THE LINNEAN

Newsletter and Proceedings of
THE LINNEAN SOCIETY OF LONDON
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THE LINNEAN SOCIETY OF LONDON

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Edited by B G Gardiner

Editorial

The main article in this issue concerns the setting up of a "Reserve for Fungi" at Dawyck in Scotland, one of Edinburgh's Royal Botanic Garden's specialist stations. Known as the Heron Wood Project, this sanctuary and reserve supports more than 1,750 different fungi.

Towards the end of the article the author mentions Beatrix Potter, who, as many of our readers are aware, presented a paper to the Society in April 1897 entitled "Germination of the spores of Agaricineae"; sadly it never reached publication (Beatrix being a perfectionist.) However, the author of the article has provided us with Beatrix's original drawings of the germinating spores of the fungus *Aleurodiscus amorphus* and its accompanying parasitic jelly fungus, *Tremulla simplex*. He has also provided a fragment of a letter to Charles Macintosh, the model for Mr Macgregor in *The Story of Peter Rabbit* (see *The Linnean* 16(1), January 2000).

This issue also includes an account of Joseph Hooker who became a Fellow in 1842. In his obituary in our *Proceedings*, it is said "We have lost one of the most renowned of all our Fellows and one of the most remarkable men who ever devoted his life to the advancement of science. "Impulsive and somewhat peppery" according to Darwin. However, when offered the option of him being buried alongside Darwin in Westminster Abbey, his widow, honouring her husband's wishes, had him buried alongside his father in St. Ann's, Kew Green".

There is a paper on *Thermoregulation in Amniotes* in which a case is made for the clade Haemothermia and the exclusion of fossil evidence with its so called primitivness.

Finally, we have an article by Sir Christopher Zeeman on the Catastrophe Theory and its application to Darwinian evolution which was originally presented to the Royal Society and was published in 1992 in *Understanding Catastrophes* (see page 20). We are most grateful to Sir Christopher for permission to reproduce this interesting article in *The Linnean*.

BRIAN GARDINER

Society News

The Society's Premises. I hope that this is the last time that I shall start this column with news on Burlington House. Although there are still one or two loose ends to be tied up I am very glad to be able to tell you that the lease negotiations are effectually over, and both sides have signed on the dotted line.

Part of the settlement of the premises issue involves the renovation of the building, and the work is now in full swing. As any recent visitors will have noticed, much of Burlington House is scaffolded and shrouded in plastic. The contractors are making good progress but there is inevitably a fair amount of disruption. The worst period for the Linnean Society will be June/July and most of the external work should have been completed by the time our next season of meetings and lectures starts in September. We hope that the scaffolding on our part of the building will come down then but that will not mean the end of building works. Our own internal refurbishments, initially in the basement and on the second floor, will start in August or September and are likely to go on until 2007.

The Charter and Byelaws. The Privy Council has now approved our new Charter although we do not yet have it in our hands. As many of you will know our new Byelaws have also been presented at the statutory three General Meetings and have been approved by Fellows. We intend to have these updated Byelaws printed along with the new Charter and they should be available within the next few months.

Anniversary Meeting. With the end in sight to a protracted period of uncertainty, the Anniversary Meeting on 24th May definitely had a more forward-looking feel to it. The Treasurer explained the background to our development campaign and it was gratifying that the meeting agreed that an approach should be made to the Fellowship for seed money for our fundraising. All the advice we get suggests that a development campaign must be firmly grounded on the support of members so we do hope that you will be willing to offer some help – the President will be writing to you about this.

The Development Campaign. The other building blocks for our development campaign are gradually being put in place. We now have an active Development Group which is preparing the ground, and we have submitted a bid to the Heritage Lottery Fund. We are reviewing our design and website and are working on promotional material. The website is particularly important and we expect it to become the major source of information on the Society – please do use it, particularly for last minute information on meetings, etc.

The Tercentenary of the birth of Linnaeus. We are fortunate that the Linnaean Tercentenary will occur in two years time. It will give a focus to our development campaign, and will be an opportunity to organise many new activities. We now have a planning group working with Jenny Edmonds, the Tercentenary Coordinator, to develop our ideas for celebrating this anniversary: do get in touch if you want to contribute or to be involved.

Gotland Visit. With this issue you will receive a copy of the flier about a planned trip to the Swedish island of Gotland in 2007. We hope that this will be attractive not only to those interested in Linnaeus and the development of his ideas but also to anyone with an enthusiasm for palaeontology – Gotland's fossil beds are world-renowned.

Meetings. Meetings during the last few months have involved a wide variety of topics and have been well attended. In April John Good gave a most impressive overview of the likely impact of climate change on the British flora and fauna, and that was followed by a stimulating presentation by Jane Thornback in May on the decline of British resources to support tropical forestry. In June Brian Ford gave a masterly lecture and presented some very interesting new ideas on the role of cells and the way that organisms organise themselves.

Scientific Meetings. The Linnean Society was abuzz with scientific discussion in the last week of April when we hosted meetings of our palaeobotany and palynology specialist groups and the Malacological Society of London on three successive days. We are keen to help our specialist groups develop so were very glad to support these activities. We welcome similar proposals.

Jack Hawkes. Many Fellows will know that Professor Jack Hawkes, our former President, will celebrate his 90th birthday at the end of June. The Society will be sending a small token and I am sure that all who know him will join us in sending our congratulations.

