Commentary

Why Darwin rejected intelligent design

As a Cambridge University undergraduate Charles Darwin was fascinated and convinced by the argument for intelligent design, as set forth in William Paley's 1802 classic, *Natural Theology*. Subsequently, during his five-year voyage on HMS *Beagle* (1831–1836), Darwin interpreted his biological findings through a creationist lens, including the thought-provoking evidence he encountered during his historic visit to the Galápagos Islands in September and October 1835. After his return to England in 1836 and his subsequent conversion to the idea of organic evolution in March 1837, Darwin searched for a theory that would explain both the fact of evolution and the widespread appearance of intelligent design. His insight into the process of natural selection, which occurred in September 1838, provided this alternative explanation. Darwin's *Origin of Species* (1859) exemplifies his skillful deployment of the hypothetico-deductive method in testing and refuting the arguments for intelligent design that he had once so ardently admired.

1. Introduction

There is considerable irony in the fact that Charles Darwin was at one time enthralled by the theory that all species are intelligently designed–a theory he later sought to banish from science in his *Origin of Species* (1859). Popularized in the seventeenth century in works such as John Ray's *The Wisdom of God Manifested in the Works of the Creation* (1691), this doctrine sought to unite a celebration of God's handiwork in the Creation with the pursuit of natural science. Such theologically inspired arguments reached their apogee a century later in the writings of William Paley (figure 1). A clergyman like Ray, Paley set forth his influential ideas in *Natural Theology; or, Evidences of the Existence and Attributes of the Deity, Collected from the Appearances of Nature* (1802). The many proofs he adduced in favour of intelligent design, including the hinges on bivalve shells and the plumes that facilitate wind dispersal of certain seeds, fascinated and convinced young Darwin (1958 [1876]:87, 119).

2. Darwin's youthful commitment to intelligent design

Natural Theology is constructed around the analogy of a watchmaker, a metaphor borrowed from previous advocates of the design doctrine. Imagine, Paley suggests, that you are walking across a heath and suddenly encounter a watch lying on the ground. After close inspection of the watch, you would be compelled to conclude that such an intricate device could not have been constructed otherwise in order for it to work. It is only reasonable to assume "that the watch must have had a maker; that there must have existed, at some time and at some place or other, an artificer or artificers who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use" (1802:3–4). In the case of living organisms Paley continued, the evidence for design is even stronger "in a degree which exceeds all computation" (1802:19), and he concluded: "The marks of *design* are too strong to be got over. Design must have had a designer. That designer must have been a person. That person is GOD" (1802:473).

The efforts by Ray, Paley, and others to unite natural history with theology were among the inducements that inclined Darwin, at the age of eighteen, to look favourably on a career in the church. Sent by his father two years earlier to study medicine at Edinburgh University, Darwin had found himself uninspired by this profession and revolted by the sight of operations, which at that time were conducted without the benefit of anesthesia. Worried that his son might turn into "an idle sporting man," Darwin's

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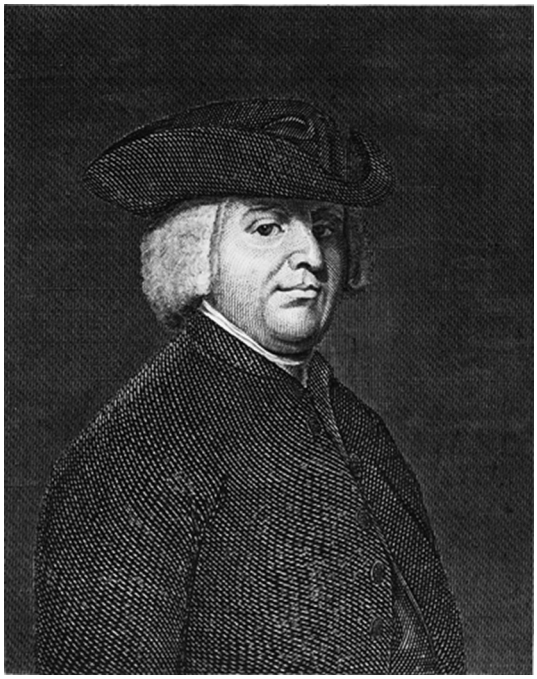

Figure 1. William Paley (1743–1805), archdeacon of Carlisle (from Paley 1860: Frontispiece). Paley's works were mandatory reading at Cambridge University from 1787 to 1920. During Darwin's undergraduate years (1829-1831), Paley's influence on the university's curriculum was second only to that of Isaac Newton (Crimmins 2004).

father, a successful physician, proposed that he attend Cambridge University in preparation for becoming an ordained minister. "Considering how fiercely I have been attacked by the orthodox," Darwin reflected on this youthful career decision in his *Autobiography,* "it seems ludicrous that I once intended to be a clergyman" (1958 [1876]:56–57).

