Theory Biosci. (2013) 132:225–237
DOI 10.1007/s12064-013-0188-1

ORIGINAL PAPER

# Engaging with Lyell: Alfred Russel Wallace's Sarawak Law and Ternate papers as reactions to Charles Lyell's *Principles of Geology*

**J. T. Costa**

Received: 5 March 2013 / Accepted: 3 June 2013 / Published online: 7 September 2013


**Abstract** Alfred Russel Wallace (1823–1913) and Charles Darwin (1809–1882) are honored as the founders of modern evolutionary biology. Accordingly, much attention has focused on their relationship, from their independent development of the principle of natural selection to the receipt by Darwin of Wallace's essay from Ternate in the spring of 1858, and the subsequent reading of the Wallace and Darwin papers at the Linnean Society on 1 July 1858. In the events of 1858 Wallace and Darwin are typically seen as central players, with Darwin's friends Charles Lyell (1797–1875) and Joseph Dalton Hooker (1817–1911) playing supporting roles. This narrative has resulted in an under-appreciation of a more central role for Charles Lyell as both Wallace's inspiration and foil. The extensive anti-transmutation arguments in Lyell's landmark *Principles of Geology* were taken as the definitive statement on the subject. Wallace, in his quest to solve the mystery of species origins, engaged with Lyell's arguments in his private field notebooks in a way that is concordant with his engagement with Lyell in the 1855 and 1858 papers. I show that Lyell was the object of Wallace's Sarawak Law and Ternate papers through a consideration of the circumstances that led Wallace to send his Ternate paper to Darwin, together with an analysis of the material that Wallace drew upon from the *Principles*. In this view Darwin was, ironically, intended for a supporting role in mediating Wallace's attempted dialog with Lyell.

**Keywords** Evolution · History · Natural selection · Alfred Russel Wallace · Charles Darwin · Charles Lyell

## Introduction

Literature-based discussions, and not infrequently arguments, have long been a hallmark of academic discourse—books and articles are means of communicating with the broader and often globally dispersed scholarly community. Indeed scholarly publications are often arguments, in the philosophical sense of seeking to establish a point of view and persuade acceptance of this view through reasoned use of evidence, whether empirical or authoritative. As such, by design arguments elicit responses positive and negative, some intentionally provoked on the part of the author and others unintentional. In the early history of modern evolutionary thought just such a literature-based discussion took place, much of it in the form of argument. Given the time (mid-nineteenth century, pre-electronic age) and highly dispersed nature of the participants (from the British Isles to the islands of modern-day Indonesia), the dialog played out over a span of months to years, through published works punctuated by letters.

I refer to the dialog between Alfred Russel Wallace (1823–1913), Charles Robert Darwin (1809–1882), and Charles Lyell (1797–1875) over what was termed the "species question" in their day: the possibility and mode of transmutation (in modern terms, evolutionary change) of

This article is a contribution to the Special Issue Alfred Russel Wallace (1823–1913): the man in the shadow of Charles Darwin–Guest Editors U. Kutschera, U. Hossfeld.

J. T. Costa (✉)
Highlands Biological Station, 265 N. Sixth Street, Highlands, NC 28741, USA
e-mail: costa@email.wcu.edu

J. T. Costa
Department of Biology, Western Carolina University, Cullowhee, NC 28723, USA

species. One aspect of this interaction that has been perhaps the most intensively studied is the receipt by Darwin of Wallace's manuscript posted from the island of Ternate in early 1858, and the subsequent reading of this manuscript with extracts of Darwin's writings on the subject at the Linnean Society of London on 1 July 1858 (Beddall 1988; Kutschera 2003; Davies 2012; Porter 2012; Van Wyhe and Rookmaaker 2012; Smith 2013). My purpose here is not to comprehensively recount or analyze the interactions between these three naturalists, let alone weigh in on the particulars of the controversy over Darwin's receipt of Wallace's manuscript. Rather, I seek to focus attention on an aspect of their interaction that is largely unappreciated.

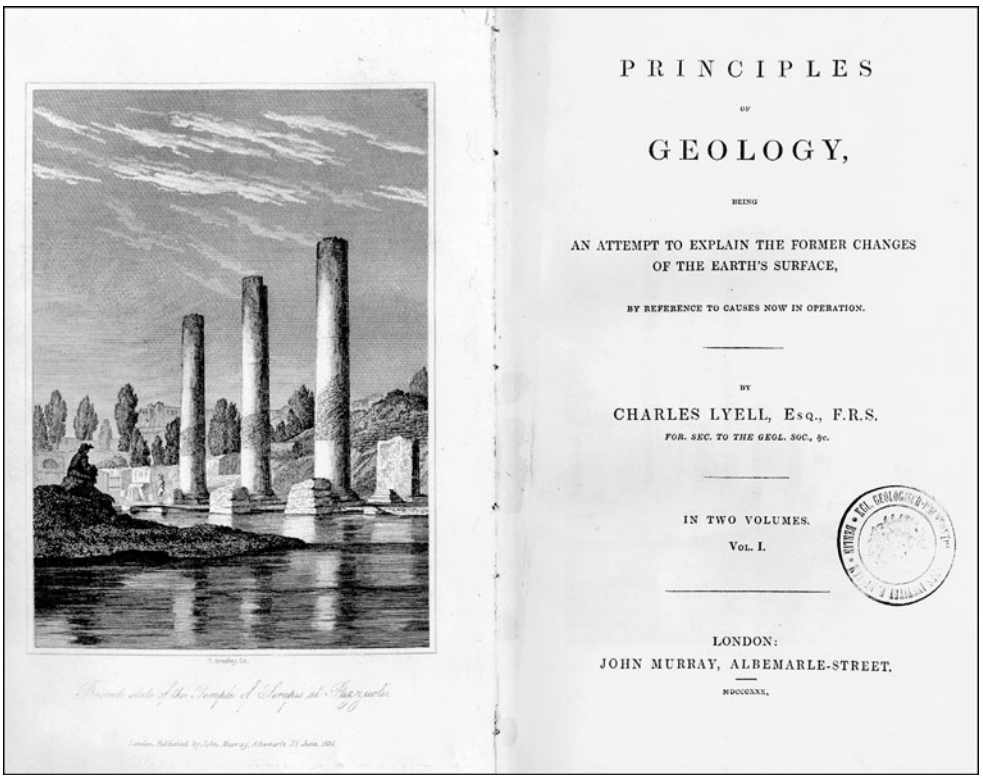
So much attention is typically paid to the Wallace–Darwin dialog that the third major player, Charles Lyell (Fig. 1), is often simply seen in a supporting role, literally and figuratively, for Darwin, as the architect (with Hooker) of the solution to Darwin's dilemma over Wallace's paper in the form of the Linnean Society readings. In fact Lyell played a more central role in the unfolding of these events by acting as both inspiration and foil for Wallace. Fichman (2004, p. 81) pointed out that Lyell's uniformitarianism was an "indispensible component of Wallace's first evolutionary pronouncements." I concur; a recent analysis (Costa 2013) of Wallace's "Species Notebook" (Linnean Society ms. no. 180), his field notebook kept between 1855 and 1860 while working in southeast Asia, underscored not only the depth and breadth of Wallace's thinking on the subject of transmutation at the time, but also that his pro-transmutation arguments were largely aimed at Lyell in *Principles of Geology* (Fig. 2). In this paper I explore the nature of Wallace's mode of argument, showing how his "Sarawak Law" and Ternate papers (Wallace 1855, 1858a, respectively) were inspired by and intended for Lyell first and foremost, with Darwin intended, ironically, for a supporting role in mediating Wallace's attempted dialog with Lyell. In so doing I first put the Wallace–Lyell dialog into perspective with a brief overview of Wallace's pursuit of the "species question," followed by a consideration of the structure and content of Wallace's 1855 and (in greater detail) 1858 papers in relation to Lyell.

