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The Eye of Reason:
Darwin's Development during the *Beagle* Voyage

*By Howard E. Gruber * and Valmai Gruber*

LATE in the voyage of the *Beagle*, in April 1836, Darwin visited the Keeling Islands in the Pacific. There he had his first opportunity to examine coral reefs and to test his theory of their formation, a theory he had arrived at quite deductively while still on the west coast of South America. On leaving the islands he wrote: "I am glad we have visited these Islands; such formations surely rank high amongst the wonderful objects of this world. It is not a wonder which at first strikes the eye of the body, but rather after reflection, the eye of reason." [1]

In examining the voyage of the *Beagle* as a phase in the development of Darwin's scientific ideas, much of our effort will be devoted to a discussion of over two thousand manuscript pages of scientific notebooks which Darwin kept during the voyage but which have been neglected ever since.[2]

* * * * *

Ex conchia omnia — all things from the shell — Erasmus Darwin's family motto poses a question, not an answer. In Charles Darwin's case, broadly speaking, we need to discover the way from his grandfather's vague poetic conception of a world taking shape through struggle to Charles' realization of this conception in a trenchant scientific argument.

In his poem, "The Origin of Society," Erasmus Darwin wrote:

> From Hunger's arm the shafts of Death are hurl'd,
> And one great Slaughter-house the warring world! [3]

* University of Colorado. The substance of this paper was read at the 1958 annual meeting of the History of Science Society, Washington, D. C. We wish to thank Mr. Robinson, Down House, Mr. H. R. Creswick, Cambridge University Librarian, and Mr. P. J. Gautrey of the Anderson Room, for their cooperation in making manuscripts available to us. We also gratefully acknowledge financial assistance received from the American Philosophical Society and from the Council on Research and Creative Work of the University of Colorado.

[1] Charles Darwin, *Diary of the Voyage of H. M. S. Beagle*, ed. Nora Barlow (Cambridge: 1934), pp. 399-400. This work is referred to as the "personal" journal. It is not to be confused with Darwin's scientific notebooks, although it certainly contains much of scientific interest as well as rich anecdotal material constituting a narrative of the voyage.

[2] These notebooks and other manuscripts kept in the University Library, Cambridge, will be referred to here as: ULC — followed by volume and page number.

[3] Erasmus Darwin, *The Temple of Nature* subtitled *The Origin of Society*, published posthumously 1803. Lines quoted are from Canto IV, lines 65-66.

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Describing the Pampas in his *Journal* Charles wrote of " one wide sepulchre " of fossil bones. And sixty years after Erasmus, he wrote, in the final passage of the *Origin of Species*: " Thus from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely the production of the higher animals, directly follows." [4]

Not only the phrasing is similar, but Erasmus too passed from the note of struggle sounded in the couplet quoted to the same quest for solace in some more hopeful outcome of struggle, and he found it in a similar place. After pages of panegyric couplets on the fecundity of organic nature, he wrote:

> The births and deaths contend with equal strife,
> And every pore of Nature teems with life.[5]

It is no wonder that Charles Darwin in 1838, in one of his first notebooks on evolution, scribbled: " My handwriting same as Grandfather." [6]

We would not dwell so much on the relation between Charles and Erasmus were we not convinced that the poetic mood is a scientifically fertile approach to nature. There is, moreover, a special need to invoke the ghost of Erasmus Darwin in order to explain Charles Darwin's early gravitation toward natural history. As an explanation, this personal ghost is a useful companion to the *Zeitgeist*, which, while it explains everyone, explains no one in particular.

In passing from Erasmus' *Origin of Society* to Charles' *Origin of Species*, we should trace with care the voyage of the *Beagle*, for it was on that circuitous journey that Charles Darwin's conception of himself as a man of science finally took shape.

At Cambridge Charles was known as " the man who walks with Henslow." His teacher, Henslow, was a botanist, but what Darwin gained from him was less botany than entrée into a distinguished company of professors. Ostensibly, he was at Cambridge to prepare himself for a life as a minister in a " very quiet parsonage," as he later wrote one of his sisters.[7] And when the opportunity to join the company of the *Beagle* presented itself, he persuaded his father to let him go with the argument that it really would not unfit him for his clerical career. Secretly, his sceptical, tyrannical father, freethinker Dr. Robert Darwin, may have been relieved to see his unfavored son at one stroke escape the clutches of the clergy and remove himself from the family scene for a long voyage.