ADRIAN THOMAS

Library

During the period from the beginning of January to the end of April the Library was open for 81 days during which 273 visitors (131FLS) were recorded. This gives a visitors/ day figure of 3.7 as compared to the previous 3.3. The percentage of Fellows among those using the library was 48 %, somewhat lower than previously (63.7 %,) but this is explained by the numbers in visiting groups who were not Fellows. Loans during this period were 71 (as compared to 46) and the usage slip records tell us that 61 readers consulted 115 items comprising 73 books, 37 journals and 14 manuscripts. These are records for items not borrowed but consulted in the Reading Room. Visits to access manuscripts numbered 22 and included visitors from Colombia, Denmark, Sweden and USA, as well as the UK.

General Library use included displays for Society general meetings on Wildlife Crime, Huxley and the Rattlesnake, the International Palms symposium, and Climatic change. The opportunity was also taken to celebrate Britain's cultural diversity with displays for the Chinese New Year, St Patrick's day, St David's day and St George's day. Some of these displays are now available on the Society's web pages under the Library pages as "Current library displays". Other events included a celebration meeting for the *New Phytologist*, two days on Palynology and Paleobotany and a joint meeting with the Malacological Society.

Group tours and pre-booked visits were made by the Library staff of the Royal Botanic Gardens, Kew, students from the University of Maryland, Professor Gani and colleagues from the Wallacea Institute of Hasanuddin University, Indonesia, Governor Bjork from Sweden and a number of other Swedish visitors concerned with Tercentenary activities.

Accessions to the Library included 183 donations and 56 purchases, totalling 239 items. These included a very large gift brought by Prof. Santiago Madrinan FLS, a donation of books from Sally Thompson daughter of the later Peter Wanstall and books from the Peal collection in Ealing Public Library. At the end of April the Revd. Jeremy Collingwood presented the Society with a collection of Cuthbert Collingwood's papers, comprising some 47 individual items. These await detailed listing but an outline inventory can be supplied if required.

Work by volunteers included excellent progress with entering records for portraits into the Library catalogue by Prof. E.A. Bell, who is now midway through the letter 'G'. Mrs Jeanne Pingree is making steady progress on listing the papers of J.C. Willis, which include a vast amount of social history as he kept every document associated with his travels. Mrs Iris Hughes continues to catalogue reprints whenever she is in London. Our most recent volunteer Dr John St Quinton, has been working on proposals for a Thesaurus construction for the Library catalogue, but has also been familiarising himself with the search mechanisms by checking lists and donations received for the book sale and other older donations.

Summer plans and changes

The exterior of our part of Burlington House is now completely behind scaffolding and repairs on windows have begun. Roof lights in the Reading Room have been boarded over and we now have minimal natural light. All the manuscripts and portraits from the Council Room are boxed and in temporary storage, pending building work. The latter part of July and the whole of August will see the usual teams of students cleaning and moving books and journals. This year we hope to reshelve any remaining books which have not yet been dealt with. As before, there may be delays in locating items when they are in transit or in temporary locations, as well as limits on working space for Readers. Please give us advance notice of what you want to see if you can. The Library catalogue can be checked on the web by going to the Library pages and following the link to the catalogue. The location information is not necessarily correct but the basic bibliographic information should be available.

The Library would like to thank all those below who have contributed to the Library and apologises for any delayed acknowledgements. This list does not include items from the estate of Peter Wanstall for reasons of space limitation, but their source can be found in the Library catalogue; nor are a substantial number of gifts received via the book sale listed as, in many cases, we do not know the source of items we have decided to retain.

GINA DOUGLAS

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Picture Quiz

Joseph Dalton Hooker (1817–1911)

The July Picture Quiz featured Joseph Dalton Hooker (1817–1911). The younger son of William Jackson Hooker (1785–1865) and his wife Maria Sarah, daughter of Dawson Turner. Born in Suffolk, he was taken to Glasgow at the age of four when his father was appointed Professor of Botany in the University. Hooker was educated at Glasgow High School and later Glasgow University whence he graduated in Medicine at the age of 22 in 1839.

Following a visit to his father by James Ross who explained to William that he hoped to mount an expedition to discover the South Magnetic Pole, William persuaded Ross to take his son to the Antarctic. Joseph was subsequently appointed assistant surgeon on HMS *Erebus* and spent the next four years exploring the southern oceans. During his second year of the voyage, Ross appointed him expedition's botanist.

Clue: Had a propensity for penguins, the geology of Skye and swallow-tail butterflies.

On his return, his father, by then the Director of the Royal Botanic Gardens at Kew, used his influence to secure an Admiralty grant of £1,000 to cover the cost of the *Botany of the Antarctic Voyage's* Plates. Eventually the whole enterprise grew into six volumes – two each for the *Flora Antarctica* (1844–1847), The *Flora Novae-Zelandiae* (1851–1853) and the *Flora Tasmaniae* (1853–1859).

In the course of these travels Hooker had come into frequent contact with fossil plants and through his father's contacts he was appointed in 1846, Botanist to the Geological Survey of Great Britain. This brief sojourn with palaeobotany ended in 1847 when he set out for India. However, it is said that he maintained an ardent interest in palaeobotany right to the end of his life.

His visit to India extended over three years which he deemed "involved a mystery equally attractive to the traveller as the naturalist". The outcome of the visit was his *Himalayan Journals* which is said to have emanated from his perusal of the unpublished proof sheets of the *Voyage of the Beagle*. These *Himalayan Journals* contain notes on ethnology, zoology, geology, meteorology and geography, although the botanical results are the most important. The *Himalayan Journals* were followed in 1855 by the first volume of the *Flora Indica,* written in conjunction with Thomas Thomson, and which is acclaimed for Hooker's introductory essay (260 pp) which presents a masterly analysis of the vegetation and physical features of India and imparts the foundations (so it is said) of the study of systematic botany.