**Fig. 1** The British geologist Charles Lyell (1797−1875)

## In pursuit of the species question

Alfred Russel Wallace's essay from Ternate in 1858 was the culmination of a decade of searching for the mechanism of species change. It is well known that Wallace was convinced of the idea of species change (then termed transmutation) by the anonymously published *Vestiges of the Natural History of Creation* (Chambers 1844), which he read in 1845. Wallace expressed to his friend and fellow naturalist Henry Walter Bates (1825–1892) more than once a desire to undertake a systematic study of the species question (see, e.g., McKinney 1972, pp. 1–12; Fichman 2004, pp. 16–24; Slotten 2004, pp. 22–46). Wallace and Bates conceived a bold plan to travel to Amazonia, financing their journey and explorations through specimen collections that would be offered for sale through an agent back in England. At the same time, significantly, they envisioned amassing a personal collection that would give insight into the nature of species and varieties in relation to geographical distribution, facts that they believed would lead to the solution of the so-called "species question." The pair was fortunate to find a talented agent (see Stevenson 2009) and arrived in Brazil in 1848; Wallace spent the next 4 years in Amazonia, Bates a total of 11 years.

Wallace's conviction of the reality of species change strengthened in his Amazonian journey, but the solution to the question of how transmutation occurs eluded him. If he thought that he might solve the mystery by studying his copious collections and records once home in England he was to be tragically disappointed: he lost his final 2 years' worth of collections and notebooks when, on the return trip home in July of 1852, his ship burned and sank so quickly that he lost nearly all of his notebooks and all of his specimens from the period that he later described as the most interesting of his 4-year journey (Slotten 2004, ch. 6; Wallace 1852). Wallace thus likely undertook his subsequent expedition to southeast Asia—a region selected after consulting with entomologists to learn where the greatest gaps existed in museum collections—for both financial reasons and to continue his species investigations. With travel support from the Royal Geographical Society



PRINCIPLES

OF

GEOLOGY,

BEING

AN ATTEMPT TO EXPLAIN THE FORMER CHANGES OF THE EARTH'S SURFACE,

BY REFERENCE TO CAUSES NOW IN OPERATION.

BY

CHARLES LYELL, Esq., F.R.S.

FOR. SEC. TO THE GEOL. SOC., &c.

IN TWO VOLUMES.

Vol. I.

LONDON:

JOHN MURRAY, ALBEMARLE-STREET.

MDCCCXXX.

**Fig. 2** Title page and frontispiece of Charles Lyell's *Principles of Geology*, Vol. I, 1830

he arrived in Singapore in April 1854 and spent the next 8 years, until the spring of 1862, criss-crossing the "Malay Archipelago" from Singapore and peninsular Malaysia in the west to New Guinea in the east. By his own reckoning in his acclaimed travel memoir *The Malay Archipelago* (Wallace 1869), he traveled some 14,000 miles in 70–80 separate journeys, collecting well over 125,000 specimens.

Despite the rigors of travel in so remote a region, frequent bouts of illness, and a full schedule of specimen collection, preparation, documentation, and shipping, Wallace managed to keep up a steady stream of scientific papers and correspondence throughout his expedition. I describe elsewhere (Costa 2013) how the papers he wrote in southeast Asia can be seen provocative explorations of the species question, a point also lucidly made by Brooks (1984) and Slotten (2004). For present purposes, the most important of Wallace's papers in this period are the papers he wrote in Sarawak (Wallace 1855) and Ternate (Wallace 1858a)—the latter being the paper in which Wallace triumphantly announced his discovery of the mechanism of species change.

## Charles Lyell and the Sarawak law

In this section I give an overview of the Sarawak Law paper in the broader context of (1) Lyell's pre-eminent role in British geology and his anti-transmutation stance and (2) Wallace's early reading of Lyell and his pursuit of the "species question." I then discuss how the paper evokes Lyell and was likely written with him in mind, and the effect of the paper in inducing Lyell to reconsider the transmutation idea. The "Sarawak Law" paper, so-named because it was written in Sarawak, Borneo, soon after Wallace's arrival in the region, is significant for its mode of argument and adducing of evidence for a highly suggestive pattern of species distribution. Wallace made a compelling argument for relationships of species in time and space—that is, in terms of their distribution in the fossil record and their geographical patterns. This not only strongly implied transmutation (although Wallace did not explicitly argue this point), but also advocated a gradualism in species change that went hand-in-hand with Lyellian gradualism in geological and environmental change.

### Lyell and the principles of geology

Certainly Charles Lyell read Wallace's paper as highly suggestive of transmutation, as will be discussed below. What Lyell may not have realized is that the arguments of the Sarawak Law paper were directed at him. Why might Wallace have done so? Lyell, it should be first noted, had a long-standing interest in the question of species change. There is evidence that Lyell was initially open to the idea

on his initial reading of French "transformist" thinking in the late 1820s (Bartholomew 1973; Corsi 1978), but misgivings over the theological implications of this doctrine for humans led him to firmly change his mind. Lyell's landmark *Principles of Geology* was published in three volumes between 1830 and 1833. Much of this work (volume II in particular) pertained more to the organic than inorganic world, and there Lyell mounted a long argument against the possibility of species change, and attacked the leading proponents of this view (notably the by-then deceased French naturalist Jean Baptiste de Lamarck) (Rudwick 1970, 1998; Recker 1990; Hallam 1998). Conservative though it may have been in terms of its biological thinking, the *Principles of Geology* was a revolutionary geological treatise that put the understanding of earth's age and history on a new foundation (see extensive treatment by Rudwick 1972, 2008). It is ironic that the very gradualism that Lyell argued for so eloquently in the inorganic world was seen by Wallace (and Darwin) as consistent with gradual change in the realm of species and varieties (Recker 1990). It is important to appreciate, too, that the *Principles of Geology* quickly came to occupy an influential position in British science. Lyell was already a well-regarded up-and-coming geologist by the end of the 1820s. He first became interested in geology attending William Buckland's (1784–1856) lectures as a student at Oxford, and although he studied law upon graduating Oxford in 1821 he did not long practice. He was elected joint secretary of the Geological Society of London in 1823, and read his first paper at the society in 1824.