Although it is true, as Darwin's biographers have emphasized, that three other nominees for the post of naturalist to the *Beagle* had refused the offer, and that Darwin got the position by default, Henslow's nomination was no mere whim. Under the spell of Humboldt's *Personal Narrative*, Darwin had been looking for a ship to take him to Teneriffe. Likewise, his sudden

[4] Charles Darwin, *On the Origin of Species*. (London: 1859). This is the widely quoted final passage, p. 415 in the 1950 reprint of the 1st ed.

[5] Erasmus Darwin, *Temple of Nature*, Canto IV, lines 379-380.

[6] ULC, vol. 125, " M notebook," p. 83, written 16 August, 1838.

[7] *Charles Darwin and the Voyage of the Beagle*, ed. Nora Barlow (London: 1945), p. 66.

spurt of interest in geology, just after taking his final examinations at Cambridge, leading to his geological tour of North Wales with Adam Sedgwick, was clearly part of a growing purpose to become some sort of man of science, on the model of the peripatetic scientific litterateur, Alexander von Humboldt. And yet, true to his emerging style of life, a style of small self-deceptions and large truths, he embarked on the voyage persuaded that he would return to the "quiet country parsonage."

When we look at the microstructure of human thought, it appears blindingly swift. So much happens in a few minutes that it is impossible to record it all, and most of it is forgotten an hour or two later. But when we look at the broader currents and changes of direction in thinking, it seems to move much more slowly.

Darwin had to go through several fairly distinct phases of thought before beginning to think in a disciplined way about organic evolution. When he embarked on the voyage of the *Beagle*, his conception of the universe was one he took from Gilbert White, Humboldt, Paley and the Reverend Professors of Cambridge. In this universe a hazy kind of harmony and order prevailed, occasionally interrupted by some great debacle, such as the Flood. An essential feature of this order was the interrelatedness of living things. Under Lyell's influence, Darwin moved into the second phase: order prevails continuously, in the sense that the same natural laws apply eternally; harmony is not so much an issue, for the focus of attention is primarily on the inorganic world — but in so far as organic nature is treated, there is a note of struggle. Change occurs constantly, not in the form of great cataclysms, but as a series of small changes which *express* the natural order rather than violate it. For Darwin, his work on the formation of coral reefs is the culmination of this phase: a biological phenomenon (the way in which the coral organism grows) is the means used to clarify a geological one (the various forms of coral reefs). In the third phase biology becomes the central issue, and geological phenomena are used to clarify biological ones; from the history of the earth's crust Darwin begins to discern the history of its inhabitants.

Each phase defines a domain of problems and leaves a complementary domain untouched. In the first phase, the problem domain is classifying the objects of nature, be they birds, rocks or plants. The system of classification and the items entered in it comprise the natural order, and the general task is to discover this system. Changes of state from one order to the next are considered to be an extra-scientific problem, the work of Creation.

In the second phase, it is these very changes of state which become the problem domain, the general task being to show that one homogeneous set of scientific laws can explain all such changes. But with regard to Darwin's thought in this phase, the problem domain is restricted to changes in the earth's crust — physical geology. The unexamined complementary domain is the series of changes in the earth's inhabitants.

In phase three, the problem domain is the series of changes in organic

forms — vertically in geological space and horizontally in geographical space. The task Darwin assumed was to erect a single rational structure that would account for the facts of geographical distribution and the differences between extinct and living species. The unexamined complementary domain (of which Darwin was fully aware) was the biological locus of heritable variations, what we now call the gene. Darwin used the existence of such variations as a cornerstone of his theory; but he never succeeded in explaining them, and he had the discipline to leave this great and attractive problem domain alone for nearly thirty years.

It probably took Darwin the full five years of the *Beagle* voyage, 1831-1836, to work through from phase one to phase two. It took him perhaps the next five or seven years to make the full transition from phase two to three, culminating in the essays of 1842 and 1844. The tortuous history of phase three itself, to which Robert Stauffer has recently contributed his transcription and analysis of the "big book" — the long manuscript preceding the *Origin of Species* — occupied the years from 1845-1859, culminating, of course, in the publication of the *Origin*.[8]

What follows deals with the transition from phase one to phase two, the change from thinking about natural history as a science of classification to thinking about it as a science of process. As we see it, this change is the main substance of Darwin's intellectual development during the voyage of the *Beagle*.

