SACRED BOVINES

# ON GENIUS & HAPPENSTANCE IN SCIENTIFIC DISCOVERY

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On June 18, 1858, Charles Darwin, a noted and widely respected British naturalist, received another letter from a fellow naturalist collecting specimens halfway around the world, in the Malay archipelago. The correspondent asked Darwin to review a manuscript and forward it on to a colleague. A conventional professional courtesy. Almost routine. But Darwin read the enclosed essay with dismay. It was, as he confided to a friend, a nearly perfect abstract of his own thoughts, which he had committed to paper some two decades earlier, but never published. The writer was Alfred Russel Wallace. Like Darwin, he had discovered the role of variation and selection in the origin of new species.

Such independent discoveries invite reflection on the role of creativity in science. Why does one person, and not another, make a significant discovery? We tend to regard momentous insights as acts of genius, an inherent property of the person. But when two scientists make the same discovery, is the genius shared or does the coincidence reflect an inevitability?

After grasping Darwin's central idea, Thomas Huxley later recalled thinking, "How extremely stupid not to have thought of that!" (Huxley, 1887, p. 197). He chastised himself and colleagues: "we reproached ourselves with dullness for being perplexed with such an inquiry." Of course, that is the nature of virtually every discovery. It seems perfectly obvious once someone has already articulated it. The prospective view is far less clear. And for that very reason, Huxley's clever remark was full of irony: namely, we owe the discovery of natural selection to exceptional insight. On Huxley's principle, generally endorsed I think, Darwin and Wallace are each honored for their genius. "Great minds think alike," we often hear (Carroll, 2009).

Here I wish to challenge the conventional view of genius and discovery, this month's sacred bovine. Science owes much more to contingency and happenstance than is conventionally acknowledged. By comparing the stories of Darwin and Wallace, one can see how the important ideas emerged from a set of parallel experiences. Discovery was primarily due to a particular constellation of circumstances, which the two just happened to share. And that is fortunate, because it means, echoing Huxley perhaps, that given the right context, anyone can conceptualize natural selection. The puzzle is easy to solve, once the right pieces are assembled and appropriately configured. Even for students today. History is a guide to the critical ensemble of experiences. In the spirit of this issue's special theme, that might bode well for evolution education. On a larger scale, it also means that scientific discovery is not the exclusive privilege of gifted minds. With good fortune and perseverance, anyone might make a great scientific discovery.

## ○ Wallace's Discovery

Darwin's story is well known to biology teachers (WGBH, 2001; American Museum of Natural History, 2005; Girard et al., 2009). The story of Alfred Russel Wallace is less familiar, but equally fascinating (Brooks, 1984; Raby, 2001; van Wyhe, 2013). Indeed, it is quite possible, following Wallace's life story, to guide students through the reasoning to develop evolutionary concepts on their own – as presented in an excellent inquiry case study by Ami Friedman (2010).

Here, I highlight just a few critical features of Wallace's biography and intellectual development. To begin, as a young adult Wallace was an avid natural-history collector, first of plants, then of beetles. He remembered encountering a lady on the street who remarked:

> "We found quite a rarity the other day – the Monotropa; it had not been found before." This I pondered over, and wondered what the Monotropa was. All my father could tell me was that it was a rare plant; and I thought how nice it must be to know the names of rare plants when you found them. (Wallace, 1905, p. 110)

A few years later he met Henry Walter Bates, who impressed Wallace with his vast beetle collection:

> I was amazed to find the great number and variety of beetles, their many strange forms and often beautiful markings or colourings.… [S]o I at once determined to begin collecting, as I did not find a great many new plants around Leicester. I therefore obtained a collecting bottle, pins and a store-box; and in order to learn their names and classifications I obtained, at wholesale price through Mr. Hill's bookseller, Stephen's "Manual of British Coleoptera," which henceforth for some years gave me almost as much pleasure as Lindley's Botany. (p. 237)

Through collecting, Wallace developed a deep appreciation of diversity. He also learned the challenging subtleties of classification in discerning species, varieties, and races. Here was the emotional and conceptual foundation for thinking about the very problem of species and how they might originate (Wallace, 1909, pp. 8–9; Berry, 2008).



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Wallace's early fascination later became his livelihood. He voyaged to the Amazon, collecting specimens for sale. As he traveled widely in the field, Wallace became sensitized to biogeography. He noticed in particular that monkeys, insects, and birds differed on either side of the Rio Negro, with Colombian types to the west and Guyanan forms to the east. He advised his fellow naturalists that it was not enough merely to record the region where one found a specimen; one also needed to document on which side of any river it was located. Wallace was developing an emerging appreciation of geographical barriers between closely allied species (Michaux, 2008).