Later came perhaps his greatest floristic work, the seven volume: *The Flora of British India* (1872–1897). Then he eventually completed Henry Trimen's, *Handbook of the Flora of Ceylon* (1898–1900), and in 1904 he published, *A sketch of the Vegetation of the Indian Empire*. Meanwhile, back in 1859, he published his, *Introductory Essay to the Flora of Australia*. In this essay he not only discussed the variation in plants and their distribution in space and time but also the analogies between mountain and insular floras.

Sojourn at Kew

For ten years (1855–1865) Hooker served under his father Sir William Hooker and on the death of the latter succeeded to the Directorship. There is no doubt that it was under the Hookers that Kew rose to fame. However, it is impossible to disentangle the respective shares of father and son in its advancing fortunes. What is uncertain is whether or not Joseph Hooker might have succeeded his father had not the latter offered his vast private herbarium to the nation on one condition that his son was appointed to succeed him!

Hooker remained the Director of Kew until his retirement in 1885. During this period he served as President of the Royal Society (1873–1877) and was a copious contributor to our Journals including: *Outlines of the Distribution of Arctic Plants* (1861) and the monograph *On Welwitschia* (1863). He served on our Council for some 21 years and was responsible for the instigation of the *Journal of the Linnean Society* in 1855.

Friendship with Darwin

Initially Hooker began work on classifying Darwin's specimens of plants from Tierra del Fuego and the Galápagos around 1844, this in turn initiated a life long correspondence in which the main topic was the distribution of plants. On the 14th January 1844 Darwin wrote to Hooker what turned out to be a most significant letter in which he confided the information "species are not immutable". Thus Hooker became the first person to learn of Darwin's secret. Over the next decade they exchanged many more letters with Darwin admitting that Hooker was "the one living soul from whom I have constantly received sympathy".

Darwin in his *Autobiography* states that he opened his first notebook on Transmutation in July 1837 and that in "June 1842 I first allowed myself the satisfaction of writing a very brief abstract of my paper in pencil, in 35 pages, which then was enlarged during the summer of 1844 into one of 230 pages".

This completed abstract was eventually shown to his two friends and confidants, Joseph Hooker and Charles Lyell. On April 25 1855 Darwin started communicating with Asa Gray who had pointed out (in *Reviews of Zuccarini's Flora Japonica*, 1846) that an unusual number of plants of western North America were also found in Eastern Asia and nowhere else (particularly the magnolias). At this stage Darwin presumably felt he needed to let Gray into his secret in order to continue receiving his valuable comments on North American botanical geography. Thus, when next he wrote (20 July, 1857) he told Gray of his hypothesis on speciation. Then in the following letter, 5 September 1857, because Gray seemed interested he enclosed a sketch of his theory. It was essentially that which he had shown to Hooker and to Lyell back in 1844 with the addition of a statement on the principle of divergence "that the varying offspring of each species will try – only few will succeed – to seize as many and as diverse places in the economy of nature as possible".

Clue: a Chemist?

Thus, in September 1857 Gray entered the circle of initiates into the concept of natural selection, but with the rider not to mention it to anyone else.

At this point Lyell urged Darwin to write out his views “pretty fully” and to publish. This Darwin did, and by the time the Wallace manuscript arrived from Teruate in May/June, 1858 overthrowing all his plans, Darwin had completed some ten chapters (half a projected book). In an accompanying letter Wallace asked Darwin to forward the manuscript to Lyell. This Darwin did, but at the same time (June 18, 1858) he wrote to Hooker telling him of Wallace’s letter and its enclosure and explicitly announcing his resolve to abandon all claim to priority for his own “outline of evolution”. He also wrote to Wallace stating “that I would not publish anything before you had published”, but before he could post it he had received Hooker’s reply reminding him that both he and Lyell had read Darwin’s outline 14 years previously and that they should not withhold this knowledge of his [Darwin's] priority. And it was Hooker who suggested a compromise: the simultaneous publication of the two, moreover if Darwin agreed he would write to Wallace accordingly. Darwin agreed provided Lyell also supported his claim. As we all know, the answer was in the affirmative and so Darwin allowed Hooker and Lyell to offer a joint paper from himself and Wallace to the Linnean Society on July 1, 1858. Darwin's contribution included extracts from his 1844 manuscript on species (4 pages) and the abstract he had sent to Asa Gray the previous September (3 pages). This abstract was published in its entirety. Darwin, owing to his illness and distress, could not be present, while Wallace was on the north coast of New Guinea. However, both Lyell and Hooker were there and after a few remarks Hooker impressed on those present the necessity for giving their most careful consideration to what they were about to hear and its bearing on the future of natural history.

Earlier, in 1854, Hooker published *The Himalayan Journals* which he dedicated to Darwin. Hooker with the aid of a government grant collected over 7,000 species in India and Nepal and on his return to England secured another government grant to classify and name them. His subsequent publication the *Rhododendrons of Sikkim-Himalaya* (1749–51), which was edited by his father and illustrated by Walter Fitch, introduced some twenty-five new rhododendrons to the fifty already known and undoubtedly was responsible for eliciting the rhododendron craze among British gardeners. Also during this period, Hooker produced some of his most important works, including: *Outlines of the distribution of Arctic Plants* (1862); *Genera plantarum* (With George Bentham, 1860–83) in which the whole of the genera of flowering plants were diagnosed and delimited. His zest for travel remained unabated: he visited Syria in 1860, the Atlas Mountains of Morocco in 1871 and together with Asa Gray, made a three month trip to the Rocky Mountains in 1877.