During the voyage, Darwin wrote copiously. Written on large sheets, most of them about 9 x 11 inches, his notes include the following:

Geological notes	1383 pp.
Zoological notes	368 pp.
"Personal" journal	779 pp.
Total	2530 pp.

In the fifty-five months of the voyage, these alone amount to a production of over a page and a half per day, including the days spent in the saddle or afoot in his numerous expeditions ashore.

In these large notebooks, specimens are described, observations recorded, incidents narrated, and most important of all for our purposes, ideas are unfolded, puzzled over, rejected and improved.

The notebooks were generally written shortly after the event, whenever Darwin had time to sit down and organize his material. But some of the notes, especially in the geological section, are longish essays, drawing together and reflecting upon the materials and ideas developed in several expeditions, such as an essay on the geology of Patagonia and another on the formation of coral reefs.

In addition, Darwin kept at least twenty-four small notebooks in which he jotted down on-the-spot notes to be transcribed and enlarged upon later.

[8] *See* Charles Darwin, *The Foundation of the Origin of Species: Two Essays Written in 1842 and 1844*, ed. Francis Darwin (Cambridge: 1909); Robert Stauffer, "'On the Origin of Species': An Unpublished Version," *Science*, 1959, *130*, 1449-1452.

These notebooks, which have been interestingly described by his granddaughter, Nora Barlow, include several catalogues listing specimens by number and giving brief descriptions. Finally, there were the letters. In addition to all the family letters and other letters, to friends, there were forty to his teacher Henslow containing enough material of scientific interest for Adam Sedgwick to read excerpts from them to the London Geological Society and Henslow to the Cambridge Philosophical Society. These excerpts were also privately printed for the members of the Cambridge Philosophical Society [9] while Darwin was still away and without consulting him — a point which he protested weakly and with perhaps some pride.

The scientific notebooks mentioned above deal almost entirely with geology and zoology. There must have existed more notes on botany than we have seen — at least a catalogue of the specimens sent home. Although we have not yet come across such botanical notes, we do not think the substance of the following remarks would be much altered by anything we would find. Of all the branches of natural history, Darwin was at the time least concerned with botany.

In his published Journal of the voyage he admitted that:

> . . . from my ignorance of botany, I collected more blindly in this department of natural history than in any other; so that certainly it was not *intentionally* that I brought the different species from different islands. If, indeed, I at all noticed their resemblance, I probably collected second and third species as duplicate specimens of the first.[10]

This passage, of course, refers to his work in the Galapagos Archipelago. None of the books or monographs resulting from the *Beagle* voyage deals with botany, and in Darwin's published account of the voyage, botany always gets the shortest shrift. It was not until after the appearance of the *Origin of Species* that he began to publish much in the field of botany — and then, of course, in earnest.

A study of the larger scientific notebooks helps to give a picture of the ebb and flow of Darwin's preoccupations and of the slow, vacillating growth of his allegiance to Lyellian geological theory. This information, in turn, may help to clarify our conception of the rate and character of the development of his evolutionary ideas during these early years.

First let us compare the actual amount of work he did in geology and zoology during the four and three-quarter years of the voyage, using as a rough index the number of pages devoted to each subject.

With the exception of the last year, 1836, the amount of geological work increases steadily throughout the voyage, whereas, with the exception of the third year, 1834, the zoological work decreases steadily. Except in the first year (1832) the geological work always far exceeds the zoological.

[9] Charles Darwin, *Extracts From Letters to Professor Henslow* (Cambridge: 1835).

[10] Charles Darwin, *Journal of Researches* (London: 1839), p. 629.

TABLE 1

Number of Pages

Year	*Geological*	*Zoological*	*Geological/ Zoological*
1832	85	145	0.59
1833	119	62	1.92
1834	303	91	3.33
1835	531	46	11.54
1836	200 *	22 *	9.09
Galapagos (1 mo. 1835)	80	25	3.20

* Corrected for number of months.

In both fields there was a notable spurt of activity stimulated by the month-long visit to the Galapagos in September-October of 1835. Both his geological and his zoological notes for this period are more than three times more copious than his average rate of productivity.

But even so, the geological notes on the Galapagos are more than three times as long as those on zoology. Darwin, on first viewing the Galapagos, was far more interested in the peculiar volcanic formations of this archipelago that he was in the peculiarities of its organic forms which he later made famous.