By that time Lyell was a well-traveled and astute student of geology, studying geological formations in his native Scotland, the Isle of Wight, and Sussex, and, earlier, recording geological observations on a lengthy tour of Europe undertaken with his father. He spent the summer of 1823 in Paris attending geological and zoological lectures. Lyell was likely introduced in a general way to Lamarckian "transformism" about this time through his friends in Paris (e.g., geologist Constant Prévost, which whom Lyell spent much time in Paris, was a student of Lamarck), and later was certainly familiar with writings on Lamarck by Edinburgh naturalists such as Robert Grant and John Fleming. He did not read Lamarck's *Philosophie Zoologique*, however, until February 1827 (Corsi 1978). In the following year he embarked upon another geological tour in Europe, this time to France and Italy (1828–1829) with geologist Roderick Impey Murchison (who was to later support Wallace's travels to southeast Asia, as president of the Royal Geographical Society). It was likely during this trip with Murchison that Lyell decided to undertake a book-length exposition of his geological ideas; this also seems to be the period in which he changed his mind about Lamarck. The first volume of *Principles of Geology* came out the year after his return to London; the treatise, which ultimately went into 12 editions and has never been out of print, made Lyell famous. By the time of Wallace's travels to southeast Asia in the mid-1850s Lyell had become the leading geologist of Britain, his illustrious career including two stints as president of the Geological Society even before Wallace had returned from Amazonia: 1835–1837 and 1849–1851 (Wilson 1973). His *Principles of Geology* was the definitive treatment of what was considered the most important and exciting science of the day. Lyell's extensive anti-transmutation arguments in the *Principles* were, accordingly, taken as a decisive refutation of the possibility of species change.

It may seem odd to modern readers that a geological treatise should dedicate so much space to biology: as I have noted most of the second volume is biological (species variability, distribution, populations, etc.). But this was not unusual for the time: the study of the Earth and its inhabitants had long gone hand-in-hand (Rudwick 2005, 2008). It is not surprising, therefore, that Wallace should integrate information from the organic and inorganic worlds in his approach to the mystery of species origins. The first expression of his attempts at synthesis, the Sarawak Law paper of 1855, did precisely that, and indeed was an effort that got Lyell's attention.

Wallace likely first read Lyell in 1845 or 1846, when he was living in Neath. He first mentioned the geologist in a letter to Bates dated 11 April 1846, commenting approvingly to his friend: "I am much pleased to find you so well appreciated 'Lyell'" (Wallace Correspondence Project, letter WCP340, 2013). McKinney (1972, 20) suggested that Wallace may have taken the *Principles* with him on his voyage to South America, and it is certain that he traveled with the 4th (1835) edition of the *Principles* in southeast Asia. Although Wallace certainly read widely, including Darwin's *Journal of Researches* and Humboldt's *Personal Narrative* (McKinney 1972, p. 5; Osborn 1928, p. 75), Lyell's *Principles* best conveyed the excitement over this relatively new science of the Earth, its history, and its inhabitants. For this reason, during his pursuit of the species question Wallace repeatedly engaged with Lyell's arguments; indeed, his Species Notebook (kept between 1855 and 1860) contains numerous extended extracts from the *Principles*, with arguments against Lyell's position (Costa 2013, pp. 100–139).

## Wallace in Sarawak

Arriving in Sarawak, northern Borneo, in November 1854, Wallace eventually moved into a small bungalow provided by Sir James Brooke (1803–1868), the so-called "white Rajah" of Sarawak, who had a fondness for natural history and philosophical ideas. Waiting out the last of the rainy

season and largely confined indoors, in February 1855 Wallace penned the paper entitled "On the law which has regulated the introduction of new species;" it was published in the *Annals and Magazine of Natural History* in September of that year (Wallace 1855). The paper appeared to be precipitated by the naturalist Edward Forbes (1815–1854), who had published a paper in support of the so-called "polarity theory," a quasi-mystical concept of an unfolding plan of life on Earth where the richness of created species starts out high, steadily decreases to a low point, and then steadily increases again. Though Wallace respected Forbes, he profoundly disagreed with his metaphysical ideas about species. He commented in a letter to Bates that "it was the promulgation of "Forbes' theory" which led me to write and publish, for I was annoyed to see such an ideal absurdity put forth when such a simple hypothesis will explain all the facts" (WCP366; emphasis in original). It is clear from the opening paragraph of his paper, however, that Wallace had Lyell's *Principles* in mind as he wrote it. The opening is framed in Lyellian terms: the "singular facts of geographical distribution" are illuminated by "geological investigations" of recent years. Those investigations were Lyell's. The second paragraph articulated a vision of gradual (Lyellian) change in both the Earth and the life upon it, and a synthetic or integrative Lyellian vision permeates the central argument of the paper in which Wallace listed nine "propositions in Organic Geography and Geology" culminating in a 10th proposition, namely, his Law: "*Every species has come into existence coincident both in space and time with a pre-existing closely allied species*" (Wallace 1855, p. 186; italics in original). Wallace argued that "the phenomena of geological distribution are exactly analogous to those of geography," and proceeded to show that slow, gradual geological change results in gradual extinction, citing "C. Lyell in his admirable 'Principles'."

In the concluding paragraph of the paper Wallace emphasized how his law "connects together and renders intelligible a vast number of independent and hitherto unexplained facts," namely (1) the natural system of arrangement of species (classification), (2) their geographical distribution (biogeography), (3) their geological sequence (paleontology), (4) "representative and substituted groups in all their modifications (convergent or analogous groups of species), and (5) "the most singular peculiarities of anatomical structure" (morphology; rudimentary structures). It is noteworthy that his paper succeeded in expressing the idea of species change without mentioning transmutation (species change) at all. Despite this, Lyell not only grasped the significance of Wallace's "law" for transmutation, but also went out of his way to draw Darwin's attention to the paper.

## Effect of the Sarawak Law paper on Lyell

Lyell was moved to initiate what grew into a series of seven notebooks on the species question within days of reading Wallace's paper (Wilson 1970). Notes on Wallace's paper fill the first pages of his first notebook: "Of innumerable ways in which Omnipotence might fit a new species to all the present and future conditions of its existence, there may be one which is preferable to all others, and if so this will cause the new species to be in all probability allied to preexisting and extinct or with many coexisting species of the same genus" (Wilson 1970, p. 6). In a related notebook (Wilson 1970, p. 66) he noted that Wallace's paper "goes far toward Lamarck's doctrine [of transmutation]."

