of Heck cattle.” Geoforum 48 (2013): 249-59.

Lorimer, Jamie and Clemens Driessen. "From "Nazi Cows" to Cosmopolitan 'Ecological Engineers': Specifying Rewilding Through a History of Heck Cattle." *Annals of the American Association of Geographers* 106, no. 3 (2016): 631-652. 10.1080/00045608.2015.1115332.

Lorimer, Jamie, Chris Sandom, Paul Jepson, Chris Doughty, Maan Barua, and Keith J. Kirby. "Rewilding: Science, Practice, and Politics." *Annual Review of Environment and Resources* 40 (2015): 39-62.

Lubbock, John. *Pre-Historic Times as Illustrated by Ancient Remains and the Manners and Customs of Modern Savages.* London: William & Norgate, 1865.

Lydekker, Richard. "Crania of Ruminants supplement." In *Memoirs of the geological Survey of India: Paleontologia Indica* I. Calcutta: Office of Superintendent of Government Printing, 1880.

Lydekker, Richard. "The Extermination of the American Bison," *Nature* 42, no. 1070 (1890): 11-13.

Lydekker, Richard. *Palaeontology of the Counties of England,* The Victoria History of the Counties of England. 1909. Geological Society of London Library.

Lydekker, Richard. *Wild Oxen, Sheep, and Goats of All Lands, Living and Extinct.* London: Rowland Ward, Ltd., 1898.

Lyell, Charles. *The Geological Evidence of the Antiquity of Man.* London: J.M. Dent & Sons, Ltd., 1914.

Lyell, Charles. *Principles of Geology* II. Philadelphia: James Kay, Jum. & Brother, 1837.

Macaulay, Thomas Babington. "The Romance of History." *Edinburgh Review* 47 (1828): 331-67.

Mach, Ernst. *Die Mechanik in ihrer Enwickelung: Historisch-Kritisch Dargestellt.* Leipzig: F.A. Brockhaus, 1883.

Mackenzie, John M. *The Empire of Nature: Hunting, Conservation, and British Imperialism*. Manchester, UK: Manchester University Press, 1988.

Maienschein, Jane. *Transforming Traditions in American Biology, 1880-1915*. Johns Hopkins University Press, 1991.

Malhi, Yadvinder. "The Concept of the Anthropocene." *Annual Review of Environment and Resources* 42 (2017): 77-104.

Manias, Chris. "Contemporaries of the Cave Bear and the Wooly Rhinoceros: Historicizing Prehistoric Humans and Extinct Beasts, 1959-1914. In *Historicizing Humans: Deep Time,* *Evolution, and Race in the Nineteenth-Century British Sciences,* edited by Efram Sera-Shriar and Theodore Koditschek, 14-43, Pittsburgh, PA: University of Pittsburgh Press, 2018.

Manias, Chris. "'Our Iberian Forefathers': The Deep Past and Racial Stratification of British Civilization, 1850-1914." *Journal of British Studies* 51 (2012): 910-935.

Marchand, Suzanne. *German Orientalism in the Age of Empire: Religion, Race, and Scholarship.* Cambridge: Cambridge University Press, 2010.

Marom, Shimon. "Neural Timescales or Lack Thereof." *Progress in Neurobiology* 90, no. 1 (January 11, 2010): 16–28. https://doi.org/10.1016/j.pneurobio.2009.10.003.

Marris, Emma. *Rambunctious Garden: Saving Nature in a Post-Wild World*. New York: Bloomsbury, 2011.

Maselli, V., Polese, G., Larson, G. *et al.* "A Dysfunctional Sense of Smell: The Irreversibility of Olfactory Evolution in Free-Living Pigs." *Evolutionary Biology* 41 (2014): 229–239. https://doi.org/10.1007/s11692-013-9262-3.

Mastromonaco, Gabriela F. and Antolio L. Gonzalez-Grajales. "Reproduction in female wild cattle: Influence of seasonality on ARTS." *Theriogenology* 150 (2020): 396-404.

Matz, Brendan. "Crossing, Grading, and Keeping Pure: animal breeding and exchange around 1860." *Endeavour* 35, no. 1 (March 2011): 7-15. 10.1016/j.endeavour.2010.12.001.