This point is corroborated in his catalogue of zoological specimens of the *Beagle* voyage, now kept at Down House. There is nothing in these notes to show that while he was on the spot he abandoned his geological preoccupations to any great extent in order to study the fauna of the Galapagos with unusual thoroughness, nor are there any remarks pregnant with evolutionary thought. None of his notes for the remainder of the voyage, now in its last year, shows any remarkable increase in zoological interest. On the contrary, the decline mentioned above continues, and while the geological notes also decrease somewhat, they maintain something like a nine to one superiority over the zoological notes.

It is not until three months later in a diary entry written in Australia (January 18, 1836) that we find a clearcut passage suggesting any evolutionary stirrings. This is a passage in which he muses on the peculiarities of geographical distribution, entertaining and then rejecting the hypothetical thoughts of an Unbeliever. He concludes with the idea of multiple creations: ". . . one hand has surely worked throughout the universe. A Geologist perhaps would suggest that the periods of Creation have been distinct & remote the one from the other; that the Creator rested in His labor." [11] This passage was written in Australia, two and a half months before he got to the Keeling Islands where he finally had the opportunity of testing the theory he had developed on the formation of coral reefs. His success there, we believe, finally convinced him of the penetrating power

[11] Charles Darwin, *Diary of the Voyage of H.M.S. Beagle*, p. 383.

of the " eye of reason," and by the same token confirmed him in his uniformitarian geological views. He did not write such a creationist passage again. But if uniformitarianism is a long way from Creation, it is also a long way to the *Origin of Species.*

Now Nora Barlow has called attention to a passage from an ornithological notebook in which Darwin concludes a description of the varieties found on different islands in the Galapagos as follows: ". . . the Zoology of Archipelagoes will be well worth examining; for such facts would undermine the stability of species." [12] Lady Barlow has suggested that this passage establishes " beyond doubt " the date when Darwin's ideas on the mutability of species crystallized. She has not, however, specified that date, nor have we been able to date this passage. The notebook in which it occurs appears to be a collation of ornithological materials collected during the entire voyage. Our guess, based on the format of the notes and the watermark of the paper, is that the whole notebook was written on the way home, in the last few months of the voyage, or nearly a year after his encounter with the Galapagos.

The date of this ornithological notebook is important enough to be considered in some detail. The notebook, now kept at Down House, is of a paper watermarked 1834, yet the first entry is dated 1832. This fact and the uniform appearance of the notes strongly suggest that they were all written in one brief period, rather than scattered over the whole voyage. The reason for suspecting that the notebook was written on the way home is the existence of a similar notebook (same 1834 watermark, same 1832 starting date, same uniform appearance) in which the final entry is Ascencion, July 1836. Moreover, we are fairly certain that Darwin did use the return voyage for writing up his notes.[13]

It would indeed be valuable to know just when Darwin first permitted himself to write that certain facts " would undermine the stability of species ": was it a quick flash of insight just after leaving the Galapagos or a reflection upon the whole voyage as he drew his ideas together, nearing home?

In the zoological notes of the large notebooks — which *can* be dated as September 1835 (during the Galapagos visit) — his undoubted interest in the unusual creatures of the Galapagos does not seem to have produced any evolutionary stirrings. The peculiar " variations " from island to island are mentioned twice, rather matter-of-factly. About the best we can do is the following passage:

> With respect to the Land Birds their extreme tameness has been described in my private Journal. Little birds can be almost caught by the hand. They will alight on your person and drink water out of a basin held in your hand — Must not this arise from the entire absence of all Cats and Mice and other similar animals and those Hawks which pursue small birds? [14]

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[12] Nora Barlow, Letter to *Nature*, September 7, 1935.

[13] *Charles Darwin and the Voyage of the Beagle*, p. 252.

[14] ULC, vol. 31, pp. 343-344.

In short, although Darwin's ideas about species may have been stirred by his Galapagos impressions, at first they stirred only slowly and faintly.

We have dwelt at length on this point because it bears on the character of scientific insight. It is a commonplace that great insights occur only to the prepared mind, or as Darwin himself might have put it, great observations only to " the eye of reason." But the time it takes to prepare a mind has not been well examined. In stressing the youthfulness of many creative scientists at the time of their greatest attainments, one may overlook the long and tortuous period of preparation. Indeed, Darwin was only twenty-eight when, very deliberately, he " opened his first notebooks on the transmutation of species." But by that time he had filled up many a notebook in other domains.