At Christ's College, Cambridge, Darwin was assigned the same rooms that Paley had occupied more than a half century earlier (Browne 1995:93). Paley's *Principles of Moral and Political Philosophy* (1785) and his *Evidences of Christianity* (1794) were among the books selected as examination topics for Darwin's BA degree in 1830. Darwin studied these works diligently, as he later recalled in his *Autobiography*:

> I am convinced that I could have written out the whole of the *Evidences* with perfect correctness, but not of course in the clear language of Paley. The logic of this book and as I may add of his *Natural Theology* gave me as much delight as did Euclid. The careful study of these works, without attempting to learn any part by rote, was the only part of the Academical Course which, as I then felt and as I still believe, was of the least use to me in the education of my mind. I did not at that time trouble myself about Paley's premises; and taking these on trust I was charmed and convinced by the long line of argumentation. (1958 [1876]:59)

On the very day of publication of the *Origin of Species* three decades later, Darwin reiterated his praise for Paley in a letter to his neighbour in Downe, John Lubbock: "I do not think I hardly ever admired a book more than Paley's *Natural Theology*: I could almost formerly have said it by heart" (1991:188). Even after the *Origin* had finally turned the tide in thinking about the theory of evolution and had introduced Darwin's even more controversial mechanism of evolutionary change–natural selection–Darwin was still subject to the compelling lure of the design doctrine. The Duke of Argyll reported a conversation he had had with Darwin on this issue during the last year of Darwin's life. The Duke had maintained that he could not look upon certain adaptations, such as those found in orchids, "without seeing that they were the effect and the expression of mind. I shall never forget Mr Darwin's answer. He looked at me very hard and said, 'Well, that often comes over me with overwhelming force; but at other times,' and he shook his head vaguely, adding, 'it seems to go away'" (Darwin 1887, 1:316).

3. The *Beagle* voyage (1831–1836)

What triggered Darwin's dramatic change of mind about the origin of species was his five-year voyage around the world on HMS *Beagle*, and especially his five-week visit to the Galápagos Islands in September and October 1835. Legend has it that Darwin underwent a eureka-like conversion to the theory of evolution during this brief visit. Shorn of the legend, the actual story of Darwin's conversion, which only occurred a year and a half later, after his return to England, tells us far more about how science is really done, especially how theory guides observation and prepares the mind, and how dogged persistence is often required to transform controversial theories into widely accepted facts.

While in the Galápagos, creationist theory primed Darwin in key ways for what he observed and understood there. Just as important, this theory also dictated what he failed to observe and understand. Commenting on his extensive efforts to collect specimens on Charles Island, the second of the four islands he visited, Darwin recorded in his personal journal, "It will be very interesting to find from future comparison to what district or 'centre of creation' the organized beings of this archipelago must be attached" (1988:356). He was clearly trying to reconcile the new and strange creatures he was encountering in this remote archipelago with the prevailing creationist paradigm. According to this theory, different "centres of creation" explained why the earth's flora and fauna differed from one region to another–for example, between continents. What is apparent from Darwin's reference is that he did not yet realize that such a tiny portion of the globe as the Galápagos archipelago might actually be its own "centre of creation."

Today, as a result of Darwin's change of scientific heart, the Galápagos are widely recognized as a classic laboratory of evolution in action, and hence (to use the pre-Darwinian terminology) as a unique centre of creation in their own right. In significant part, the islands owe their biological celebrity to the fact that they are geologically young–about 3 million years old, although a few former islands, now eroded down by the ocean and submerged beneath the sea, date back as much as 17 million years (Christie *et al.* 1992; Werner and Hoernle 2003). Based on his own geological observations, Darwin correctly realized that life in these distant islands had been given a new beginning. He later reflected on this conclusion in his *Journal of Researches*:

> Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period geologically recent the unbroken ocean was here spread out. Hence, both in space and time, we seem to be brought somewhat near to that great fact–that mystery of mysteries–the first appearance of new beings on this earth. (1845:377–378)

Certain unexpected facts about the Galápagos undermined the credibility of a creationist solution to this "mystery of mysteries." In particular, each island in the Galápagos group has evolved many of its own distinct species over time, following the stocking of the islands by chance colonists who managed to arrive there from the Central and South American mainland, almost 600 miles away. Darwin was first alerted to this possibility by Nicholas Lawson, the vice-governor of the islands, whom Darwin encountered on Charles Island. As he reported in his *Journal of Researches,* Lawson insisted that "the tortoises differed from the different islands, and that he could with certainty tell from which island any one was brought" (1845:394). Unfortunately, Darwin did not at first pay sufficient attention to the vice-governor's testimony, in part because of an error in the contemporary zoological literature. Like other naturalists, Darwin was under the mistaken impression that the Galápagos tortoise, which was at that time classified under the misleading scientific name *Testudo indicus*, was not native to the Galápagos but had been transported there by buccaneers or ocean-going Polynesians, from islands in the Indian Ocean, where similar forms of giant tortoise are found (Darwin 1839:465, 628; FitzRoy 1839:505). Only after Darwin's return to England did it become clear that these two taxa were separate species (Sulloway 1982b).

There was a second reason why Darwin initially overlooked the vice-governor's remarks about the tortoises. Creationist theory held that species can and do change in response to local environments. Like an elastic band that resists being stretched, any discrepancies among varieties from the supposedly immutable specific type were thought to be temporary deviations, maintained by unusual ecological conditions. During his Galápagos visit, Darwin therefore appears to have concluded that possible island-to-island differences among the giant land tortoises were no more remarkable than if introduced goats were also to differ from island to island in characteristics such as colour and size. These sorts of local

differences were readily interpretable as short-term perturbations somehow induced by transport to new and demanding environments.

As a result of his creationist perspective on species and varieties, Darwin–astonishingly, from our modern evolutionary viewpoint–failed to collect a single specimen of giant tortoise for scientific purposes during his Galápagos stay. After he had left the Archipelago and was sailing to Tahiti, Darwin had one last opportunity to rectify this collecting oversight. The *Beagle* had stocked 48 tortoises from Chatham, the first of the four islands Darwin had visited. As they sailed across the Pacific, Darwin and his fellow shipmates gradually ate their way through the evidence that was later, in the form of hearsay, to revolutionize the history of science. The carapaces of these 48 tortoises, which could have been compared with other specimens in European museums, were unfortunately all thrown overboard with the rest of the *Beagle*'s garbage (Sulloway 2009).

This same creationist mindset helps to explain why Darwin at first failed to understand the most famous Galápagos exemplar of evolution in action–namely, Darwin's famous finches. Fourteen species of finches have evolved in the Galápagos Islands from an ancestral form now known to be a close relative of the *Tiara* group (grassquits), which is found in Central and South America (Petren *et al.* 1999). Over the last 2 million years or so, this evolutionary process has resulted in such impressive adaptive radiation into diverse ecological niches that some of these 14 Galápagos species are not particularly finchlike in appearance. Although 4 of the 14 species feed primarily on seeds, as finches generally do, another 2 species feed on the fruits, flesh, and flowers of cactus. Seven additional species are primarily insectivorous, and one very remarkable species feeds almost exclusively on leaves (Lack 1947; Grant and Grant 2008). It is not surprising, then, that Darwin was fooled by some of these finches into thinking they were not finches at all but the species they had come to mimic through a process known as convergent evolution (Sulloway 1982a). In his specimen notebook, for example, he listed the warbler finch as a "Wren"–which is what this bird, to an untrained eye, appears to be. Similarly, he listed the cactus finch, which has a long pointed bill for getting at the fruits and flowers of the *Opuntia* cactus, as a member of the Icteridae, which is the family of meadowlarks and orioles.

So confusing was the case of the Galápagos finches that Darwin did not grasp, at the time of their collection, that all these birds were closely related or that the peculiarly large number of species in this one avian group might result from their having evolved on different islands. He therefore made no effort to label his ornithological collections by island, something he was later to regret when he finally surmised the evolutionary origins of this peculiar group of birds (Sulloway 1982c). Nor did Darwin have the opportunity to observe these finches in sufficient detail to realize that their beak sizes and shapes were closely related to their diets, an important insight that the legend wrongly ascribes to him.