With his death on Sunday, December 10th 1911, in his 95th year, the Linnean Society was said to have lost the most renowned of all its Fellows and one of the most remarkable men who ever devoted his life to the advancement of science. Offered the option of having him buried alongside Darwin in Westminster Abbey, his wife decided to go along with his wishes to be buried alongside his father in the churchyard of St. Anne's on Kew Green on December 17th 1911.

Hooker became a Fellow of the Linnean Society on June 7th 1842. In his will he left us £100. His Form of Recommendation was signed by Robert Brown, Francis Boott, John Bennett, Edward Forbes, Joseph Woods, J. Westwood, N.B. Ward and J Forbes Royle.

Hooker was notorious for his irritability – while Darwin described him as "impulsive and somewhat peppery in temper".

B. GARDINER

Correspondence

From: GAVIN BRIDSON Carnegie Mellon University, Pittsburgh, USA
15 March 2005

Robert McCracken Peck's article on "Cuting up Audubon for science and art" [*The Linnean* 21(1)] no doubt arouses surprise in some people, largely because the present high money value of natural history prints by Audubon and others has tended to make us see them as antique treasures rather than the paper "specimens" that they were really intended to be. John Gould's decision to make a collection of "Clippings" was not quite as unusual as Peck's article might suggest. There have been several instances of naturalists collecting personal "paper museums" principally derived from plates detached from books and/or original drawings. They had some distinct and obvious advantages over specimen collections, being easily stored and handled, and perhaps including images for which representative specimens were, for one reason or another, virtually unobtainable. Museum workers were normally forbidden to keep personal collections of the same material that they were employed to curate but a "paper museum" did not violate that rule. At The Natural History Museum in London four examples come to mind. Probably building upon a collection started by William Clift, John Hunter's last pupil, Sir Richard Owen accumulated an extensive collection of some 3,500 palaeontological and zoological drawings done by himself and over a hundred other artists with the addition of some prints and photographs. In that, he was continuing the practice of earlier workers such as John Hunter who kept a working collection of about 700 natural history and pathological drawings in his museum, and Georges Cuvier who maintained an extensive reference collection of palaeontological drawings made by himself and many others in his wide network of correspondents. Another Natural History Museum man, J.E. Gray, had a collection that has apparently largely been dispersed. Two parts remain as evidence in the Museum's Zoological Library, a two-volume Collection of illustrations of Cetacea and Sirenia, prints, drawings, tracings and photographs, and illustrations of Protozoa and other micro-organisms forming part of an attempt to make an illustrations collection of the animal kingdom. His brother G.R. Gray also made a large illustrations collection that was sold at auction by Sotheby's in 1872, viz., "Collectanea Ornithologica, being an immense collection of original drawings and engravings of birds, forming the most extensive and best history ever compiled, in 25 folios, and 28 quartos of manuscript and printed descriptions." Its present whereabouts are not known to me. A.C.L.G. Günther was the fourth such collector at the Natural History Museum. His surviving collection, preserved at the Linnean Society, comprises 39 folio volumes of prints, drawings, photographs, and printed ephemera on terrestrial and marine fauna of all regions. Günther's collection, the latest of this group, includes a much greater number of printed illustrations. With the increasing number of published illustrations during the 19th century it had become possible to assemble such a collection more readily whereas the earlier reference collections could only be assembled by the preparation of specially prepared original drawings.

I am sure that there are many other examples to be found and you will no doubt hear of them from various correspondents. Perhaps the assemblage and use of personal collections of prints and drawings by 19th century naturalists for purposes of scientific study, rather than simply "art" collecting, deserves further study.

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From: R.A. BAKER University of Leeds, 9th March 2005

I read with interest John Marsden's letter [*The Linnean* January 21(1) page13] about his collection of artificial pearls which were made from the scales of the bleak, *Alburnus alburnus*. He asked readers where the process was carried out.

The town of Ohrid in the former Yugoslavian Republic of Macedonia has several shops selling 'Ohrid pearls' made by the process described in John's letter. The bleak comes from the nearby lake Ohrid.

This ancient and deep lake is of enormous interest to biologists because it contains many relic, endemic and endangered species including the famous Ohrid trout, *Salmo letnica* Karaman.

There may of course be other regions where the same process is carried out but 'Ohrid pearls' are probably the best known.

I understand David Pescod has a digital image of a necklace made of Ohrid pearls which is owned by one of our Vice-Presidents, Jenny Edmonds. You may like to look at this. (*See photo by David Pescod right*.)

Lost Opportunity !

An item was tabled at a meeting of the North American Mycological Association council over ten years ago covering the possibility of setting up a Reserve for Fungi somewhere in the States. Alas it only reached the discussion stage and not much further until 2003 but if it hadn't happened then we may never have taken up the idea in Scotland where the Heron Wood project was born at Dawyck, one of the Edinburgh Royal Botanic Garden's specialist stations.

It was to Heron Wood that Linnean Society Fellows were going to be directed during a tour of Edinburgh Royal Botanic Gardens, a tour which unfortunately never materialized because of distance and the Foot & Mouth epidemic. So what is this project? Simply it is an area of planted beech woodland which has been colonized over twenty five years ago by an invasion front of birch from a neighbouring property which has been left for the growth of fungi and other cryptogams. For some unknown reason the birch invasion front stopped half way through the wood leaving a mosaic of habitats. Difficulties in funding towards the beginning of the 1990s led the Royal Botanic Garden to make cut-backs and the development of the plot of land known as Heron Wood was put on hold as no one could foresee when the financial climate would change signifcantly. For every cloud there is a silver lining and this cloud certainly had one. I posed the question whether the Heron Wood could be used for cryptogams, suggesting that this would require little or no financial input. The site would be managed by not managing with no attendant staff costs. Any money needed for the project would be raised outside the system. Now ten years on the Garden has established itself and is enjoying being host to a series of exciting field studies.