Lyell visited Darwin in April 1856, during which he became the second person in whom Darwin confided his natural selection theory (the first was Joseph Hooker). Lyell immediately understood the significance of Wallace's "Sarawak Law" for Darwin's ideas. As Beddall (1988) has pointed out, it is unclear if Darwin was made aware of Wallace's paper by Lyell or was already familiar with it. In any case Darwin seemed far less impressed with Wallace's paper than was Lyell. Soon after his visit Lyell urged Darwin to write up his ideas for publication, the 1855 paper clearly suggesting to Lyell that Wallace was converging on Darwin's ideas: "I wish you would publish…& so out with the theory & let it take date—& be cited—& understood" [Darwin Correspondence Project (DCP, 2013) letter no. 1862; 1–2 May 1856]. Although Darwin did not agree with Lyell's fears, on 14 May 1856 he initiated at last a treatment of his species theory "by Lyell's advice" (De Beer 1959, p. 14). Wallace, far away in the Malay Archipelago, had no idea of the effect that his paper had on Lyell. He was in fact disappointed that the paper, expressing his "views on the order of succession of species," a subject discussed by Lyell in the *Principles*, did not seem to get any notice at all, and said as much in a letter to Darwin (with whom he had established a correspondence in October 1856): "I had begun to be a little disappointed that my paper had neither excited discussion nor opposition…" (DCP letter no. 2145; 27 September 1857). Darwin, however, knew that Lyell had paid close attention to Wallace's paper, and reassured Wallace: "you must not suppose that your paper has not been attended to; two very good men, Sir C. Lyell and Mr E. Blyth at Calcutta specially called my attention to it" (DCP letter no. 2192; 22 December 1857). Edward Blyth, based in India, had a long (15-year) correspondence with Darwin regarding the nature of species and varieties (Beddall 1972; Brandon-Jones 1997), and commented in glowing terms on Wallace's paper in a letter to Darwin in late 1855 (DCP letter no. 1792; 8 December 1855).

To summarize this section, Wallace's 1855 paper was the most cogent "evolutionary" argument that had been published to date; it deeply impressed Charles Lyell, who initiated his notebooks on the "species question" as a direct result of reading it. Wallace did not know of the effect he had on Lyell until Darwin told him in a letter written in December 1857 (received by Wallace March 1858). By the opening of 1858 Wallace had adduced many lines of evidence for transmutation, and lacked only a *mechanism* for the pattern of species relationship in time and space that he outlined in his 1855 paper. The mechanism, natural selection, occurred to him in February 1858, shortly before receiving Darwin's letter. I next briefly consider the events of 1858 as a prelude for considering, finally, the Ternate essay of 1858 as the next phase of Wallace's ongoing engagement with Lyell.

## The dialog continues

Wallace was on the island of Ternate, in the Moluccas, when Darwin's letter of December 1857 arrived. The date of arrival was very likely 9 March 1858, the very steamer on which Wallace is posited to have sent his famous "Ternate essay" to Darwin. A comprehensive review of the events surrounding the writing and mailing of the Ternate essay is beyond the scope of this paper, but it is important to note, briefly, that Wallace had at last succeeded in solving the mystery of species origins while in the field on the neighboring island of Gilolo in February 1858, and the receipt of Darwin's letter thus coincided with a time of great excitement for Wallace. By his own account he had sudden insight into the process later called natural selection while stricken with illness, and in the subsequent two or three evenings wrote out a short and concise essay on the subject (Wallace 1905, vol. 1, pp. 361–362; McKinney 1972, pp. 80–83, 131–132; Slotten 2004, pp. 142–148). He had only just returned to Ternate, his base of operations and the region's center of commerce and administration, when Darwin's letter arrived.

It has been long supposed that Wallace mailed his essay to Darwin on the 9 March steamer, but van Wyhe and Rookmaaker (2012) recently argued that it was more likely sent at a later date. These authors suggested that Wallace's letter and essay were sent in reply to Darwin's letter of 22 December 1857, and that it would have been difficult for Wallace to have mailed off a package to Darwin on the very same day that a delivery from Darwin was received (but see Davies 2012; Smith 2013). The reasoning behind the idea that Wallace's essay and letter were sent in reply to Darwin's letter pertains to a comment that Wallace made in his autobiography (Wallace 1905, 1: p. 363) that he had asked Darwin to show his essay, if he thought it "sufficiently important," to Lyell, "who had thought so highly of my former paper." The "former paper" is the Sarawak Law paper, but the only way that Wallace could have known that Lyell thought highly of it is from Darwin's letter of 22 December 1857 —the letter in which Darwin told Wallace that "two good men" (Lyell and Blyth) had especially commended his 1855 paper. That letter was received by Wallace on 9 March 1858.

That Wallace's Ternate essay was intended for Lyell's eyes is suggested by Darwin's letter to Lyell upon receiving Wallace's essay the following June, in which Darwin stated that Wallace "…asked me to forward [the essay] to you." It is likely, then, that Wallace sent his essay to Darwin partly because he knew, from previous correspondence, that the elder naturalist was preparing a work pertaining to the nature of species and varieties (Beddall 1988; Porter 2012) and partly as an attempt to get Lyell's attention directly. Wallace desired to get Lyell's attention because the Ternate essay was largely written with him in mind. I next consider the Ternate essay and its Lyellian connections in detail.

## Charles Lyell and the ternate essay

The Ternate essay (the full title of which is "On the tendency of varieties to depart indefinitely from the original type," Wallace 1858a) presented an argument for natural selection—that is, a mechanism of species change that gives rise to a pattern of bifurcating ancestor–descendant species relationships over time (Slotten 2004, pp. 141–148). In this section I summarize the Ternate essay paragraph by paragraph, highlighting the many ways in which Wallace drew on the *Principles* (summarized in Table 1) to underscore the point that in Wallace's pursuit of the species question the authority he most wished to convince was Lyell, owing to the preeminence that Lyell's *Principles* held in establishing the anti-transmutation position.

1. Wallace opens the Ternate essay by stating that one of the strongest arguments cited for the permanence of species is the putative instability of domestic varieties, that is, that such varieties readily revert to the parental form in a state of nature. This tendency, Wallace says, is generally assumed to apply to all varieties, even natural ones. Lyell advanced this argument forcefully in the 4th (1835) edition of the *Principles* (volume III, pp. 437–448).
2. Wallace next points out that while this argument has great weight with naturalists, yet they also recognize "permanent or true varieties." In this discussion Wallace may have had in mind Edward Blyth's 1835

**Table 1** Correspondence between concepts found in the Tenate essay (Wallace 1858a) and the *Principles of Geology* (4th edition; Lyell 1835)

| Ternate essay (page)[a] | Concepts/terms/observations/ideas | *Principles*[b] (vol./pages) |
|---|---|---|
| 53 | Domestication (anti-transmutation argument based on) | III/437–448 |
| 54 | Struggle for existence | III/9, 59, 108–109, 140, 162 |
| | Wild asses of the Tartarian deserts | III/59 |
| | Pops. increase rapidly, yet there is appearance of equilibrium | III/108–120 |
| 55 | Power of population increase | III/113–115 |
| 56 | Migration necessary to birds' existence | III/66–70 |
| 58 | Antelopes: variation and fleetness | II/415 |
| | Result of "alteration of physical conditions" of a district | III/152 |
| | Destruction of vegetation by locust irruptions | III/115–116, 123 |
| | Question of varieties return to original form, or not | III/162 |
| 59 | ARW argues, contra Lyell, for continued change in varieties | III/162 |
| | Geological time: "periods of time…so near to infinity…" | I/111, 114, 127; III/449 |
| 60 | Result of turning animals like horses, oxen loose on the Pampas | III/134–137 |
| 61 | Hypothesis of Lamarck | II/407–425, 426–448, 449–465 |
| | Origin of the giraffe's long neck | II/415 |
| 62 | ARW, contra Lyell: continual divergence from parental type | II/438–439 |
| | Succession of species through past ages | I/222–239;III/155, 164–166 |