Later, Wallace ventured to the Malay archipelago, with its prospect for profit from the abundance of unfamiliar and exotic species, from birds to butterflies to beetles. Wallace's biogeographical awareness deepened. For example, he found trogons, elegant and colorful birds he had seen earlier in South America. But in Asia they were all black-backed, whereas in the Amazon all were green-backed. Why? For someone already keenly aware of biological diversity, such coupled similarities and differences observed across an ocean posed puzzles about the relationships of unique groups and the separations between them.

Wallace's thinking was significantly shaped by working in an archipelago. The pattern of similarities and differences among organisms could be mapped across the neighboring islands. Each species seemed to succeed the next. He was also impressed by the discontinuity that we now call the Wallace Line. In 1856 he wrote home to his agent in London about the distribution of cockatoos:

> The birds have, however, interested me much more than the insects, as they are proportionably much more numerous, and throw great light on the laws of geographical distribution of animals in the East. The Islands of Baly and Lombock, for instance, though of nearly the same size, of the same soil, aspect, elevation and climate, and within sight of each other, yet differ considerably in their productions, and, in fact, belong to two quite distinct zoological provinces, of which they form the extreme limits. As an instance, I may mention the cockatoos, a group of birds confined to Australia and the Moluccas, but quite unknown in Java, Borneo, Sumatra and Malacca; one species, however (*Plyctolophus sulphureus* [the lesser sulfur-crested cockatoo]), is abundant in Lombock, but is unknown in Baly, the island of Lombock forming the extreme western limit of its range and that of the whole family. (*Zoologist*, vol. 15 [1857], p. 5415)

Wallace's thoughts began to coalesce noticeably when he collected a new species of bird-wing butterfly – part of a group of spectacular large butterflies, ≥20 cm across, with vivid green markings on a black background. Several nearby species were similar, but another was strikingly different (Figure 1). Wallace could see the continuities and discontinuities at the same time. That framed the key final puzzle: Why were the transitional forms missing?

Finally, through reflection, Wallace realized what would account for the absent intermediates. They had died, unable to compete with