Mazower, Mark. *Dark Continent: Europe's Twentieth Century.* New York: Vintage Books, 2000.

McClintock, Anne. *Imperial Leather: Race, Gender, and Sexuality in the Colonial Contest.* Abingdon: Routledge, 1995.

McNeill, John Robert, and Peter Engelke. *The Great Acceleration: An Environmental History of the Anthropocene since 1945*. Cambridge, MA: The Belknap Press of Harvard University Press, 2014.

Medlicott, H.B. and W.T Blanford. *A Manual of the Geology of India.* Calcutta: Geological Survey Office, 1877.

Meek, Ronald L. *Social Science and the Ignoble Savage.* Cambridge: Cambridge University Press, 1976.

Meiring, H. "Scientific patronage in the age of Darwin: The Curious Case of William Boyd Dawkins." *Studies in History and Philosophy of Science* 89 (2021): 267-282.
M.F.H.A. "James Cossar Ewart, 1851-1933." *Obituary Notice to Fellows of the Royal Society* 1 (1934).

Mohr, E. “Von Wisenten und Wisent-Bastarden. *Aus Der Natur* 18, no. 3 (1939): 76-81.

Morris, Steven. “Devon farmer forced to offload aggressive Nazi-bred ‘super cows.’” *The Guardian*, January 5, 2015.

Morse, Edward S. “Biographical Memoir of Charles Otis Whitman, 1842-1910.” In *National Academy of Sciences Biographical Memoirs* Vol VII. Washington DC: National Academy of Sciences, 1912.

Morse, Elisha W. *The Ancestry of Domesticated Cattle.* Washington: Government Printing Office, 1912.

Moss, Charles E. *Vegetation of the Peak District.* Cambridge, UK: Cambridge University Press, 1913.

Moss, Charles E., W.M Rankin, and A.G. Tansley. “The Woodlands of England.” *New Phytologist* 9 (1910): 113-149.

Murchison, Charles, ed. *Palaeontological Memoirs and Notes of the Late Hugh Falconer: With a Biographical Sketch of the Author Compiled and Edited by Charles Murchison* II. London: Robert Hardwicke, 1868.

Murray, James, ed. *A New English Dictionary on historical principles: founded mainly on the materials collected by the Philological Society.* Oxford: Clarendon Press, 1888.

Navarro, Laetitia M. and Henrique M. Pereira. “Rewilding Abandoned Landscapes in Europe.” *Ecosystems* 15 (2012): 900-12.

Nehring, Alfred. “Über das Skelett eines weiblichen Bos Primigenius.” *Sitzungsberichte der Gesselschaft Naturforschender Freunde zu Berlin* 4 (1888): 54-62.

Newton, Alfred. “Bison not aurochs.” *Nature* 42, no. 1073 (May 22, 1890), 28.

Newton, Alfred. “Bison not aurochs.” *Nature* 42 (May 8, 1890), 81.

Nicholson, Daniel J., and John Dupré, eds. *Everything Flows: Towards a Processual Philosophy of Biology*. Oxford, United Kingdom: Oxford University Press, 2018.

Nyhart, Lynn. *Modern Nature: The Rise of the Biological Perspective in Germany.* Chicago: University of Chicago, 2009.

Odling-Smee, F. John, Kevin Laland, and Marcus Feldman. *Niche Construction: The Neglected Process in Evolution*. Princeton: Princeton University Press, 2003.

Ogle, Vanessa. *The Global Transformation of Time, 1870-1950.* Cambridge, MA: Harvard University Press, 2015.

Oldham, Richard Dixon ed. *A Manual of the Geology of India* 2nd Edition. Calcutta: Geological Survey Office, 1893.

Orland, Barbara. “Turbo-Cows: Producing a Competitive Animal in 19th and Early 20th Century Switzerland.” In *Industrializing Organisms,* edited by Susan Schrepfer and Philip Scranton. New York: Routledge, 2004.

Otter, Chris. *Diet for a Large Planet: Industrial Britain, Food Systems, and World Ecology.* Chicago: University of Chicago Press, 2020.