4. Darwin's conversion to evolution (1837)

Despite being armed with an inadequate theory during his Galápagos visit–a theory that served to undermine his collecting methodology by causing him to believe that the Galápagos Islands were part of a much larger centre of creation–Darwin was too good a naturalist not to notice that the four mockingbird specimens he had collected, each from a different island, were either distinct varieties or species (figure 2). Not being an expert in ornithology, Darwin was unsure just what to make of this anomaly, but he did record localities for these four specimens. In July 1836, nine months after his Galápagos visit, Darwin reflected on this unusual case of the mockingbirds and recalled as well what he had been told about the tortoises:

> When I see these Islands in sight of each other, & possessed of but a scanty stock of animals, tenanted by these birds, but slightly differing in structure & filling the same place in Nature, I must suspect they are only varieties. . . . If there is the slightest foundation for these remarks the zoology of Archipelagoes–will be well worth examining; for such facts would undermine the stability of Species. (1963 [1836]:262)

The key to interpreting this famous passage–which broaches the Darwinian revolution only to back away from it–is the phrase "I must suspect they are only varieties," a presumption that Darwin understood to be fully consistent with creationist theory (Sulloway 2009). What kept Darwin from taking the crucial step from scientific orthodoxy to heterodoxy at this point in the *Beagle* voyage was a lack of information

Figure 2. Darwin's Galápagos mockingbird specimens (genus *Nesomimus*). From top to bottom, the birds are arranged in the order Darwin collected them (on Chatham, Charles, Albemarle, and James). The first two specimens (*N. melanotis* and *N. trifasciatus*) are considered separate species from the third and fourth specimens (*N. parvulus*). The three species differ in bill length, eye colour, and plumage. (Courtesy of the Natural History Museum, Tring.)

about proper ornithological classification, which would only become available to him back in England through access to museum collections and especially the judgements of expert ornithologists, who were much more familiar than Darwin was with the defining features of species and varieties, especially in the particular Galápagos taxa he had collected. Faced with an absence of crucial information to resolve the issue, Darwin continued to give a nod toward the prevailing creationist assumption that variation within immutable species can lead to new varieties or subspecies that are adapted to local environments. Despite any doubts Darwin may have entertained on this subject during the remainder of the *Beagle* voyage, this scientific position was perhaps the most responsible one for him to have taken at that time.

Darwin returned to England on 2 October 1836. Three months later, he deposited his *Beagle* collections of birds with John Gould, the ornithological expert at the London Zoological Society. Gould, who was in the process of becoming famous for his beautifully illustrated monographs on birds of the world, immediately realized the extraordinary nature of Darwin's Galápagos specimens and described them first, ahead of other birds from the *Beagle* voyage (Gould 1837a, b).

Darwin did not obtain a full report on Gould's findings until early March 1837, when he moved from Cambridge to London. After the two men had discussed these findings in detail, Darwin's life and scientific thinking were never the same. Gould informed Darwin that 3 of his 4 specimens of Galápagos mockingbird were distinct species, new to science and different from all known mockingbirds. Gould also informed Darwin that his collection included 13 or possibly 14 species of very unusual finches, all so closely related that Gould had placed them in a single new group. As for the land birds as a whole, 25 of the 26 species were judged to be new to ornithology and unique to the Galápagos, something Darwin could not have known without access to the museum collections and previously published descriptions

available to Gould. All of a sudden, following Gould's taxonomic analyses, the Galápagos Islands had become their own distinct "centre of creation." Darwin now found himself directly confronted by the problem of the origin of species in a way he had not been when he was visiting those islands.

Darwin appears to have been stunned by Gould's conclusions. He quickly realized that if Gould was right about the mockingbirds–and Darwin (1841:63–64) pressed him on this point to be certain–the supposedly immutable barrier that exists between separate species had somehow been broken by these birds, isolated on the different islands of the Galápagos group. Gradual evolution through geographic isolation was the only plausible explanation, unless one believed that God, like an obsessive-compulsive gardener, had gone from one island to the next in the Galápagos group whimsically creating separate but closely allied species intended to fill the same ecological niches. As for the much more complex case of the finches, once Gould had convinced Darwin that these birds were all closely related by analogy with the simpler and more compelling case of the mockingbirds, Darwin was able to see the finches in a radically new light (figure 3). As he later observed in his *Journal of Researches*: "Seeing this gradation and diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends" (1845:380). Only now did he appreciate the extent of his previous oversight in failing to label the bulk of his Galápagos birds by island. Such evidence, he realized, would help to account for why so many different species of finches lived in this archipelago.