Heron Wood is within the setting of the 300 plus years of botanical plantings at Dawyck and the present collection so admirably described by the present Curator David Knott (2000). Although emphasis was to be placed on fungi, experience had been gained whilst setting up the Cryptogamic Garden in Edinburgh that other cryptogams, such as lichens and mosses, should be included to give a year round appeal. Much later a display of ferns was planted at the interface of Heron Wood and the public footpath. Heron Wood was divided into the Sanctuary, where nothing would be touched, not even clearing away fallen trees, and the Reserve, where some essential maintenance would have to be carried out. The whole area is 7.5 hectares with over half making up the Sanctuary. All the trees in the area were tagged and numbered as where all the trunks and stumps. In addition, within the Sanctuary a Feest Transect and a 100 metre permanent Biodiversity quadrat were set up, the latter with two metre quadrats in each of the quarters of the plot, making eight in all. Demonstration boards depicting ectomycorrhizals, forest pathogens, litter rotters, lichens and mosses were prepared and erected, paid for by various society donations and with a generous gift from a private donor enough money was given for a chalet to be placed at the edge of the Sanctuary to give protection from the Scottish elements. The chalet also allows the various participating organizations to advertse: British Mycological Society who generously started the ball rolling with a financial pump primer, British Lichen Society, British Bryological Society, Botanical Society of Scotland, Plantlife International and the Friends of the Royal Botanic Garden, Edinburgh.

Since 1994 all the fungi in the Sanctuary and Reserve, as elsewhere in the Garden have been catalogued at least every month with the number of the tree that they are most likely to

Amanita muscaria

be associated with noted. Naturally, in the autumn many more visits are made. 129 visits in all have been made and they have produced an enormous data set covering 954 different fungi based on 9499 records. Of course, the records focus on the larger fungi but there are records too of the micro-forms. The lichens, or lichenized forms, because they are a union of a fungus and an alga, the former dominating the partnership, are not included in this figure. My former colleague Brian Coppins kindly identified the lichens, numbering 79spp. in a total of 187 for the Garden as a whole, of which 12 are either rare or localised in their distribution. Over a third of the recorded fungi have been found in the Sanctuary and Reserve and the millenium year was one of the best years ever, certainly since the Project became official. By the end of October 2000 fruiting bodies of *Russula nigricans* were still being counted in their hundreds. Only ten days before that there were scarcely any fruit-bodies, everything exploding in a matter of days and, once fruiting had started, it continued well into December which, until the last few years, is quite exceptional, especially as Dawyck would have expected temperatures well below zero by then. Indeed the temperature in previous years regularly fell to air temperatures of minus 15 degrees centigrade; summer temperatures rarely exceed 27 degrees. With a small meteorological station on site it is possible to examine correlations between climate, tree growth patterns and fungal production. It is estimated that the total number of fungi for the Dawyck Specialist Garden will be in excess of 1,750 different taxa.

Additional to the fungi and the lichens, the mosses and liverworts of the Garden have been catalogued by my former colleague David Long (34 spp. in the Sanctuary and Reserve out of 102 for the whole Garden) and the native Higher plants listed by another former colleague, Douigla McKean. A note of the birds and animals has been made, and even the fungi on dung samples of some of the latter have been analysed by my friend Mike Richardson. In addition at Dawyck there are the Scottish Rare Plant and David Douglas trails. It is interesting to note that nearly a third of the ectomycorrhizal fungi recorded from Dawyck

Phaeolepiota aurea

Leucopaxillus rhodoleucus

are associated with at least one of Douglas' introductions, especially the Douglas Fir. In all the major groups interesting or uncommon taxa have been found.

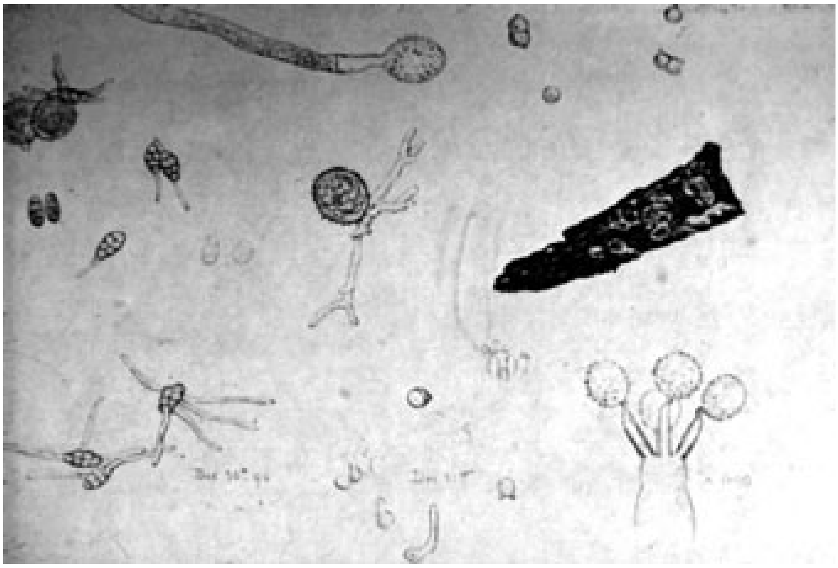
Ten years on and the Sanctuary plays host to an ambitious programme in its early stages associated with Abertay University, Dundee where the fungal activity, bacteria and invertebrates in the soil are being analysed using both chemical and DNA procedures, and examined within a framework of abiotic factors. Analyses are on-going and the results have spawned fifteen multi-authored publications so far. Thus the concentration of ergosterol, used as a measure of fungal activity, is signifcantly related to soil organic matter, soil pH and bacterial numbers, whilst the biomass of endomycorrhizal fungi measured by the glomalin assay was only related to soil organic content. In addition, numbers of soil amoebae were signifcantly related to microbial feeding nematodes, soil pH and protozoan flagellates. The abundance of bacteria was related to total fungal biomass, plant feeding nematodes, soil amoebae, soil organic content and soil pH. Surprisingly, bacteria appear to be extremely active in those winter months analysed, the glomalin activity is greater under the birches than beeches, and endomycorrhizal behaviour is related to position in the soil profile. These results confirm the interdependency of the dynamics of different microbial groups. The work continues.