Owen, Richard. *A History of British Fossil Mammals, and Birds.* London: J. Van Voorst, 1846.

Owen, Richard. “Notes on the Anatomy of the Male Aurochs (*Bison europeaus).*” *Proceedings of the Zoological Society of London,* 16 (1848).

Park, Stephen D E, David A. Magee, Paul A. McGettigan, Matthew D. Teasdale, Ceiridwen J. Edwards, Amanda J. Lohan, Alison Murphy, et al. “Genome Sequencing of the Extinct Eurasian Wild Aurochs, Bos Primigenius, Illuminates the Phylogeography and Evolution of Cattle.” *Genome Biology* 16, no. 1 (December 2015): 234. https://doi.org/10.1186/s13059-015-0790-2.

Pauly, Daniel. “Anecdotes and the Shifting Baseline Syndrome.” *Trends in Ecology and Environment* 10 (1995).

Pawley, Emily. “The Point of Perfection: Cattle Portraiture, Bloodlines, and the Meaning of Breeding, 1760-1860.” *Journal of the Early Republic* 36, no. 1 (Spring 2016): 37-72.

Petronievics, Branislav. *On the Law of Irreversible Evolution.* Washington D.C.: Government Printing Office, 1920.

Pickens, Donald K. *Eugenics and the Progressives.* Nashville, Tenn.: Vanderbilt University Press, 1968.

Pigliucci, Massimo. “Do We Need an Extended Evolutionary Synthesis?” *Evolution* 61, no. 12 (December 2007): 2743–49. https://doi.org/10.1111/j.1558-5646.2007.00246.x.

Plumb, C.S. “Edward Lewis Sturtevant: A Biographical Sketch.” *Missouri Botanical Garden Annual Report* (1899): 71-84.

Prinsep, James. “Note on the Fossil Bones Discovered Near Jabálpur.” *Journal of the Asiatic Society of Bengal* 2 (1833): 585.

Prinsep, James. “Note on the fossil bones of the nerbudda valley, discovered by G.G. Spilsbury, near nersinhpur.” *Journal of the Asiatic Society of Bengal* 3 (1834): 396.

Prinsep, James. “Note on the Jabalpur Fossil Bones.” *Journal of the Asiatic Society of Bengal* 1 (1832): 456-458.

Prior, Jonathan and Kim J. Ward. “Rethinking Rewilding – a Response to Jørgensen.” *Geoforum* 69 (2016): 132-5.

Pusch, Georg Gottlieb. *Polens Paläontologie; oder, Abbildung und Beschreibung der vorzüglichsten und der noch unbeschriebenen Petrefakten aus den Gebirgsformationen in Polen, Volhynien und den Karpathen.* Stuttgart: Schweizerbart, 1837.

de Queiroz, Alan. *The Monkey’s Voya*ge: *How Improbable Journeys Shaped the History of Life*. New York: Basic Books, 2014.

Raj, Kapil. *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900.* Hampshire, UK: Palgrace, 2006.

Rea, G.G. “Sir Jacob Wilson,” Obit. *Journal of Royal Agricultural Society* 66 (1905), 4-5.
Reichert, Hermann. *Das Nibelungenlied: Text und Einführung*. Berlin: De Gruyter, 2017.

Reif, Wolf-Ernst. ‘‘Evolutionary Theory in German Paleontology.’’ In *Dimensions of Darwinism: Themes and Counterthemes in Twentieth Century Evolutionary Theory,* edited by Marjorie Grene and Werner-Reimers-Stiftung, 173-203. Cambridge, UK: Cambridge University Press, 1983.

Reif, Wolf-Ernst. “The Search for a Macroevolutionary Theory in German Paleontology.” *Journal of the History of Biology* 19, no. 1 (March 1986): 79–130. https://doi.org/10.1007/BF00346618.

Reif, W.E., T. Junker, and U. Hossfeld. “The synthetic theory of evolution: General problems and the German contribution to the synthesis.” *Theory in Biosciences* 119 (2000): 41-91.