[a] Wallace 1858a, [b] Lyell 1835

paper which attempted to distinguish between species and different kinds of varieties. (Wallace extracted this paper in the Species Notebook; Costa 2013, p. 156). He surely had in mind the point made in his "Note on the theory of permanent and geographical varieties," which was published the month before he penned the Ternate essay (Wallace 1858b). In that short paper Wallace underscored the difficulty of telling varieties from species, which would seem to be inconsistent with the idea of "permanent invariability" of species, and highlighted the flawed logic behind the idea of "permanent varieties"—these points are at the heart of his comments in this paragraph of the Ternate essay. The final sentence of the paragraph returns to the Lyellian argument made against species change: the difficulty is resolved by assuming that "varieties have strict limits, and can never again vary further from the original type…," and that this is taken as highly probable on the basis of the domestication analogy.

3. Concluding his opening argument, Wallace says that the view he related depends entirely on there being an analogy between varieties in a state of nature and those under domestication. This analogy, he aims to show, is false; indeed, the mechanism he is going to describe (which ensures domestic varieties revert to the parental form) is the very same mechanism that ensures that natural varieties will not return to the parental form.
4. This important paragraph is the first in setting up Wallace's argument for the operation of this remarkable mechanism. He opens with the memorable line: "The life of wild animals is a struggle for existence." The phrase "struggle for existence" was used by Thomas Robert Malthus (1766–1834) in his *Essay on Population* (1798, chapter three): "And when they fell in with any tribes like their own, the contest was a struggle for existence, and they fought with a desperate courage, inspired by the rejection that death was the punishment of defeat and life the prize of victory." Wallace later maintained that he recalled Malthus to mind, whose treatise he had read some dozen years previously, in his flash of insight into natural selection (e.g., Wallace 1905, v. 1, pp. 361–362; Wallace 1909, pp. 111–118; see summary by McKinney 1972, pp. 160–163), and several authors have addressed the importance of Malthus for Wallace (McKinney 1972, pp. 80–96; Moore 1997). But what could have brought the idea of Malthusian struggle immediately to Wallace's mind was Lyell's discussion of struggle in the *Principles*. Lyell does not quote or cite Malthus explicitly, but in volume III of the 4th edition of *Principles* he described struggle in at least four places and used the word "struggle" in three of them. In the first case Lyell described how "in the universal struggle for existence, the right of the strongest eventually prevails; and the strength and durability of a race depends mainly on its prolificness [sic]…" (Lyell 1835; III, p. 9). Lyell next quoted from an 1820 essay by Augustin Pyramus de Candolle (1778–1841): "All the plants of a given country," says de Candolle, in his usual spirited style, "are at war one with another.

> The first which establish themselves by chance in a particular spot, tend, by the mere occupancy of space, to exclude other species—the greater choke the smaller, the longest livers replace those which last for a shorter period, the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill" (III, pp. 108–109).

The Candollean "struggle between species" is vividly described in Lyell (III, p. 140), where every species must, Lyell says, "maintain its ground by a successful struggle against the encroachments of other plants and animals." On pp. 162–163 of volume III Lyell wrote more vividly, drawing a parallel between human conquests and the struggles of species in nature: "A faint image of the certain doom of a species less fitted to struggle with some new condition in a region which is previously inhabited, and where it has to content with a more vigorous species, is presented by the extirpation of savage tribes of men by the advancing colony of some civilized nation." Wallace's statement in this paragraph that wild animals must give the "full exertion of all their faculties and all their energies…to preserve their own existence and provide for that of their infant offspring" is resonant with the Malthusian struggle as depicted by Lyell. Wallace concludes this paragraph pointing out that "struggle" is a determinant of population size, and seen in this light, we can gain insight into why some species are abundant and others rare.

5. Wallace describes the ecological pyramid at the outset of the next, very long (~2.5 page) paragraph: carnivores cannot outnumber their prey. In addition, environment plays a role: the "wild asses of the Tartarian deserts cannot equal in numbers the horses of the more luxuriant prairies and pampas of America." (Lyell mentions the wild asses of the Tartarian deserts on p. 59 of volume III.) Wallace then points out that it is mistakenly assumed that fecundity is the main determinant of population abundance or scarcity. This, he writes, "really has little or nothing to do with the matter," continuing: "Even the least prolific of animals would increase rapidly if unchecked, whereas it is evident that the animal population of the globe must be stationary…." Lyell addresses this very point in some detail on pp. 108–120 of volume III, where he argues that the number of species on Earth, and their relative abundance, are maintained at an equilibrium. A conception of a harmoniously balanced nature was commonplace in the natural theology view, which Lyell espoused. The struggle for existence was for him a mechanism by which this balance was maintained. Wallace attacked Lyell's talk of balance and harmony in nature in the species notebook (Costa 2013, pp. 130–133). In the Ternate essay he does so by first framing the Malthusian formulation: species (the ornithologist Wallace uses birds as an example) "do not go on increasing every year in a geometrical ratio, as they would do, were there not some powerful checks to their natural increase." He states that in a mere 15 years a single breeding pair of birds would have some 10 million descendants, but later realized that this was an underestimate. In a personal copy of the printed essay sent by his agent Stevens, Wallace wrote in the margin "really more than 2000 millions!" and also changed this in later reprints of the essay (see Beccaloni 2008; emphasis Wallace's). Whether 10 or 2000 million descendants in 15 years, clearly neither is realized in nature; in fact we would be hard pressed to establish that the overall population changes at all in 150 let alone 15 years. The population appears stationary, and so "It is evident…that each year an immense number of birds must perish—as many in fact as are born." He expands on this startling point with an even more startling one, calculating that whatever the average population size of a species might be, double that number must perish each year, typically by cold, hunger, and predators. We see as much Lyell as Malthus in this argument. Just as Lyell mentions the struggle for existence without mentioning Malthus, so too does he discuss the power of population increase and the way species balance other species (III, pp. 108–121). Lyell frames his discussion of struggle and population pressure in dramatic terms by citing examples of prolific insects, such as one attributed to the French naturalist René-Antoine Réaumur (1683–1757): "in five generations one aphis may be the progenitor of 5,904,900,000 descendants"—and what's more, there could be 20 generations in the space of just one year (III, p. 114). Clearly we are not buried in aphids, or any other species. This is where the balance of nature comes in: after recounting instances of exploding populations of locusts, aphids, flies and caterpillars, Lyell discusses "reciprocal influence" of species, checking one another's populations.

Wallace continues his argument about population growth and growth checks (In a poignant irony, he cites the passenger pigeon, *Ectopistes migratorius*, perhaps the most abundant bird in North America in the mid-19th century but driven to extinction by the early 20th). Lyell does not mention passenger pigeons in the 4th edition of the *Principles*, but in the 6th edition he quoted this very passage by Wallace on the immensity of passenger pigeon populations. Wallace's discussion focuses on the abundant and stable food supply of the passenger pigeon as underpinning their

huge populations. Abundance and rarity of species' populations all boils down, to Wallace, to abundance and constancy of food supply. This is what drives some birds to migrate, something that Lyell does discuss at length (III, pp. 66–70)—another point of intersection between the Ternate essay and Lyell's *Principles*.