We have looked carefully through Darwin's zoological notes, and while they contain few suggestions of evolutionary thought, three significant themes occur repeatedly. The first is Darwin's difficulty in classifying new species within the existing systems of classification — but with no particular criticism of the systems. The second is the interrelatedness of living organisms. Here are two examples which we have chosen because they also suggest a certain progression in Darwin's thinking. In June 1833, he wrote on the peculiar absence of dung-feeding insects in South America:

> After being accustomed to the great numbers of coprophagous insects in England, — It was at first with surprise that I here found the ample repast afforded by the immense herds of horses and cattle almost untouched. . . . M. Video was founded 1725 . . . Cattle and horses here perhaps only for about 80 years. This absence of coprophagous beetles appears to me to be a very beautiful fact; as showing a connection in the creation between animals so widely separate as mammalia and Insecti Coleoptera, which when one of them is removed out of its original zone can scarcely be produced by a length of time and the most favorable circumstances. . . .[15]

A similar theme occurs a year later. In July 1834, on Chiloe, he commented on a report that the indigenous lice live well on the Indians but die in three or four days on European sailors: " If these facts were verified their interest would be great — Man springing from one stock according to his *varieties* having different species of parasites. — It leads me into many reflections." [16] The last sentence is crossed out, perhaps because he decided to defer these reflections.

The third theme which recurs in the zoological notebooks is Darwin's constant surprise and delight at finding new species in new places, coupled from time to time with a few reflections on the general subject of geographical distribution.

When we turn from the zoological notebooks to the geological, the picture is entirely different. Almost from the very beginning definite hypotheses are formulated, tested, and reformulated. At least one important change in

[15] ULC, vol. 30, p. 200.

[16] ULC, vol. 31, p. 315. The words, " species of," were inserted by Darwin, seemingly as an afterthought.

vocabulary becomes a matter of concern, reflecting shifting theoretical allegiances. Broader and broader integrations of ideas are attempted and pursued, eventuating in connected essays inserted in the notes and in the personal journal. During the voyage Darwin began to think of himself more and more as a geologist, and toward the end of it he wrote to Henslow asking to be proposed as a member of the Geological Society of London. He should not have anticipated any hesitation, as some of his work had already been heard with approval there.

Darwin's intense interest in geological work leads to one difficulty in re-tracing his ideas. Far more than in the zoological notes, he has shuffled and re-shuffled his papers, assembled and reassembled his thoughts. Some entries cannot really be dated within a year. But most entries are dated, and some doubtful ones can be cleared up by considering the year the paper was manufactured, particulars of format, and internal evidence in the written matter itself. All in all, one can reconstruct a satisfactory chronological account of the development of his ideas.

From the very first page of these notes, mingled with the descriptive material, there is an obvious pleasure in making hypotheses, and this within the framework of a peculiar blend of uniformitarian and creationist ideas.

In his entries for January 17-18, 1832, describing Quail Island, Cape Verde, it is quite clear that he believes in something like the Flood, but he also describes continuous, on-going and gradual geological processes: "There is now going on a very remarkable process on the coast of this island: viz: the formation of an extremely hard conglomerate . . . daily . . . increasing under my own eyes." [17] And on the next page: "I have not mentioned a small covering of diluvium on the Western side of the Island. — At first I thought it merely debris from the upper feldspathic rock. — but on examining. . . . It looks to me like a part of the long disputed Diluvium." [18]

These lines were written in the first month of the voyage, en route to South America. Sometime later, possibly in September, 1836, on the way home, when he again stopped in the Cape Verde Islands for a few days, he added: "This account was written before I had examined any part of St. Jago. . . . I have drawn my pen through those parts which appear absurd." [19] The parts crossed out, of course, include the sentence about "the long disputed Diluvium."

Less than a month later, in February 1832, writing about St. Jago, he re-examines the same diluvial theme, but the conclusion has a less biblical tinge: "I am decidedly of an opinion that these valleys were formed by great bodies of water and not by gradual effects. . . ." [20] His discussion of the action of water ends: "I thought it might have been the sea. — but the valleys terminate and divide in so usual a manner that I was obliged to give up this idea. & go back to the torrents of rain that usually are said to accompany volcanic action." [21]

[17] ULC, vol. 32, p. 19.
[18] *Ibid.*, p. 20.
[19] *Ibid.*, p. 20.
[20] *Ibid.*, p. 33.
[21] *Ibid.*, p. 35.