Rewilding Europe. *Annual Review* (2021). www.rewildingeurope.com/wp-content/uploads/publications/rewilding-europe-annual-review-2021/.

Rewilding Europe. “The Comeback of the European Icon.” November 8, 2012. rewildingeurope.com/news/the-comeback-of-the-european-icon/.

Rewilding Europe. “Second Generation of Tauros Now Grazing in the Lika Plains.” Accessed April 22 2023. https://rewildingeurope.com/news/second-generation-of-tauros-now-grazing-in-lika-plains/.

Rewilding Europe. “Public Disclosures.” Accessed February 2023. https://rewildingeurope.com/public-disclosures/.

Rheinberger, Hans-Jörg and Staffan Müller-Wille. "Heredity Before Genetics." In *Heredity Explored: Between Public Domain and Experimental Science, 1850-1930,* edited by Staffan Müller-Wille and Christina Brandt, 143-166. Cambridge, MA: The MIT Press, 2016.

Richards, Evelleen. "The 'moral anatomy' of Robert Knox: The Interplay between biological and social thought in Victorian scientific naturalism." In *Ideology and evolution in nineteenth century Britain: Embryos, monsters, and racial and gendered others in the making of evolutionary theory and culture*, 89-143. New York: Routledge, 2021.

Richards, Robert J. *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe.* Chicago: University of Chicago Press, 2002.

Richards, Robert J. *The Tragic Sense of Life: Ernst Haeckel and the Struggle over Evolutionary Thought.* Chicago: University of Chicago Press, 2008.

Rieppel, Lukas. *Assembling the Dinosaur: Fossil Hunters, Tycoons, and the Making of a Spectacle.* Cambridge, Massachusetts: Harvard University Press, 2019.

Ritvo, Harriet. *The Animal Estate: The English and Other Creatures in the Victorian Age.* Cambridge, Massachusetts: Harvard University Press, 1987.

Ritvo, Harriet. *Noble Cows and Hybrid Zebras: Essays on Animals and History.* Charlottesville: University of Chicago Press, 2010.

Ritvo, Harriet. "Race, Breed, and Myths of Origin: Chillingham Cattle as Ancient Britons." *Representations* 39 (1992): 1-22.

Robbins, Paul and Sarah A. Moore. "Ecological Anxiety Disorder: Diagnosing the Politics of the Anthropocene." *Cultural Geographies* 20, no. 1 (2012): 3-19.

Robertson, Forbes W. "Genetics." *Proceedings of the Royal Society of Edinburgh* 84B (1983).
Robertson, William and Dugald Stewart. *The Works of William Robertson* Vol I. London: T. Cadell, 1840.

Rosenberg, Daniel and Anthony Grafton. *Cartographies of Time*: *A History of the Timeline.* Princeton, NJ: Princeton Architectural Press, 2013.

Rossiianov, Kirill. "Beyond Species: Il'ya Ivanov and His Experiments on Cross-Breeding Humans with Anthropoid Apes." *Science in Context* 15 (2003): 277-316.

Rudwick, Martin J.S. *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution.* Chicago: University of Chicago Press, 2005.

Rudwick, Martin J.S. *Georges Cuvier, Fossil Bones, and Geological Catastrophes: New Translations and Interpretations of the Primary Texts.* Chicago: University of Chicago Press, 1997.

Rudwick, Martin J.S. *The Meaning of Fossils: Episodes in the History of Paleontology.* Chicago: University of Chicago Press, 1972.

Rudwick, Martin J.S. *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World*. Chicago: University of Chicago Press, 1992.

Rudwick, Martin J. S. *Worlds Before Adam: The Reconstruction of Geohistory in the Age of Reform*. Chicago: University of Chicago Press, 2008.

Russell, Edmund. *Evolutionary History: Uniting History and Biology to Understand Life on Earth.* Cambridge, UK: Cambridge University Press, 2011.

Russell, Edmund. "The Garden in the Machine: Toward an Evolutionary History of Technology." In *Industrializing Organisms,* edited by Susan Schrepfer and Philip Scranton. New York: Routledge, 2004.