After the area was scheduled, labelling completed and the chalet erected we had an official opening in 1996 by the Earl of Selborne FRS, well known in the UK for his interest in biology. Excellent media coverage, both local and national was obtained. A good start indeed with representatives of important UK organizations attending, as they did in 1999 for the launch of the second batch of the UK Biodiversity Action Plans, which included a whole series of larger fungi receiving Governmental recognition. This time it was to have been the Scottish Minister of Agriculture, Lord Sewell, but at the last moment he was detained in Brussels in connectiion with European Agricultural subsidies and was replaced by a senior Civil Servant. The opportunity nonetheless was taken, then and later when Lord Sewell caught up with the gathering, to emphasize the importance of identifying and naming, not only fungi, but all organisms.

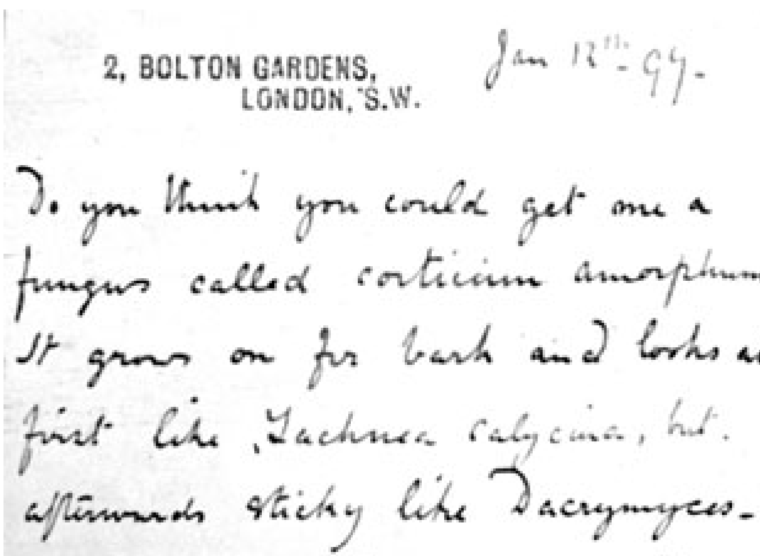
Although Dawyck Garden is in the Scottish Borders it still recieves a good number of visitors, many of whom climb to the top of the hill to view the Sanctuary. To complement the on-going research programme, Heron Wood is used as a teaching and study resource for children, teachers, university and college students, and society and institute members (British Mycological Society, Inst. of Biology & Inst. of Horticulture, Plantlife International and Edinburgh Nat. Soc., to name but a few) in addition to the general public. In fact, for twelve years an annual foray had been organized to demonstrate larger fungi but with so many people showing an interest an additional one is held for the more experienced. In addition, along the beech avenue for the last few years a monitoring experiment has been undertaken to assess whether picking and non-picking of chanterelles effects fruiting.

Some of the treasures of Dawyck are *Dendrocollybia racemosa* with its small conidial heads growing from the surface of the stem and the very recently recognized *Collybia fagiphila*, the genuinely agaric-looking *Squamanita paradoxa* which parasitises the mushroom *Cystoderma amianthinum* replacing the cap with its own. *Phaeolepiota aurea* makes a great spectacle in the autumn producing in one site by the Skunk Cabbage literally hundreds of fruiting bodies; quite close to this show over the last few years has been found *Leucopaxillus rhodoleucus* growing in rings, now 3 in number, under an old *Chamaecyparis nootkatenisis*; this makes this the second site for the UK, although since its appearance at Dawyck it has again been found in the south of England. *Boletus pulverulentus* fruiting under lime trees (*Tilia*) in the Car Park and close to the citron-yellow *Chrysomphalina wynniae* on old conifer poles is very impressive, instantaneously blueing when handled. This bolete is southern and western in its general distribution. On wood there are good shows of the annulate Oyster mushroom, *Pleurotus dryinus*, and the uncommon soft and succulent *Ischnoderma benzoinum* on an old fallen *Abies alba*, the cinnamon-brown polypore *Phellinus ferreus*, covering metres of a fallen trunk and also occurring in the canopy of near-by oaks and *Aleurodiscus wakfeldiae*, not very impressive in the field but wonderful under the microscope with its huge amyloid, spiny basidiospores and tree-like cystidia; the

Aleurodiscus amorphus



Beatrix Potter's illustration showing basidiospores and fruiting body of *A. amorphus* and the spores of *Tremella simplex*.



2, BOLTON GARDENS,
LONDON, S.W.

Jan 12th - 97.

Do you think you could get me a fungus called corticium amorphum? It grows on fir bark and looks at first like Lachnea calycina, but afterwards sticky like Dacrymyces.