Bringing this long paragraph to a close, Wallace summarizes the argument thus far, pointing out that "so long as a country remains physically unchanged", species' populations in that country "cannot materially increase." A key element of the argument to come is that countries do *not* remain physically unchanged—as Lyell eloquently argues in the *Principles* (III, pp. 142–164), inexorable (albeit slow and steady) geological and climatic change leads to the extinction of some species. Getting there in his argument, Wallace once again states that the numbers of individuals that die annually is immense: it is "a struggle for existence," in which those that succumb tend to be the weakest (the young, aged, and diseased) and "least perfectly organized" (Wallace 1858a, pp. 56–57).

6. Here Wallace introduces a curious concept: the same struggle he just described among individuals "must also occur among the several allied species of a group." The wording is suggestive of species-level selection, as if Wallace did not appreciate that the abundance or rarity of species is simply a function of what he just described for individuals. One passage in this paragraph echoes Lyell: those species best able to "defend themselves against the attacks of their enemies and the vicissitudes of the seasons" will enjoy large populations, paralleling Lyell's discussion of the effects of the "vicissitudes of climate" on species (III, p. 160).
7. Wallace summarizes his two key points, with emphasis, namely (1) that animal populations are generally stationary, kept in check by limitations of food and other factors and (2) that the relative rarity or commonness of a species is due to its structure ("organization") and habits as they relate to survival and procuring food. Establishing these points, Wallace announces that we are now in a good position to consider how this bears on varieties.
8. Here the language is more individual-centered than that of paragraph 6. "Most or perhaps all the variations from the typical form of a species must have some definite effect, however slight, on the habits or capacities of the individuals." He then relates how changes, even in characters like color or quantity of hair or the dimensions of a structure or organ, affect for good or ill "the powers of prolonging existence." The example he then provides—"An antelope with shorter or weaker legs must necessarily suffer more from the attacks of the feline carnivora…"—comes from Lamarck (1809), via Lyell (II, p. 415): "…the antelope and gazelle were not endowed with light agile forms (Lamarck says) in order that they might escape by flight from carnivorous animals; but, having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity…"

A variety with even slightly increased "powers of preserving existence" will over time achieve superiority in numbers. Based on this Wallace asserts that varieties fall into two classes: those which under a given, constant, set of conditions never increase to the population level of their parental species, and those which will eventually surpass the parental species in numbers. Then, he says, shake things up by altering physical conditions, which in the Lyellian view is inevitable: "Hence it must happen that, when the nature of those localities is changed, the species will perish…" (III, p. 152). To Wallace, it may happen that one or more of the "offspring" varieties do better under the new conditions than the parent. One of the examples of perturbing effects that Wallace gives next also comes from Lyell—"destruction of vegetation by locusts," described at length by Lyell in vol. III (pp. 115–116 and 123).

9. In this paragraph Wallace argues that new varieties will not only replace their parental species, but "would be a more perfectly developed and more highly organized" form. A key point for Wallace is that, contrary to the assertion of Lyell and others that varieties always revert to the parental form, here is a circumstance where this is impossible because, he argues, the parental form is inferior and cannot compete. This is Wallace's answer to Lyell's argument in vol. III p. 162 of the *Principles*, where he maintains that it is idle to speculate about species changing one into another during episodes of environmental change, because such change results in migration or extinction. Wallace next introduces the important concept that new-and-improved varieties might themselves, over time, give rise to newer varieties, the net effect of which is to yield "several diverging modifications of form," any one of which might become dominant. "Here, then, we have *progression and continued divergence* deduced from the general laws which regulate the existence of animals…" (original emphasis). Wallace's use of the word "divergence" is noteworthy—the context is departure from the parental form, becoming increasingly dissimilar over time. Several additional key terms and concepts come up in the remainder of this paragraph: (1) an awareness that the newer, offspring variety could end up less well

adapted after all than its parental form, going extinct while the parent form flourishes; (2) recognition that variation is ubiquitous: "variations in unimportant parts might also occur…;" (3) an awareness of the statistics of low probabilities and large numbers: "though the doctrine of chances or averages can never be trusted on a limited scale, yet, if applied to high numbers, the results come nearer to what theory demands… Now the scale on which nature works is so vast—the numbers of individuals and periods of time with which she deals approach so near infinity, that any cause, however slight… must in the end produce its full legitimate results." Lyell (1835) expresses well both the immensity of geological time (I, pp. 111, 114, 127; III, p. 449) and of population growth potential (III, pp. 113–115).

10. Wallace returns to domesticated varieties, arguing once again that they hold no lessons for us. There is a significant difference between the circumstances of animals in a state of nature and those in a state of domestication in terms of activity, safety and procuring food, Wallace says.
11. Wallace then contrasts domesticated with wild animals more explicitly, aiming to impress upon the reader how every aspect of animals in the wild must be "brought into full action for the necessities of existence… It creates as it were a new animal, one of superior powers, and which will necessarily increase in numbers and outlive those inferior to it."
12-13. Continuing this line of argument, Wallace points out that our domestic varieties by and large could never survive in a state of nature, mentioning among others fanciful breeds like pouter pigeons and poodles. Neither race horses with their "great speed but slight endurance" nor draft horses with their "unwieldy strength" would long survive turned loose on the pampas. This may be a reasonable supposition with regard to these particular breeds, though Wallace would seem to part ways with Lyell on this point. In the *Principles* (III, pp. 134–137) Lyell describes the explosive population growth of horses, oxen, etc. turned loose on the pampas, leading to the extirpation or displacement of native species. Lyell does not discuss "reversion" of these feral domestic varieties, though Wallace emphasizes with italics that "Domestic varieties, when turned wild, *must* return to something near the type of the original wild stock, *or become altogether extinct*." Wallace penned a qualifier in his personal copy of the paper, reading "That is, they will vary and the variations which render them best adapted to the wild state and therefore approximate them to wild animals will be preserved. Those that do not vary quickly enough will perish" (Beccaloni 2008, pp. 95–96). This is a more nuanced explanation of the process by which they revert.

This point is continued in paragraph 13, which opens "We see, then, that no inferences as to varieties in a state of nature can be deduced from the observation of those occurring among domestic animals." This is, of course, a major point of difference between Wallace and Darwin, one that perhaps reflects their respective trajectories of discovery of the evolutionary process.