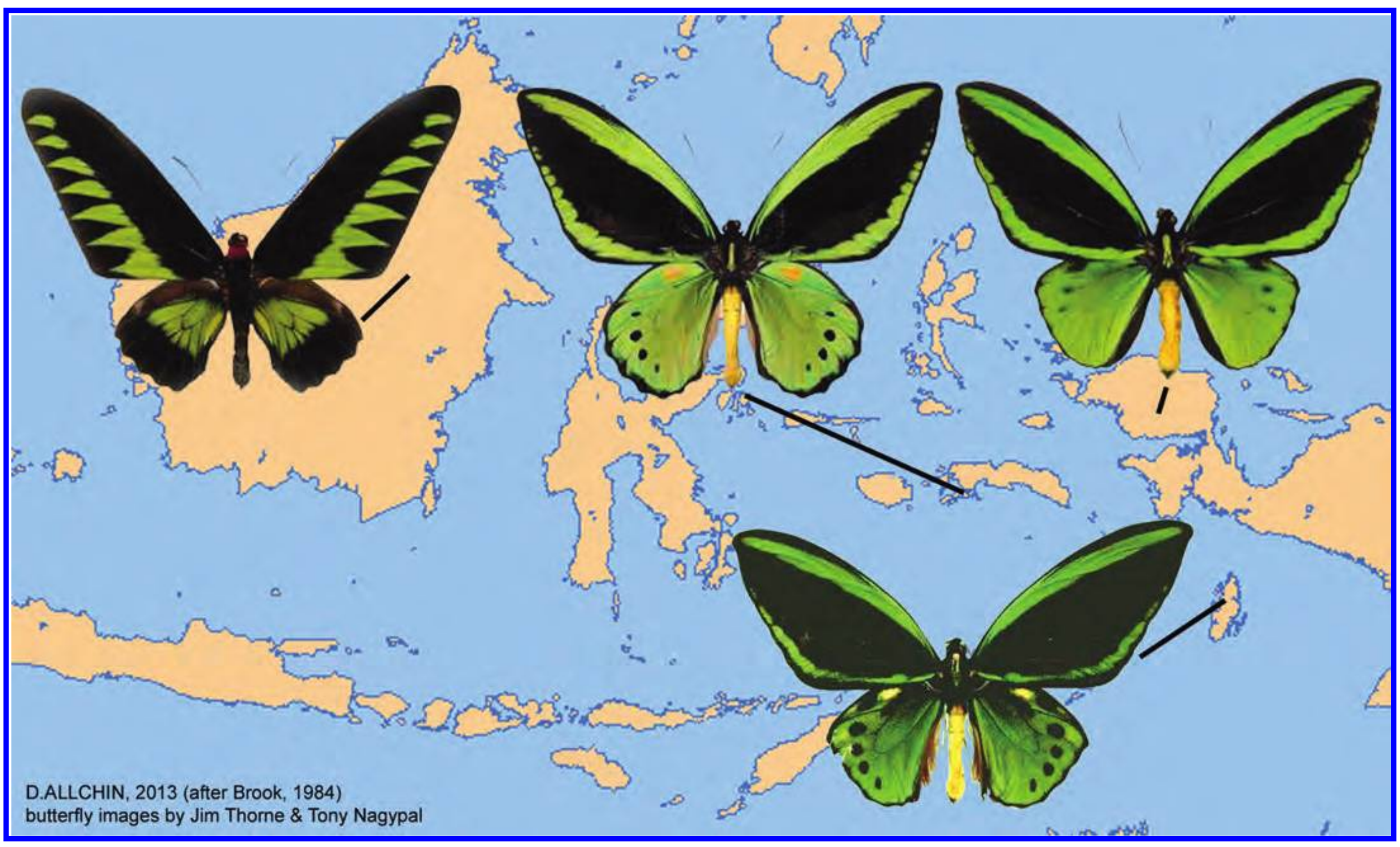


**Figure 1.** Distribution of bird-wing butterflies that helped lead Wallace to understanding the interaction of geographical isolation and selection in the origin of new species.

the forms that survived. He recounted his insight in a now famous passage:

> I was…suffering from a sharp attack of intermittent fever, which obliged me to lie down every afternoon during the cold and subsequent hot fits which lasted together two or three hours. It was during one of these fits, while I was thinking over the possible mode of origin of new species, that somehow my thoughts turned to the "positive checks" to increase among savages and others described in much detail in the celebrated *Essay on Population*, by Malthus, a work I had read a dozen years before. These checks – disease, famine, accidents, war, &c. – are what keep down the population, and it suddenly occurred to me that in the case of wild animals these checks would act with much more severity, and as the lower animals all tended to increase more rapidly than man, while their population remained on the average constant, there suddenly flashed upon me the idea of the survival of the fittest – that those individuals which every year are removed by these causes – termed collectively the "struggle for existence" – must on the average and in the long run be inferior in some one or more ways to those which managed to survive. (Wallace, 1903)

Malthus's essay provided Wallace the final piece in assembling the concept of competition and selection as the process that led to the origin of new species from isolated populations. That was what Wallace described in his fateful 1858 communication to Darwin.

## ○ Wallace & Darwin Compared

Wallace followed a very different trajectory than Darwin, whose voyage on the *Beagle* is widely retold. But it was also remarkably similar. Precisely those shared features, I contend, help us understand their shared discovery (Figure 2). Darwin, too, was an avid collector as a youth. His beetle-collecting habits were even lampooned by his peers. In a 1908 commemoration, Wallace, at least, attributed the discovery of his and Darwin's theory to their both being "ardent beetle-hunters," impressed "by the almost infinite number of its specific forms, the endless modifications of structure, shape, colour, and surface-markings that distinguish them from each other, and their innumerable adaptations to diverse environments" (1909, p. 8).

During his voyage on the *Beagle*, Darwin had also been impressed by rivers as barriers – in his case, the Rio Negro of Patagonia, which separated two species of the ostrich-like rhea. The rhea was to reappear at a pivotal point in Darwin's thinking about divergence and evolutionary trees (*B Notebook*, pp. 13, 16, 37; *Red Notebook*, p. 153; Darwin, 1837; 1839, pp. 108–109; 1859, p. 349; Laden, 2008). Third, Darwin also noticed the relationships of species across vast expanses of ocean. For him, it was the resemblance of the Galápagos mockingbirds, finches, and other organisms to those on the South American mainland that drew his attention:

> It was most striking to be surrounded by new birds, new reptiles, new shells, new insects, new plants, and yet by innumerable trifling details of structure, and even by the tones of voice and plumage of the birds, to have the temperate plains of Patagonia, or the hot dry deserts of Northern Chile, vividly brought before my eyes. Why, on these small points of land, which within a late geological period must have been covered by the ocean, which are formed of basaltic lava, and therefore differ in geological character from the American continent, and which are placed under a peculiar climate – why were their aboriginal inhabitants, associated, I may add, in different proportions both in kind and number from those on the continent, and therefore acting on each other in a different manner – why were they created on American types of organization? (Darwin, 1845, p. 393)

Darwin, too, had experienced the characteristic clustering of species in an archipelago – notably the different tortoises of the eponymous Galápagos Islands, as well as their mockingbirds (*B Notebook*, p. 7; Darwin, 1845, pp. 394, 397) (later, his appreciation would include the finches, as well). From these experiences, Darwin likewise reasoned about the role of isolation in the divergence of species.