Part of a letter from Beatrix Potter to Charles McIntosh asking for *Coriticum amorphus* (= *Aleurodiscus*)

last fungus is named after the late Dr. Elsie Wakefield, a former senior mycologist at the Royal Botanic Gardens, Kew. Interestingly there is also a record from Dawyck of the closely related *A. amorphus* with its accompanying jelly fungus, *Tremella simplex* both of which were fungi Beatrix Potter studied and illustrated, managing to germinate spores before the turn of the century. Two Red Data List fungi also occur in the Garden, the purple *Clavaria zollingeri* and the Earth Tongue relative, the yellow *Spathularia flavida*. Apparently a feature of Dawyck is the presence of the very rare jelly fungus *Tremella hypogymniae* on the lichen

Hypogymnia physodes and amongst the micro-fungi *Cornutispora triangularis* growing on the lichen *Pertusaria pertusa* is a new record for the UK. So why not visit the Dawyck cryptogamic Sanctuary and Reserve to see many of the interesting cryptogams present and obtain a different angle on horticulture, and how fungi play an important role in their growth. And all this set in the grounds of a world beating horticultural collection.

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ROY WATLING
Caledonian Mycological Enterprises, Edinburgh, Scotland

Thermoregulation in Amniotes

In an article 'On Sweating', *The Linnean*, 19(3): 46-49, Cloudsley-Thompson showed that uniquely in mammals the thermoregulatory evaporation of water takes place by way of sweat glands. The article noted that some mammals (viz cattle, sheep, dogs and cats) like birds cool themselves by panting. This fact caused me to reassess the whole problem of thermoregulation in mammals and birds. Taking mammals first, I found that monotremes are presumed to have limited thermoregulatory abilities with no vasculomotor control of skin capillaries, do not pant and have but a rudimentary ability to sweat, while shivering seems to be their primary control of internal temperature (Carter, 1967). However, these early observations suggesting that thermoregulation was imperfect in monotremes was probably due to use of stressed animals and, according to Griffiths (1958), they can regulate as well as many eutherians. I also found (Gardiner, 1982) that the resting metabolic rate of birds and mammals was at least five time higher than all other amniotes of comparable size and similar body temperature. Following from this I deduced that birds and mammals shared similar thermoregulatory mechanisms, including being able to alter their body insulation by the use of smooth erector muscles at the bases of the hairs and feathers. Both structures are induced by special groups of underlying cells.

Other features shared by both groups include non-shivering thermogenesis, panting and similar behavioural responses such as huddling. They also show seasonal changes in plumage and pelt.

Perhaps the striking resemblance between feathers and hair is a developmental feature whereby melanin is passed from melanocytes associated with the feather tracts or hair follicles into the bases of the developing feathers or fur via an epidermal melanin unit. Although crocodiles have similar melanocytes below the epidermis (Kemp, 1988) only in mammals and birds does the morphogenetic concept apply whereby melanin is extruded into the developing feather or fur [= the epidermal melanin unit].

It is also worth pointing out that both mammals and birds possess bristle-like tactile sinus hairs on their faces which are provided with striped muscle fibres. In insectivorous and nocturnal birds these are not only present around the base of the beak but also round the eyes and ears. In both groups these are both longer and stronger than other hairs.

Artist's impression of a basal member of the clade Haemothermia – courtesy of *La Recherche*.

Both feathers and hairs are continuously growing and the only real difference between them is said to be their method of formation which is, birds' feathers develop as open tubes and then sink deep into the dermis, coming to lie in a kind of pocket. However, this is exactly how the hairs develop in *Ornithorhynchus*, where, as in birds, the developing hair in its tube sinks into a pocket in the dermis. Moreover, in the young hedgehog Owen (1868) has shown how the reflected integument forms a sheath or tube in the dermis which gradually shortens and draws the quill nearer to the surface. Thus the hedgehog quill development, like hair development in *Ornithorhynchus*, is very similar to feather development in birds.

Hairs are said to contain only " keratin, unlike feathers which are comprised of ß keratin. Nevertheless, the quill medulla of the American porcupine as well as the scales of the pangolin are comprised soley of ß keratin.

Feathers and hair are arranged in groups and both are used as organs for the sensation of touch. They are both used for temperature control and to signal aggression (crests or hackles). The logical explanation for all these similarities (or synapomorphies) is that feathers and hair are part of the same developmental process which specifies the group Haemothermia.

In many birds the feathers retain throughout life the essential characters of down with more or less differentiation (eg ratites especially the cassowaries), but in most cases the down becomes covered or replaced by the contour feathers, the proximal barbs of which still retain their down-like character. The contour feathers are arranged in feather tracts separated by down covered spaces. When birds hatch they have a down feather covering in which the individual filaments or barbs are all soft and separate. The pelt of mammals on the other hand is made up of both fine and coarse elements with a richer, finer covering characterising the embryonic condition.

In both birds and mammals the dermis is irregularly felted with smooth muscle fibres inserted into the follicles. Also present round the beak and in the feather follicles and dermis of birds are Herbst=s Corpuscles which measure pressure changes. Homologous with these in mammals are Pacinion corpuscles which occur in the dermis, conjunctiva and ligaments and are similarly concerned with registering pressure. In both groups nerve fibres are wound round the bases of the papillae which have encapsulated lamellar corpuscles. It is these corpuscles with their associated nerves which transmit pressure changes to the brain from hair or feather. Also present round the beak in birds are corpuscles of Grandry which are touch receptors. These are presumed to be homologous with Meissner=s corpuscles in mammals. Thus I conclude Herbst=s corpuscles and Pacinian corpuscles are homologous as are Grandry=s corpuscles and Meissner=s corpuscles making two synapomorphies to add to my 1982 list (see Gardiner, 1982).