Russell, Nicholas. *Like Engend'ring Like: Heredity and Animal Breeding in Early Modern England.* Cambridge, UK: Cambridge University Press, 1986.

Rütimeyer, Ludwig. *Die Fauna der Pfahlbauten in der Schweiz.* Basel: Schweighauser, 1861.
Rütimeyer, Ludwig. *Versuch Einer Natürlichen Geschichte des Rindes.* Zürich: Zürcher und Furrer, 1867.

Saraiva, Tiago. *Fascist Pigs: Technoscientific Organisms and the History of Fascism.* Cambridge, MA: MIT Press, 2016.

Sax, Boria. *Animals in the Third Reich: Pets, Scapegoats, and the Holocaust.* New York: Continuum, 2000.

Sax, Boria. "What is a 'Jewish Dog?' Konrad Lorenz and the Cult of Wildness." *Society and Animals* 5, no. 1 (1997): 3-21.

Schade, Oskar. *Altdeutsches Wörterbuch* Vol. 2. Halle a.S.: Buchhandlung des Waisenhauses, 1882.

Schama, Simon. *The Embarrassment of Riches: An Interpretation of Dutch Culture in the Golden Age.* Berkeley, CA: University of California Press, 1988.

Schama, Simon. *Landscape and Memory.* London: Harper Collins, 1995.

Schmidt, Oscar. *The Mammalia in their relation to Primeval Times.* New York: D. Appleton and Company, 1886.

Schrepfer, Susan and Philip Scranton, eds. *Industrializing Organisms: Introducing Evolutionary History.* New York: Routledge, 2004.

Schroeder-Gudehus, Brigitte. “International Science from the Franco-Prussian War to World War Two: An Era of Organization.” In *The Cambridge History of Science*, edited by Hugh Richard Slotten, Ronald L. Numbers, and David N. Livingstone, 8:43–59. The Cambridge History of Science. Cambridge: Cambridge University Press, 2020. doi:10.1017/9781139044301.005.

Scott, Walter. “The Ballad of Cadyow Castle.” In *Minstrelsy of the Scottish border: consisting of historical and romantic ballads, collected in the southern counties of Scotland: with a few of modern date, founded upon local tradition,* 386-396. Edinburgh: Longman and Rees, 1803.

Sebastiani, Silvia. *The Scottish Enlightenment: Race, Gender, and the Limits of Progress*. New York: Palgrave MacMillan, 2013.

Sepkoski, David. *Catastrophic Thinking: Extinction and the Value of Diversity from Darwin to the Anthropocene.* Chicago: University of Chicago Press, 2020.

Sepkoski, David. “The Earth as Archive: Contingency, Narrative and the History of Life.” In *Science in the Archives,* edited by Lorraine Daston. Chicago: University of Chicago Press, 2017.

Sepkoski, David, and Marco Tamborini. “‘An Image of Science.’” *Historical Studies in the Natural Sciences* 48, no. 1 (February 1, 2018): 56–109. https://doi.org/10.1525/hsns.2018.48.1.56.

Shyrock, Andrew and Daniel Lord Smail, eds., *Deep History: The Architecture of Past and Present.* Berkeley, CA: University of California Press, 2011.

Simpson, George Gaylord. *Tempo and Mode in Evolution*. A Columbia Classic in Evolution. New York: Columbia University Press, 1984.

Simpson, Thomas. “Historicizing Humans in Colonial India.” In *Historicizing Humans: Deep Time, Evolution, and race in Nineteenth-Century British Sciences,* edited by Efram Sera-Shriar and Theodore Koditschek, 113-137. Pittsburgh, PA: University of Pittsburgh Press, 2018.

Sinding, Mikkel-Holger S., and M. Thomas P. Gilbert. “The Draft Genome of Extinct European Aurochs and Its Implications for De-Extinction.” *Open Quaternary* 2 (September 27, 2016): 7. https://doi.org/10.5334/oq.25.

Smith, John Alexander. “Notes on the ancient cattle of Scotland. *Proceedings of the Society of Antiquaries of Scotland* 9 (1873): 587-674.

Smith, William. “A Delineation of the Strata of England and Wales, with part of Scotland. London: John Cary, 1815.