Finally, in rereading Malthus's essay, Darwin, like Wallace, recognized the role of variation and selection in adaptive change. Many others had read that essay too, of course, but not primed with the same background and perspective.

| Shared Experience | Wallace | Darwin |
|---|---|---|
| natural history collecting in childhood | plants & beetles | beetles |
| different species separated by rivers | monkeys, insects & birds in Amazon (Rio Negro) | rheas in Patagonia (Rio Negro) |
| similar species across oceans | trogons (South America & Malay) | mockingbirds, finches (American mainland & Galápagos) |
| species similarities & differences in archipelago | cockatoos, bird-wing butterflies & others (Malay) | tortoises, finches (Galápagos) |
| Malthus, *On Population* | 1846 reading | 1838 leisure reading |

**Figure 2.** Parallel experiences that significantly shaped Wallace's and Darwin's thinking.

Together, these five benchmarks (Figure 2) help delineate a path of commonplace reasoning to the concepts of species transmutation and natural selection. While Darwin and Wallace ultimately differed in style, emphasis, and conceptual details (Eiseley, 1961, pp. 287–324; Kutschera, 2003; Fagan, 2007), they shared many experiences. Those parallels significantly shaped the core of their discovery. Darwin and Wallace aptly exemplify convergent evolution in scientific thinking.

Two features of this ensemble of critical observations are worth noting. First, biogeographical patterns seem to have been central for both thinkers.

This contrasts with the relative insignificance of the topic in most modern biology instruction, judging from popular textbooks. Evolution education might thus benefit from greater emphasis on understanding the patterns of species distributions and what they indicate (Rosenau, 2012). Students need a sampling of detailed biogeographical knowledge if they are to truly appreciate evolutionary ideas.

Second, the discovery in each case was "backwards" from the reasoning that seems to drive the process forward causally. That is, Darwin's and Wallace's formal arguments began with Malthus and the "struggle for existence." They then proceeded through selection to the effects on species change. For Darwin, geographical distribution was presented relatively late (chapters 11 and 12 of fourteen in the *Origin*), as a consequence of the theory, rather than as the initial seed for reasoning about divergence. Historically, however, both discoverers originally tracked the process "upstream" from the observed outcome. Malthus was ultimately the final, not the first, item, from which comprehensive undertstanding cascaded. Again, this can provide important clues to educators interested in guiding students gradually through thinking about evolution and the natural history of species.

## ○ Reconsidering the Role of Genius

Nobel Prize–winning biochemist Albert Szent-Györgyi famously characterized discovery as "seeing what everybody else has seen, and thinking what nobody else has thought" (Philpott, 2004, p. 42). While surely inspirational, the phrase may also have been self-serving, mindfully rendering scientists (like himself) as privileged individuals with rare endowments. However, an analysis of Wallace and Darwin's parallel achievement indicates that "thinking what nobody else has thought" may in fact be related, more mundanely, to just what one uniquely "sees." What one sees and considers salient, in turn, arises concretely from personal biography and circumstance. Not from special or innate ability. Discovery may owe as much to happenstance as to a basic intellect that can capitalize on any particular suite of observations.

Ironically, great minds *do not* think alike. Huxley, Lyell, Hooker, Segwick, Owen, Agassiz, and other luminaries of the time did not discover natural selection. But it was not because they were not great minds. Their other achievements amply demonstrate their professional competence. Rather, their constellation of experiences led them down different paths, to other insights and discoveries.

Of course, as Huxley acknowledged, they were able to follow Darwin and Wallace, once the path was laid out explicitly for them. It may have seemed obvious in retrospect. But again, that is the enigmatic asymmetry of discovery: noticing how selected items in a chaotic set of unorganized observations exhibit a coherent pattern. It may seem like special creative insight, or genius. But certain new ideas seem to evolve naturally from certain precursors given just the right environment. With appropriate guidance, even today's students can share Wallace's and Darwin's great discovery for themselves.

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