The long discussion of the valleys of St. Jago also contains some conflicting remarks on the age of the earth. Remarking on the age of an Adansonia tree, he suggests that 6,000 years is " a large fraction of the time that this world has existed." In the next sentence: " Of course the valley must be still older. . . ." After some description of the actual rock formations, he concludes with a sentence suggesting that he was then struck by the apparent *im*mutability of species: " To what a remote age does this in all probability call us back and yet we find the shells themselves and their habits the same as exist in the present sea. . . ." [2]

Regardless of the conclusion he happened to draw at that early stage of the voyage, it is clear that he was already beginning to focus attention on some of the crucial issues, and that at least in the field of geology he was ambitious to be far more than a thoughtless collector of specimens.

In October, 1832, he arrived in Bahia Blanca in Brazil, and made several excursions to a nearby fossil bed at Punta Alta. His description is still written in the language of catastrophe:

> This mixture of such quantities of bones of land animals with shells, must be explained by supposing a body of water sweeping over the plains and bringing with them the bones strewed on the surface and the living animals. . . . The upper gravel only differs from the lower in containing fewer bones (We may conjecture the first inundation swept the plains clear) and that the action of water is evident in breaks and furrows on the Tosca. — This latter I imagine to have been deposited under similar circumstances but in calmer water. — it is impossible to behold it without immediately saying it is the mass of earth which a debacle tearing across the country would deposit.[23]

During the year following this first visit to Bahia Blanca, we can find passages indicating the direction of change in Darwin's ideas. For instance, from Bahia Blanca he went to Monte Video and there was beginning to be impressed by the possibility that gradual, non-violent changes might, in a long time, have large effects:

> It may be observed how strange it is that in a country which has suffered so remarkably little from the convulsions of nature. that this stratification should be vertical. — How is it possible that horizontal plates, deposited beneath water should be elevated through a space of 90° — and yet the country be one of the most unbroken on the face of the globe.[24]

But a few months later, January 1833, Fort Desire, he is again writing about the " diluvium " and, in his own words, " a cause much more violent than now exist." [25]

In August and September of 1833, Darwin returned to Bahia Blanca, on an overland journey in the saddle. His experience had broadened, and he was moving closer to uniformitarianism: " Having revisited P. Alta after seeing the neighboring country my opinion respecting its geology is

[22] *Ibid.*, p. 34.
[23] *Ibid.*, p. 65.
[24] ULC, vol. 34, p. 6.
[25] *Ibid.*, pp. 29-34.

completely altered. . . . Many phenomena are best explained by small modern upheaval. . . ." [26]

One of the most important kinds of evidence that convinced Darwin of the correctness of Lyell's views was the appearance of recency in fossil specimens found far from their natural habitat, suggesting that although some geological changes are remote in time, many are recent. If geological change can be recent, it can be going on today — according to a homogeneous set of laws throughout. Darwin was, therefore, on the lookout for any signs of recent geological change. A passage written in 1834 — not his only use of linguistic evidence — illustrates this interest:

> 1834 Nov. Arch. of Chiloe.
> In my notes to S. Carlos I have attempted to show the land to this day is rising: a proof of it exists in the names of places — ' Huapi ' in the Indian Language means islands. Now many peninsulas, joined by low land have at the present day the Huapi affixed to them. — The inhabitants state they were formerly islands.[27]

By 1835 the change is complete. In describing the valley of Copiapó in Chile, he writes: " From the description of the valleys in this line of coast, an extent of about 400 miles, the following conclusions appear to me inevitable. — That the sea, during a long and quiet residence deposited those masses of Shingle stratified with seams of sand and Clay. which in Europe would be called Diluvium." Note the specific disclaimer of the term " Diluvium." He goes on to explain how a variety of specific geological formations in the region can be explained by the " quiet residence " of the sea.[28]

Thus it took Darwin at least two years, and possibly three, from the time he set out on the voyage and began to read Lyell to become firmly convinced that the history of the earth's crust could be explained by means of one homogeneous set of laws, that these laws were still operating, and that — viewed on a large enough scale of space and time — geological events of cataclysmic proportions from a human point of view were only small incidents in a slow process of change.