Soulé, Michael and Reed Noss. “Rewilding and Biodiversity: Complementary Goals for Continental Conservation.” *Wild Earth* 8 (1998): 19-28.

Specht, Joshua. *Red Meat Republic: A Hoof-to-Table History of How Beef Changed America.* Princeton, NJ: Princeton University Press, 2019.

Spilsbury, G.G. "Notice of new sites of fossil deposits in the Nerbudda Valley." *Journal of the Asiatic Society of Bengal* 6 (1837): 488.

Stark, John. "On the Supposed Progress of Human Society from Savage to Civilized Life, as Connected with the Domestication of Animals and the Cultivation of the Cerealia." *The Edinburgh New Philosophical Journal* 31 (1841).

Stocking, Jr., George W. *Delimiting Anthropology: Occasional Essays and Reflections.* Madison, WI: University of Wisconsin Press, 2001.

Stocking, Jr., George W. *Victorian Anthropology.* New York: Free Press, 1987.

Storer, John. *The Wild White Cattle of Great Britain: An Account of their Origin, History, and Present State.* London: Cassell, Peter & Galpin, 1879.

Swenson, Astrid. *The Rise of Heritage: Preserving the Past in France, Germany, and England, 1789-1914.* Cambridge, UK: Cambridge University Press, 2013.

Sykes, Tom. "'Nazi Cows' Tried to Kill British Farmer." *The Daily Beast,* January 6, 2015.
Tansley, Arthur G*. The British Islands and their Vegetation*, 3rd edition. Cambridge, UK: Cambridge University Press, 1953.

Tansley, Arthur G. ed. *The Types of British Vegetation.* Cambridge, UK: University of Cambridge Press, 1911.

Theunissen, Bert. *Beauty or Statistics: Practice and Science in Dutch Livestock Breeding, 1900-2000.* Toronto, University of Toronto Press, 2020.

Theunissen, Bert. "Breeding for Nobility or for Production? Cultures of Dairy Cattle Breeding in the Netherlands, 1945-1995." *Isis* 103, no. 2 (June 2012): 278-309.

Theunissen, Bert. "Breeding Without Mendelism: Theory and Practice of Dairy Cattle Breeding in the Netherlands 1900–1950." *Journal of the History of Biology* 41, no. 4 (December 2008): 637–76. https://doi.org/10.1007/s10739-008-9153-0.

Theunissen, Bert. "The Oostvaardersplassen Fiasco." *Isis* 110, no. 2 (2019): 341-5.
Thomas, Julia Adeney. "History and Biology in the Anthropocene: Problems of Scale, Problems of Value." *American Historical Review* 119 (2014): 1587-1607.

Thomas, Phillippe. "Recherches sur les bovidés fossiles de l ' Algérie." *Bulletin de la Société Zoologique de France* 6 (1881): 92 – 136.

Toulmin, Stephen Edelston and June Goodfield. *The Discovery of Time.* Chicago: University of Chicago Press, 1982.

Trautmann, Thomas R. *Clash of Chronologies: Ancient India in the Modern World.* New Delhi: Yoda Press, 2009.

Turner, G.T. "Fat Stock at the Smithfield Club Show." *The Livestock Journal* 30 (1889).
Turner, W. "On fossil bones of mammals obtained during excavations at Silloth." *Proceedings of the Royal Physical Society of Edinburgh*, 8 (1885): 333-338.

Turner, W. *Proc. Roy. Phys. Soc*. 2 (1859): 70.

Upadhay, M.R., et al. "Genetic origin, admixture and population history of aurochs (*Bos primigenius)* and primitive European cattle." *Heredity* 118 (2017): 169-76.

Valde, Katherine. "Philosophical Perspectives on Time in Biology." PhD diss., Boston University, 2019.

Vera, Frans W.M. "Large-scale Nature Development: the Oostvaardersplassen." *British Wildlife* 29 (2009): 28-36.

Vera, Frans W.M. *Grazing Ecology and Forest History.* Wallingford UK: CABI Publishing, 2000.