14. This paragraph is set up by pointing out that while Lamarck's formulation of transmutation has been easily refuted, this does not mean the question is settled; Wallace aims to show that by the principles he outlines Lamarck's hypothesis is unnecessary, but gives similar results (transmutation). The point about obviating Lamarck (1809) is also made in the Species Notebook (Costa 2013, p. 124), which in turn is aimed at Lyell who goes to great lengths to refute Lamarck in the *Principles* (II, pp. 407–465). Wallace discusses how the Lamarckian interpretation of organic change by "volition" or activity is not correct, giving the examples of the "powerful retractile talons" of birds of prey and felines, or the long neck of giraffes. Lyell does not discuss talons, but does cite Lamarck's example of the giraffe's neck, using the then-current name of "camelopard" for this animal (II, p. 415). Other examples reflect Wallace's own field experience: camouflage, or cryptic coloration of insects "so closely resembling the soil or the leaves or the trunks on which they habitually reside" that they are well hidden from enemies. Camouflage is explained easily by his principle (selection, though he does not use that word) acting on the "varieties of many tints that may have occurred" over time.

Wallace draws an analogy between his "principle" (what we know as natural selection) and the steam engine's centrifugal governor, "which checks and corrects any irregularities almost before they become evident…." Interestingly, Lyell also draws an analogy with steam engines, though in a different context. On p. 112 of vol. III Lyell writes of the power of insect populations to rapidly grow and then diminish, like the ability of a steam-engine to bring the power of "many hundred" horses to bear instantly, and then just as quickly abate. Wallace's steam-engine governor is a conservative force, reflecting natural selection's power of elimination or weeding. In the essay Wallace writes of this mechanism correcting any "unbalanced deficiency." He then returns to the bigger-picture result of his principle: "the many lines of divergence from

a central type, the various modifications seen in a given organ or structure in a set of allied species, or in a succession of species. It also explains the tendency for more recent species to have more specialized structures than earlier, extinct species, Wallace says, citing Richard Owen (1804–1892) (and echoing a similar remark he made on p. 54 of the Species Notebook (Costa 2013, p. 140), in which he also cites Owen in this context).

15. The final paragraph of the Ternate essay summarizes Wallace's main point: establishing "a tendency in nature to the continued progression of certain classes of *varieties* further and further from the original type" (emphasis Wallace's). Moreover, there is no reason to ascribe a priori limits on this progress (*contra* Lyell, in III, p. 21), and this also explains reversion of domestic varieties to the parental type (as argued by Lyell in II, pp. 438–439). Wallace's choice of words in the final sentence are worth quoting in full: "This progression, by minute steps, in various directions, but always checked and balanced by the necessary conditions, subject to which alone existence can be preserved, may, it is believed, be followed out so as to agree with all the phenomena presented by organized beings, their extinction and succession in past ages, and all the extraordinary modifications of form, instinct, and habits which they exhibit." The key terms are "minute steps" and "in various directions"—change is gradual, and neither teleological nor uni-directional. The key observations of paleontology, "extinction and succession in past ages..," that his hypothesis agrees with are discussed by Lyell at length (the latter critically): extinction in III, pp. 104–108, 155, and 164–166, and succession in I, pp. 222–239.

## Aftermath

Soon after the publication of the Darwin and Wallace papers in the *Proceedings of the Linnean Society*, Wallace (still in southeast Asia) wrote Darwin to ask about Lyell's reaction. Darwin responded jocularly: "You ask about Lyell's frame of mind. I think he is somewhat staggered, but does not give in, and speaks with horror often to me, of what a thing it would be and what a job it would be for the next Edition of Principles, if he were "*per*verted".—But he is most candid and honest and I think will end by being *per*verted.—Dr. Hooker has become almost as heterodox as you or I. —and I look at Hooker as *by far* the most capable judge in Europe" (DCP, letter 2405; emphases in original). Wallace succeeded in getting Lyell's attention with the Ternate essay. His return to England in April 1862 marked the start of a long personal dialog with Lyell over scientific questions; Fichman (2004, p. 81) well described their "philosophic kinship" and frequent discussions, often over the implications of natural selection for humans.

## Conclusion

Wallace's Sarawak Law paper and Ternate essay were part of an ongoing pro-transmutation argument aimed at Lyell. In almost every paragraph of the latter in particular there are references, often direct, to statements made in the *Principles of Geology*. The themes considered by Wallace include domestication, struggle for existence and species ("ecological," to use a modern term) interaction, extinction and succession of species, abundance and rarity of populations, gradual environmental change and its perturbing effects on species, etc. Even Wallace's citation of Malthus in connection with his insight into struggle and natural selection may stem from Wallace's reading of struggle in Lyell's principles, based on the strikingly similar terms in which Lyell discussed the factors (in this case extrinsic) holding down populations: at the edge of the range, against a barrier, when environment is changing, "stragglers are ready to multiply rapidly on the slightest increase or diminution of heat, rainfall, etc. that may be favorable to them" (III, p. 160). This view of the Sarawak Law paper and Ternate essay accords with Wallace's close reading of Lyell as reflected in his Species Notebook, in which 23 pages consist of closely argued criticisms of Lyell's anti-transmutationism (e.g., on such topics as domestication, balance and harmony in nature, limits of variability, et al.; Costa 2013, Appendix II).

This analysis suggests that Lyell should be seen as playing a very different role in the events leading up to the reading of Wallace and Darwin's 1858 papers than he is commonly considered to have played. Far from simply mediating with Hooker the resolution of Darwin's quandary regarding his priority in the face of Wallace's de facto "scooping" of Darwin in the Ternate essay, Lyell's elaborate and effective anti-transmutation arguments in the *Principles of Geology* provided Wallace with a foil with which to argue as he pursued the species question. Wallace no doubt hoped that his "evolutionary" papers would be widely read and discussed, but the most pre-eminent and potentially severest critic to convince was Lyell. For this reason, Wallace planned a book arguing for transmutation by arguing against Lyell (see Costa 2013, pp. 6–7) and sent his Ternate essay to Darwin (with whom he had corresponded) as an entree to Lyell (with whom he had not corresponded), asking Darwin in his cover letter to show the paper to Lyell "if he thought it sufficiently interesting."

Lyell was at the same time Wallace's muse, in that his vision of a gradually changing earth resonated deeply with Wallace, who fully embraced Lyell's concept of uniformity and drew upon the empirical observations of the *Principles* in terms of geographical distribution and paleontology. Lyell also inspired Darwin, who wrote in 1844 that he always felt "as if my books came half out of Lyell's brains" (DCP, letter 771). It is a long-appreciated irony that Lyell influenced Darwin (and Wallace's) thinking about species change despite his own misgivings over transmutation (e.g., McKinney 1972, ch. 7). Indeed, it is to Lyell's credit that, despite his misgivings, he encouraged Darwin's heterodox ideas on species, urging him to publish when he thought that Wallace might discover the same principle, as, in fact, soon occurred. He is not likely to have been the severe critic that Wallace may have assumed. Although Darwin and Wallace soon became the central figures of this narrative upon the reading of the 1858 papers and Darwin's publication of the *On the Origin of Species* the following year—understandably so, as co-discoverers of natural selection—from Wallace's perspective Darwin was up to that point playing more of a supporting role in Wallace's ongoing pursuit of the species question and his literature-based engagement with Lyell.