Fortunately, Darwin knew that three other collectors on the *Beagle* (Captain FitzRoy, FitzRoy's steward Harry Fuller, and Darwin's own servant, Syms Covington) had also collected specimens in the Galápagos. All of these specimens turned out to have been labelled by island; significantly, it was the nonscientists on the *Beagle*, who were not as theory-driven as Darwin, who recorded the scientific evidence that Darwin, based on a creationist approach, had considered superfluous. After his meeting with Gould, Darwin diligently sought out this locality information, and he later used it to support his case about the mockingbirds and tortoises, although the evidence was still uncomfortably tenuous (Sulloway

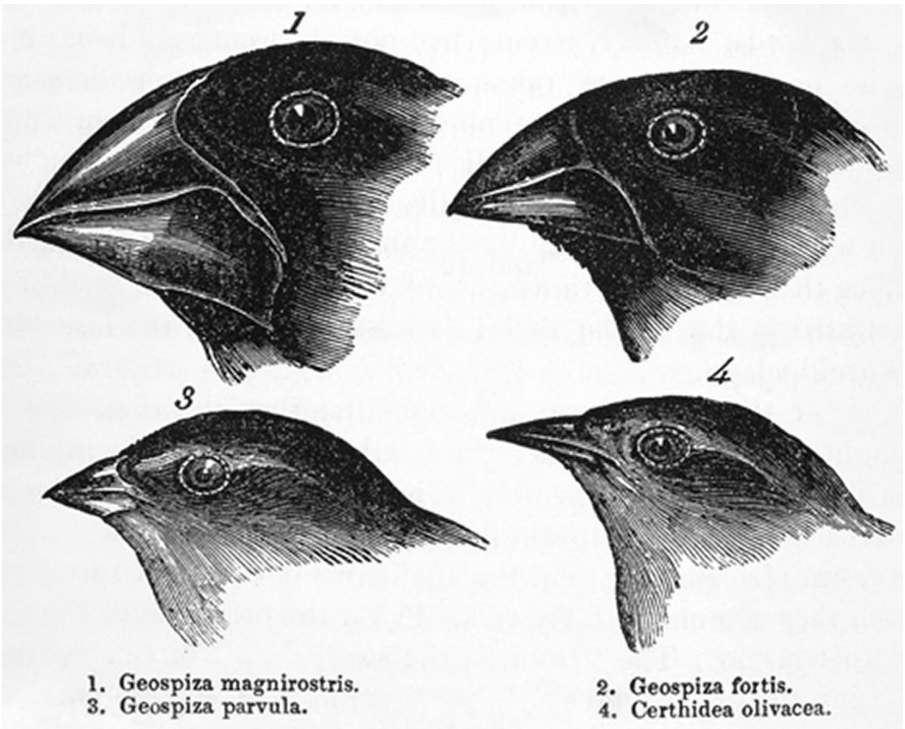

Figure 3. Four of the 14 species of Darwin's Galápagos finches (Geospizinae), as illustrated in the second edition of Darwin's *Journal of Researches* (1845:379). *Top left*, the large ground finch; *top right*, the medium ground finch; *bottom left*, the small tree finch; *bottom right*, the warbler finch, which is closest genetically to the common ancestor of this avian group. (Woodcut by James Lee.)

1982c, 1984). Fortunately, additional sources of information over the next two decades, which were drawn in part from reports about other oceanic archipelagos, would transform this suggestive evidence into incontrovertible fact.

Jolted by the Galápagos results, and struck by similar evidence about geographic distribution that began to emerge from taxonomic judgements about his South American collections, Darwin began a search in the spring of 1837 for a mechanism that would explain not only evolutionary change but also the most elusive puzzle about species–their highly adaptive nature. As he later recorded in a private journal: "In July [1837] opened first note book on 'Transmutation of Species'–Had been greatly struck from about Month of previous March on character of S. American fossils–& species on Galapagos Archipelago. These facts origin (especially latter) of all my views" (Darwin 1959:7).