Following Lyell's prescription, he became interested in coordinating his fossil finds with other geological data; from an early date he took great pains to identify the strata in which his fossils occurred. For example, in October 1832 en route from Bahia Blanca to Monte Video, the *Beagle* stopped briefly at Monte Hermoso and Darwin went ashore. He made a good haul of fossils, including some bones which he thought belonged to the " ante-diluvial Megatherium." [29] Most of his attention was given to the formation in which the fossils were found: " The remains of this animal have always been described as being in superficial gravels and caverns — or as it is sometimes called, diluvial formations. — Now it appears to me that the beds

[26] ULC, vol. 32, p. 74.
[27] ULC, vol. 35, p. 297.
[28] ULC, vol. 37, pp. 675-676.
[29] Charles Darwin, *Diary of the Voyage of H.M.S. Beagle*, p. 106.

which I have described do not come in this class." He gives his geological reasons and then concludes: "I have been thus particular in describing those beds in which organic remains occurred — for the comparison of formations in different parts of the world which contain animals of equal grade in the chain of nature seems at present to be much wanted in Geology." [30]

Naturally enough, in going through these notes we were at pains to look for signs of the growth of evolutionary thought. During the first year of the voyage there are a few passages, one of which we have already cited, that suggest a belief in the *im*mutability of species. But as to a shift toward mutability, the notes offer little. There is one suggestive passage, about Chiloe, off the coast of Chile, probably written in January 1835, rather late in the voyage: "To what an epoch does this consideration lead the mind when in the older strata, not only is the local habitation of species altered, but the species and even genera are changed." [31] But it should be remembered that this remark can be readily assimilated to the idea, expressed by Lyell in the *Principles of Geology*, of a succession of organic beings called into existence by a succession of creative acts. There is some evidence [32] that Lyell himself did not entirely believe in a series of divine creations when he wrote about it in 1830, but in 1835 Darwin probably did. Whatever the succession of species and even genera may have meant to Darwin, it certainly did not take hold of him with any force. He was preoccupied with his grand ideas on the elevation of South America. Darwin has given a good description of the kind of hypotheses that interested him during this period of the voyage, in a passage written in Chile, sometime between August and November of 1834.

> Often when sailing about the intricate bays and channels in the South I had tried to picture to myself what appearance this country when elevated would assume. — it was no ordinary satisfaction to find in Chili answers to all my conjectures. I will now give what more purely geological reason I possess in support of these views.[33]

The passage quoted is one of many exemplifying the way in which Darwin's hypotheses seem to have taken shape in the form of visual imagery — a characteristic about which he wrote explicitly later on.

In our opinion Darwin's remarks on the process of extinction, which he was led to consider by virtue of his many fossil finds of extinct species, are

[30] ULC, vol. 32, pp. 58-60.

[31] ULC, vol. 35, p. 303.

[32] Charles Lyell, *Life, Letters and Journals* (London: 1881). See especially Lyell's letter to Poulet Scrope, June 14, 1830. Scrope was about to review the forthcoming *Principles of Geology* in the *Quarterly Review* and Lyell undertook to supply him with guidance in writing the kind of review that would win a favorable reception for the book despite its contradiction of Genesis. Lyell freely admits that he pulled his punches: "If I have said more than some will like, yet I give you my word that full half of my history and comments was cut out, and even many facts; because either I, or Stokes, or Broderip, felt that it was anticipating twenty or thirty years of the march of honest feeling to declare it undisguisedly." It is a sad commentary that Lyell's longer estimate, thirty years, takes us almost exactly to the publication date of the *Origin of Species*.

[33] ULC, vol. 35, p. 404.

the most directly suggestive of organic evolution in these notebooks. There are several such remarks, but none resembles the character of his later thought in the *Origin* so much as this one, written in May, 1834. Speaking of certain beds of sea shells, he writes: "A [sudden] change in the nature of the bottom, must destroy many animals, and when of great extent if the species are not in proportion more extended, they must perish from the world." [34]

Lyell had already expressed the same idea at length, so that there is nothing very original in Darwin's making this point. Nevertheless, first hand contact with some of the major facts of geographical distribution was one of the crucial advantages Darwin gained from the voyage.

His geological notes on the Galapagos in September and October of 1835 are a lengthy attempt to work out the role of volcanic action in forming these islands. The idea that most strikes his fancy is a hypothetical "mud volcano" which he discusses at length. He has a long section on the complete absence of coral from these islands, and in the end he accepts Captain Fitzroy's hypothesis that the cold ocean currents around the Galapagos are the cause.

All in all, then, it would be a mistake to interpret the few faint suggestions of organic evolution in these notebooks as signifying the important part of Darwin's intellectual development during the *Beagle* voyage. He was during this period first and foremost a geologist — as indeed he wrote repeatedly in his letters home. And at that time geology to him chiefly meant the history of the earth's surface, not of its inhabitants.