**Acknowledgments** I thank the Guest Editor, U. Kutschera, for his kind invitation to contribute to the *Theory in Biosciences* special issue dedicated to Alfred Russel Wallace. This paper was written while a 2012–2013 Fellow of the *Wissenschaftskolleg zu Berlin*; I gratefully acknowledge the support of the *Wissenschaftskolleg* and Western Carolina University's Scholarly Leave program in making my stay in Berlin possible, and I thank the *Wissenschaftskolleg's* librarians Sonja Grund, Anja Brockmann, Marianne Buck, and Kirsten Graupner for their considerable assistance. I have benefitted greatly from my many enjoyable discussions concerning Wallace with Andrew Berry and George Beccaloni. Many thanks, finally, to Leslie Costa for helpful comments and criticisms on the manuscript.

## References

Bartholomew M (1973) Lyell and evolution: an account of Lyell's response to the prospect of an evolutionary ancestry for man. Brit J Hist Sci 6:261–303

Beccaloni GW (2008) Wallace's annotated copy of the of the Darwin-Wallace paper on natural selection. In: Smith CH, Beccaloni G (eds) Natural selection and beyond: the intellectual legacy of Alfred Russel Wallace. Oxford University Press, Oxford, pp 91–101

Beddall BG (1972) Wallace, Darwin, and Edward Blyth: further notes on the development of evolution theory. J Hist Biol 5:153–158

Beddall BG (1988) Darwin and divergence: the Wallace connection. J Hist Biol 21:1–68

Blyth E (1835) An attempt to classify the "varieties" of animals, with observations on the marked seasonal and other changes which naturally take place in various British species, and which do not constitute varieties. Mag Nat Hist 8:40–53

Brandon-Jones C (1997) Edward Blyth, Charles Darwin, and the animal trade in nineteenth-century India and Britain. J Hist Biol 30:145–178

Brooks JL (1984) Just Before the Origin: Alfred Russel Wallace's theory of evolution. Columbia University Press, New York

Chambers R (1844) Vestiges of the natural history of creation. John Churchill, London [Facsimile reprint: Secord J (ed) (1995) Vestiges of the natural history of creation and other evolutionary writings. University of Chicago Press, Chicago and London]

Corsi P (1978) The importance of French transformist ideas for the second volume of Lyell's Principles of Geology. Brit J Hist Sci 2:1–2

Costa JT (2013) On the organic law of change: an annotated transcription of Alfred Russel Wallace's species notebook, 1855–1859. Harvard University Press, Cambridge (in press)

DCP (2013) Secord J et al (eds) [Darwin Correspondence Project]. http://www.darwinproject.ac.uk/. Accessed April 2013

Davies R (2012) How Charles Darwin received Wallace's Ternate paper 15 days earlier than he claimed: a comment on van Wyhe and Rookmaaker (2012). Biol J Linn Soc 105:472–477

de Beer G (ed) (1959) 'Darwin's Journal.' Bull Brit Mus (Nat Hist), Hist Series 2:1–21

de Candolle AP (1820) Géographie botanique. In: Cuvier G (ed) Dictionnaire des sciences naturelles. Paris, 18:359–422

Fichman M (2004) An elusive victorian: the evolution of Alfred Russel Wallace. University of Chicago Press, Chicago

Hallam A (1998) Lyell's views on organic progression, evolution and extinction. In: Blundell DJ, Scott AC (eds) Lyell: the past is the key to the present, vol 143. Geological Society Special Publication, London, pp 133–136

Kutschera U (2003) A comparative analysis of the Darwin-Wallace papers and the development of the concept of natural selection. Theory Biosci 122:343–359

Lamarck J-B (1809) Philosophie zoologique, ou exposition des considérations relatives à l'histoire naturelle des animaux [...]. Paris

Lyell C (1830–1833) Principles of geology, vol I–III. John Murray, London

Lyell C (1835) Principles of geology, vol I–IV, 4th edn. John Murray, London

Malthus TR (1798) First essay on population. J. Johnson, London

McKinney HL (1972) Wallace and natural selection. Yale University Press, New Haven

Moore J (1997) Wallace's Malthusian moment: the common context revisited. In: Lightman B (ed) Victorian science in context. University of Chicago Press, Chicago, pp 290–311

Osborn HF (1928) Impressions of great naturalists. Charles Scribner's Sons, New York

Porter D (2012) Why did Wallace write to Darwin? Linnean 28:17–25

Recker D (1990) There's more than one way to recognize a Darwinian: Lyell's Darwinism. Phil Sci 57:459–478

Rudwick MJS (1970) The strategy of Lyell's Principles of Geology. Isis 61:5–33

Rudwick MJS (1972) The meaning of fossils: episodes in the history of palaeontology. MacDonald & American Elsevier Inc., London

Rudwick MJS (1998) Lyell and the Principles of Geology. In: Blundell DJ, Scott AC (eds) Lyell: the past is the key to the present, vol 143. Geological Society Special Publication, London, pp 3–15

Rudwick MJS (2005) Bursting the limits of time: the reconstruction of geohistory in the age of revolution. University of Chicago Press, Chicago

Rudwick MJS (2008) Worlds before Adam: the reconstruction of geohistory in the age of reform. University of Chicago Press, Chicago

Slotten RA (2004) The heretic in Darwin's court: the life of Alfred Russel Wallace. Columbia University Press, New York

Smith CH (2013) A further look at the 1858 Wallace-Darwin mail delivery question. Biol J Linn Soc 108:715–718

Stevenson B (2009) Samuel Stevens, naturalist (1817–1899). Microscape Mag. no. 166 (http://www.microscopy-uk.org.uk/mag/indexmag.html)

Van Wyhe J, Rookmaaker K (2012) A new theory to explain the receipt of Wallace's Ternate essay by Darwin in 1858. Biol J Linn Soc 105:249–252

Wallace AR (1852) Letter concerning the ship fire dated 19 Oct. 1852. Zoologist 10:3641–3643

Wallace AR (1855) On the law which has regulated the introduction of new species. Annals Mag Nat Hist 16(2nd series):184–196

Wallace AR (1858a) On the tendency of varieties to depart indefinitely from the original type. Proc Linn Soc 3:53–62

Wallace AR (1858b) Note on the theory of permanent and geographical varieties. Zoologist 16:5887–5888

Wallace AR (1869) The Malay archipelago; the land of the orang-utan and the bird of paradise. Harper & Brothers, New York

Wallace AR (1905) My life: a record of events and opinions, vol 2. Chapman & Hall, London

Wallace AR (1909) Note on the passages of Malthus's 'Principles of Population' which suggested the idea of natural selection to Darwin and myself. The Darwin-Wallace Celebration Held on Thursday, 1st July 1908, by the Linnean Society of London. Longmans Green & Co., London

WCP (2013) Beccaloni GW (ed) Wallace letters online [Wallace Correspondence Project]. http://www.nhm.ac.uk/wallaceletters online. Accessed 12 April 2013

Wilson LG (1970) Sir Charles Lyell's scientific journals on the species question. Yale University Press, New Haven

Wilson LG (1973) Charles Lyell. In: Gillispie CC (ed) Dictionary of scientific biography, vol VIII. Charles Scribner's Sons, New York