Based on the evidence of the Galápagos mockingbirds, Darwin now understood that geographic isolation was a crucial part of the answer to how species transform themselves over time (Sulloway 1979; Mayr 1982). But isolation, although it could account for the origin and multiplication of new species over time, was insufficient to explain the often remarkable adaptations that species manifest to local environments. After exploring and rejecting a number of hypotheses about evolutionary change, Darwin happened to read, in September 1838, the 1826 edition of Thomas Malthus's *Essay on the Principle of Population.* Malthus argued that populations have an inherent tendency to grow geometrically. Yet, in nature, the food supply is limited, so most offspring do not survive, being killed by predators, famine, and diseases. On reading Malthus's book, Darwin immediately realized that in the ever-present struggle for existence, slight variations of a beneficial nature would tend be naturally selected, leading to increased survival and hence an increase in adaptive traits, just as the breeder of domesticated animals achieves desired traits by selecting the qualities that are esteemed in these animals. "Here, then," Darwin remarked in his *Autobiography*, "I had at last got a theory by which to work" (1958 [1876]:120). Here also was a credible answer to William Paley–one entailing a natural (as opposed to a supernatural) explanation of adaptations. Natural selection, Darwin realized, was none other than Paley's designer, an equivalence that later sometimes led Darwin to personify this evolutionary process, as in this celebrated passage from the *Origin*: "It may be said that natural selection is daily and hourly scrutinising, throughout the world, every variation, even the slightest; rejecting that which is bad, preserving and adding up all that is good; silently and insensibly working, whenever and wherever opportunity offers, at the improvement of each organic being in relation to its organic and inorganic conditions of life" (1859:84).

5. Intelligent design tested and refuted

Inspired by the striking evidence from the Galápagos Islands, and armed with his novel theory of natural selection, Darwin began to reexamine the basic assumptions of creationism and to compare the predictions one would make based on these two radically different theories. The more extensive his reexamination became, the more he realized that the theory of intelligent design, which gave creationism its scientific legitimacy, was overwhelmingly contradicted by the available evidence. Darwin's reassessment reached its culmination twenty-one years later in *On the Origin of Species by Means of Natural Selection*, a book that Darwin himself aptly characterized toward the end as "one long argument" (1859:459). It was as much an argument *against* creationism, and especially against the validity of intelligent design, as it was an argument *for* evolution, as Mayr (1991) has emphasized. Although Paley is mentioned only once in the *Origin*, his specter is everywhere apparent in Darwin's repeated discussions highlighting the lack of truly intelligent design in nature. Indeed, Darwin's "one long argument" was in many ways a direct response to "the long line of argumentation" by which Paley had charmed young Darwin as a Cambridge University undergraduate (1958 [1876]:59).

Not surprisingly, the evidence about geographical distribution, particularly about oceanic islands and their biological relationships with the nearest continents, plays a substantial role in Darwin's argument. The numerous problems that such islands raised for creationism had been surprisingly overlooked prior to Darwin's discussions of the subject, and this powerful class of evidence was the only topic to which Darwin devoted two whole chapters in the *Origin*. The Galápagos, for example, are home to various species of animals and plants closely allied to those from the neighbouring American continent, yet the environmental features of these islands do not at all resemble those of the nearest parts of the continent, which are tropical.

By contrast, the harsh volcanic environment of the Galápagos does closely resemble that of the Cape Verde Islands, 400 miles west of Africa. Yet the Cape Verdean flora and fauna are most strongly allied to species living on the African mainland, not to those in the Galápagos. Why would a Designer, Darwin asked, place two completely different creative stamps–one African and one American–on species that live in nearly identical environments and fill similar ecological niches? Creationist theory, he argued, ought to predict that such island species would either be identical or closely allied, based on the similar environments to which they are supposedly adapted by intelligent design. But the true circumstances are "utterly inexplicable on the ordinary view of independent creation of each species" (1859:406). By contrast, anyone who accepts the theory of evolution would expect precisely this sort of evidence.