Vera, Frans. W.M. "Large-scale Nature Development: the Oostvaardersplassen," *British Wildlife* 29 (2009): 28-36.

Vidmar, Polona. "Cæsari in Mis Omni Hora Fidelis Servivi: The Portraits of Sigismund Herberstein and Walter Leslie in Diplomatic Robes." *Radovi Instituta Za Povijest Umjetnosti*, no. 43 (February 2, 2020): 75–90. https://doi.org/10.31664/ripu.2019.43.06.

Walton, John R. "Pedigree and Productivity in the British and North American Cattle Kingdoms before 1930." *Journal of Historical Geography* 25, no. 4 (October 1999): 441-62. https://doi.org/10.1006/jhge.1999.0161.

Warming, E. *Oecology of Plants: an Introduction to the Study of Plant Communities.* Oxford, UK: Clarendon Press, 1909.

Watkins, Aja. "The Epistemic Value of the Living Fossils Concept." *Philosophy of Science* 88, no. 5 (December 2021): 1221–33. https://doi.org/10.1086/714875.

Wegener, Alfred. "Die Herausbildung der Grossformen der Erdrinde (Kontinente und Ozeane), auf geophysikalischer Grundiage." *Geologische Rundschau* 3 (1912): 276-292.

Wells, H. G. *The Time Machine.* New York: Henry Holt and Company, 1895.

Whatmore, Sarah. *Hybrid Geographies: Natures, Cultures, Spaces*. London: SAGE, 2002.

White, Hayden. *Metahistory: The Historical Imagination in Nineteenth-Century Europe.* Baltimore: Johns Hopkins University Press, 2014.

Whitman, Charles Otis. "A Biological Farm for the Experimental Investigation of Heredity, Variation and Evolution, and for the Study of Life-Histories, Habits, Instincts and Intelligence." *The Biological Bulletin of the Marine Biological Laboratory* 3, no. 5 (October 1902): 214-224.

Whitman, James Q. *Hitler's American Model: The United States and the Making of Nazi Race Law.* Princeton, NJ: Princeton University Press, 2017.

Wilson, Jacob. "The Chillingham White Cattle." *Land Magazine* 3 (1899).

Wilson, James. *The Evolution of British Cattle and the Fashioning of Breeds.* London: Vinton & Co., 1909.

Wolloch, Nathaniel. "The Civilizing Process, Nature, and Stadial Theory." *Eighteenth-Century Studies* 44, no. 2 (December 2011): 245–59. https://doi.org/10.1353/ecs.2011.a411979.

Woods, Rebecca J.H. "Bert Theunissen. *Beauty or Statistics: Practice and Science in Dutch Livestock Breeding, 1900-2000." ISIS* 113, no. 4 (December 2022): 887-888. https://doi.org/10.1086/721996.

Woods, Rebecca J. H. *The Herds Shot Round the World: Native Breeds and the British Empire, 1800-1900*. Flows, Migrations, and Exchanges. Chapel Hill: University of North Carolina Press, 2017.

Wrześniowski, August. "Studien zur Geschichte des polnischen Tur." *Zeitschrift für wissenschalftliche Zoologie* 30 (1878).

Zeiler, Jørgen Tiemen. "Hunting, fowling and stock-breeding at neolithic sites in the western and central Netherlands*."* PhD diss., University of Groningen, 1997.

Zeuner, F.E. "Domestic Cattle and the Aurochs." *Oryx* 3, no. 6 (1956): 319-322.

Zimmermann, Walter. *Die Phylogenie der Plfanzen.* Jena: G. Fischer, 1930.

Zvereva, G.V. "Professor I.I. Ivanov – founder of artificial insemination of animals." *Veterinariia* 7 (1970): 88-90.

Archival Sources

British Library, London, UK.

Buxton Museum and Art Gallery, Buxton, UK.
Boyd Dawkins Archives.

Geological Society of London Archives.

National Museums Scotland, Collection Centre, Edinburgh, UK.

Oxford University Museum of Natural History.
Paleontology Collections.

University of Chicago Special Collections.

University of Edinburgh Archives.
James Cossar Ewart Papers.
Animal Breeding Committee Papers.