If we wish to find the beginning of Darwin's evolutionary thought in the voyage of the *Beagle,* there is something far more interesting than a few vague hints of organic evolution. Darwin worked out a theoretical model that bears a striking *formal* resemblance to his later work on organic evolution. We refer to his theory of the formation of coral reefs, worked out in 1835 when he was still on the west coast of South America. Just as he had speculated on the geology of the west coast while still on the east coast, he now continued to extrapolate westward. Concomitant with the general elevation of the level of the continental land mass, he believed that there must have been a general subsidence of the ocean floor. His thory of the formation of coral reefs by "the upward growth of the corals during the sinking of the land" [35] is really an extension of this idea.

The two theories (organic evolution and coral reefs) display several basic similarities:

1. Both theories contain a principle of population growth — in the case of coral reefs, the assumption is that the coral organism does not grow beyond some limiting distance from the surface of the sea. In both cases the principle of population growth is described by Darwin as struggle — in the case

[34] ULC, vol. 34, p. 149. The word "sudden" was inserted above the line by Darwin.

[35] Charles Darwin, *Journal of Researches,* 2nd ed. (London: 1845), p. 475.

of coral formations the struggle is, he said, " between the two nicely balanced powers of land and water." [36]

2. Both theories employ a general approach to physical geology, taken together with the principle of population growth, to explain the major facts of geographical distribution. In the case of coral reefs, the hypothesis of a general subsidence of the Pacific floor determines the places in which the coral organism can grow and form reefs. Occasional elevations determine the particular form of certain reefs.

3. Finally, both theories are capable of generating a continuous series of forms where direct experience had previously revealed only a few classes. In Darwin's words, summarizing his theory: " On this view, the three classes of reefs ought to graduate into each other. Reefs having intermediate character . . . do exist." [37] And later, " fringing-reefs are thus converted into barrier-reefs; and barrier-reefs, when encircling islands, are thus converted into atols, the instant the last pinnacle of land sinks beneath the surface of the ocean." [38]

With regard to scientific method it might be added that once possessed of an idea Darwin worked in the same way in both cases. The general theory gave rise to a host of particular hypotheses. In so far as the hypotheses were supported, the case for the theory was strengthened.

Developing the theory of coral reefs may well have provided Darwin with a simplified model on which to frame his evolutionary ideas. By the same token, it may explain his preoccupation with a creative geological idea to such an extent that he cast a blind eye at first to the importance of the biological phenomena he observed in the Galapagos and elsewhere during the last year of the voyage.

Considered as a phase in Darwin's intellectual development, then, the five-year voyage of the *Beagle* provides us with the crucial change in his view of natural history. He began the voyage conceiving of natural history as a descriptive and classificatory science confronted with a relatively static order of nature, unchanging except for catastrophic events. He ended it conceiving of natural history rather as the analysis of ongoing processes in a continuously changing natural order. Throughout the voyage, even in the Galapagos Islands, Darwin was chiefly concerned with geological questions rather than biological ones. The scientific notebooks he kept during the voyage reveal almost nothing directly suggestive of belief in, or even thoughts about, organic evolution.

As a theoretical model, however, Darwin's theory of the formation of coral reefs displays *formal* characteristics strikingly similar to the theory of evolution through natural selection. Although the *material content* of the theory of coral reefs has little bearing on organic evolution, the formal structure of the theory may have crystallized for Darwin the general approach he later used in explaining organic evolution.

[36] Charles Darwin, *On the Structure and Distribution of Coral Reefs* (London: 1890), p. 24. Originally published 1842.

[37] *Ibid.*, p. 78.

[38] *Ibid.*, p. 109.

On the one hand, Darwin's development provides no support for the view that scientific theories spring Minerva-like from the head of the scientist on first sight of the evidence. On the other hand, the slow growth of his thought in a number of distinguishable phases does not imply a trial-and-error process of blind groping. In an orderly way, the completion of one phase set the stage and provided the intellectual pre-conditions for the emergence of another. There is, in fact, a certain quality of inevitability and perhaps great significance in a sequence of items in Darwin's Diary:

> 1837 May: Read papers on Coral Formation, and on the Pampas, to the Geological Society.
> July: Opened first notebook on Transmutation of Species.[39]

[39] Charles Darwin, *More Letters*, ed. F. Darwin and A. C. Seward (London: 1903), vol. I, p. xviii.