Elsewhere in the *Origin*, Darwin generalized this argument about oceanic islands, which he described as having "the widest application throughout nature" (1859:403). One of the additional examples he offered was alpine species, which are almost always more closely related to nearby lowland forms than to alpine forms found in other parts of the world. Similarly, the same kind of geographic relationship was generally observed among so-called relict populations on continents, such as the blind organisms (rodents, reptiles, insects, crustaceans, and fish) that live within deep caverns. Few environments, Darwin argued, are more similar than the habitats characterizing cavern systems, because these systems are insulated from major changes in temperature, humidity, and the seasons. Yet blind cave animals, which often have rudimentary eyes that serve no purpose, are not most closely allied to other blind cave animals living in different parts of the world. Instead, these organisms closely resemble the surface-dwelling organisms on each of the continents where the caverns are found and from which their denizens have been derived by descent with modification (Darwin 1859:138, 404). In short, such facts about relict populations do not admit of a rational explanation in terms of the theories of independent creation and intelligent design. Such facts do, however, agree with expectations derived from evolutionary theory.

Islands like the Galápagos focused Darwin's attention on another class of facts inimical to the theory of intelligent design. Remote oceanic islands have very skewed floral and faunal distributions. Absent from such island populations are large terrestrial mammals as well as amphibians (frogs, toads, and newts). Yet bats, which can reach oceanic islands by flight, are regularly found to inhabit the islands of every major ocean. The physical conditions of such islands, Darwin maintained, do not explain the absence of amphibians and large terrestrial mammals, for when such animals have been introduced to oceanic islands–and Darwin presented relevant evidence in the *Origin* from numerous island localities–they have generally flourished "so as to become a nuisance" (1859:393). Although creationism and intelligent design supplied no explanation of such facts, this evidence was perfectly consistent with colonization by accidental transport. As Darwin noted, amphibians and their eggs are easily killed by immersion in salt water. By contrast, reptiles, which are often found on remote islands, are much better able to survive extraordinary ocean journeys.

The ease with which exotic animals and plants, brought by occasional visitors and colonists, have become naturalized on remote islands provided Darwin with another example of a fundamental weakness in design theory. Almost everywhere that animals and plants have been introduced to oceanic islands, the introduced forms have largely exterminated the native forms. When Darwin visited the Galápagos in 1835, this pernicious process had just begun, so he could refer to the looming problem there only in general terms. Commenting on the extreme tameness of the birds and animals in these islands–a disposition that allowed them to be easily killed by the colonists for food or sport–Darwin remarked, "What havoc the introduction of any new beast of prey must cause in a country, before the instincts of the indigenous inhabitants have become adapted to the stranger's craft or power" (1845:401). In support of this Galápagos observation, Darwin drew in the *Origin* on cases of oceanic islands that had been colonized much earlier. Of New Zealand he noted that the endemic organisms were "now rapidly yielding before the advancing legions of plants and animals introduced from Europe," and the original and highly endemic flora of Ascension Island, he reported, was all but extinct (1859:201).

Had the native animals and plants on those islands been specially designed by God for residing there, surely they ought to have prevailed over introduced organisms, which were presumably designed to live elsewhere. In contrast, evidence showing the consistent superiority of introduced forms was fully in accord, Darwin argued, with the theory of evolution by natural selection, because natural selection acts only on organisms as they compete with one another within local communities. Hence this evolutionary

process "will produce perfection, or strength in the battle for life, only according to the standard of that country." Remote islands, which typically have a meager collection of denizens compared with mainland ecological communities, have generally experienced less intense selection over time, and their residents "often yield, as we see they do yield, to the inhabitants of another and generally larger country" (1859: 205).

Once Darwin began to catalog instances of imperfect design in nature, more and more examples came to his attention through the revealing lens of evolutionary theory. In the *Origin* he provided scores of additional examples, drawn from biological domains such as morphology, classification, and embryology. The ultimate message in his relentless critique was simple: Any theory of the origin of species had to account not only for adaptations but also for their frequent imperfections. The main problem with the creationist doctrine was the copious evidence of poor design. To account for such evidence, Paley and his predecessors had to assume that their presumed Watchmaker was somehow lacking in foresight and sometimes just plain derelict or even malicious. Darwin, of course, was careful not to push that argument too far, lest he offend his more theologically-minded readers. But he did allude more than once in the *Origin* to the dark side of intelligent-design doctrine; for instance, he noted that it seemed preferable to explain the behaviour of baby cuckoos ejecting their foster siblings from the nest, or parasitic wasps injecting their eggs into caterpillars (which are then devoured alive by the larvae) as "small consequences of one general law, leading to the advancement of all organic beings" rather than as the outcome of "specially endowed or created instincts" (1859:244). Privately he was more forthcoming. To botanist Joseph Hooker he wrote in 1856, "What a book a Devil's Chaplain might write on the clumsy, wasteful, blundering low & horridly cruel works of nature!" (1990:178).

6. Darwin's use of the hypothetico-deductive method

Ultimately, what Darwin's transformation from creationist to evolutionist reveals about him, and about science more generally, is that the best science is conducted in the service of a really good theory. Darwin's own scientific methodology was remarkably modern for a period when Baconian induction–supposedly letting the facts speak for themselves–was the predominant scientific philosophy. Although Darwin sometimes implied that he was a Baconian scientist in his methods (doubtless to assure people of his efforts to be unbiased) he was anything but a Baconian in practice; throughout his long career he employed what is known as the hypothetico-deductive method, by which hypotheses are used to generate predictions and to guide the collection of relevant evidence–information that is then used either to confirm or reject the hypotheses (Ghiselin 1969).

During the *Beagle* voyage, Darwin was guided by creationist theory. As a result of his fateful Galápagos visit and certain other voyage experiences, he discovered that this theory led to false expectations–and also encouraged, as one unfortunate consequence, inappropriate collecting methods. The deeper Darwin probed, the more he realized that creationist theory was abundantly contradicted by the available biological and paleontological evidence. So he rejected this theory and eventually developed a better one, the theory of evolution by natural selection. He then turned this new theory on the same set of phenomena he had once sought to explain by means of creationism and its explanatory handmaiden, intelligent design. Patiently, over the next two decades, Darwin sifted through scientific journals, old tomes about voyages of exploration, gardeners' magazines, and numerous other sources of scientific data, and he also continually prodded his colleagues for pertinent facts–all in a search for evidence that could be used to test his theory against the creationist doctrines he had imbibed prior to the *Beagle* voyage (figure 4).

In 1859 Darwin's revolutionary argument was startling to many, and it provoked enormous controversy on publication (Glick 1972). But it eventually carried the day, as Darwin's scientific contemporaries, following in Darwin's intellectual footsteps, addressed the many problematic theoretical issues, highlighted by abundant empirical evidence, that he had raised in the *Origin*. In doing so, most of them came to realize, just as Darwin had previously done, that intelligent design fails to explain anything that cannot be fully explained by natural selection–and far more damningly–that whatever this theory does claim to explain, it explains badly or not at all.

In current debates about intelligent design, it is often asserted that this theory is unscientific because it is untestable. The real problem with this doctrine, however, is that numerous straightforward tests have

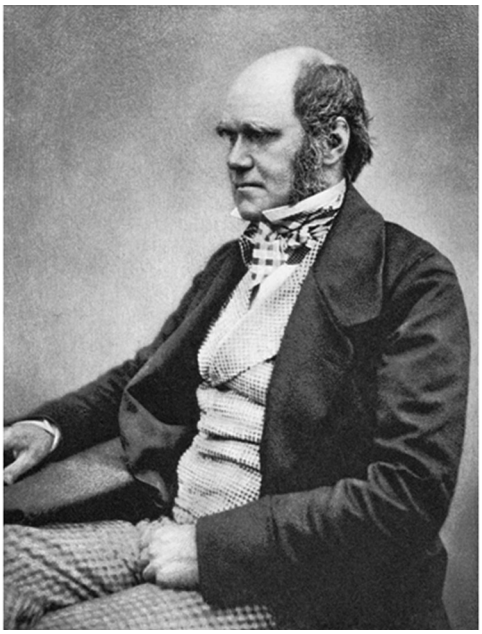

Figure 4. Darwin (ca. 1854), as he was beginning to write the *Origin of Species* (from Seward 1909: Frontispiece). Darwin's understanding of the hypothetico-deductive method is exemplified by a remark he made to economist Henry Fawcett in 1861: "About thirty years ago there was much talk that geologists ought only to observe and not theorise; and I well remember some one say that at this rate a man might as well go into a gravel-pit and count the pebbles and describe all the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!" (Darwin 1903, 1:195).

overwhelmingly failed to support it. In lucid and cogent prose, Darwin's "one long argument" in the *Origin of Species* tells us not only why he was personally compelled to reject intelligent design but also why any well-informed person ought to reject it.

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