Back in 1982 I produced some 17 synapomorphies in support of the clade Haemothermia (comprising mammals and birds). This was subsequently challenged by Gauthier *et al* in 1988, who found that by the addition of fossils (with their very primitivness) they were able to overturn a theory of relationships based on Recent biota. Although they accepted five of my characters they considered a further eight had arisen independently (convergently) in mammals and birds. These were: three meninges, scroll-like turbinals, adventitious cartilage, fusion of atlas and axis centra, vascularised islets of pancreas, macula densa, loop of Henle and a compact myocardium. Thus this leaves some 13 of my original synapomorphies supporting the clade Haemothermia to which has been added (see above) a further four synapomorphies.

I conclude that these additional synapomorphies are more than sufficient to overthrow the fossil evidence and at the same time add further support to the clade Haemothermia.

BRIAN GARDINER

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Evolutionary Theory

In 1989 I attended the Faraday Lecture at the Royal Society by Professor Sir Christopher Zeeman FRS on Evolution and catastrophe theory. It seemed to me, a mere pilgrim in the foothills of evolutionary theory, that the paper had considerable relevance for evolutionary biologists, and I looked in vain for its publication. Seeing Sir Christopher, formerly Principal of Hertford College, Oxford, at the Robert Hooke event late in 2003 in Oxford†, I sought the fate of the paper and was told that Cambridge University Press had published it in 1992 in *Understanding Catastrophe*, edited by J. Bourriau, pp.83-101.

It seemed to me that the Zeeman paper reconciled Darwin's gradualism and Eldredge and Gould's punctuated equilibrium. I was unable to consult Darwin on this matter, but I did talk with Stephen J. Gould before his sad death a couple of years ago; he was unaware of the paper and its possible significance. Sir Christopher has generously agreed to its reproduction here.

JOHN MARSDEN

Catastrophe theory applied to Darwinian evolution

Sir Christopher Zeeman FRS*

Introduction

Catastrophe theory is the name given to a method of mathematical modelling introduced by René Thom in the 1960s. It is based on deep theorems in topology, and is particularly applicable to phenomena in which continuous causes produce discontinuous effects. Without a model such effects can be unexpected, and if they happen to be harmful are liable to be called catastrophes – hence the name. On the other hand, with an appropriate model the effects can be understood and anticipated. The easiest way to explain the method is to describe a particular example, and so in honour of Darwin College I have chosen an application to Darwinian evolution.

Charles Darwin assumed that the causes of evolution were gradual: small random variations and natural selection. Yet some of the observed effects appear to be discontinuous. As a result there has been continual debate over the matter ever since he published his famous book *The Origin of Species* in 1859. Indeed, Darwin himself was worried about it and devoted a whole chapter of the book, Chapter 6, to 'difficulties on theory'. And his strongest supporter T.H. Huxley wrote to him the day before the book was published warning him: 'You have loaded yourself with an unnecessary difficulty in adopting *Natura non facit saltum* (nature does not make jumps) so unreservedly'. Even today the argument continues: for instance, Niles Eldredge and the late Stephen Jay Gould have introduced the term *punctuated equilibria* to describe the fact that species tend to remain stable for a long time, but if one species evolves into another it often does so relatively rapidly. Other biologists emphasise Darwin's gradualism and dismiss punctuated equilibria by saying that of course there are likely to be varying rates of evolution but nothing to make a fuss about.

† Paul Kent & Allan Chapman, 2005. *Robert Hooke and the English Renaissance*. Leominster: Gracewing.

We shall reconcile the two points of view by making a catastrophe model of continuous cause and discontinuous effect as follows. We translate Darwin's gradualist hypotheses into mathematics in the simplest possible way, and then deduce from the mathematics that punctuated equilibria is not a contradiction to, but a *consequence of*, those hypotheses.

Furthermore we shall explain why *multiple speciation* is likely to occur at the punctuation points. Both phenomena, punctuated equilibrium and multiple speciation, are observed in the fossil record. Some evolutionary theorists suggest that multiple speciation is not 'generic' and should be replaced by a sequence of bifurcations, but the mathematics suggests the opposite, vindicating Darwin's original picture (in fact the only picture) in *The Origin of Species*, Figure 1, left).

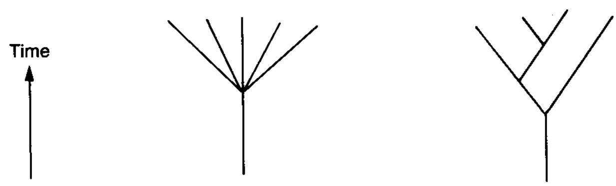

Figure 1 Left: multiple speciation. Right: bifurcations.

Catastrophe theory has been applied to evolution by Maurice Dodson and a number of other authors but this is the first explanation of multiple speciation.

Before getting down to the business of making the model let us review in more detail the observed discontinuities in the evolution of species that the model ought to explain. There are three types: discontinuities in time (punctuated equilibria); discontinuities in space (abrupt frontiers); and discontinuities in form (speciation, canalisation).

Discontinuities in time

These can be observed in the fossil record. A typical example is a surface parallel to the rock strata, below which the strata contain fossils of a species A, and above which the species A has been replaced by a species B (see Fig. 2, left). The corresponding point on the geological time-scale is called a *punctuation point*. This sudden disappearance of A at the punctuation point and its replacement by B is usually interpreted as B invading A's territory and occupying the same ecological niche that was previously held by A.

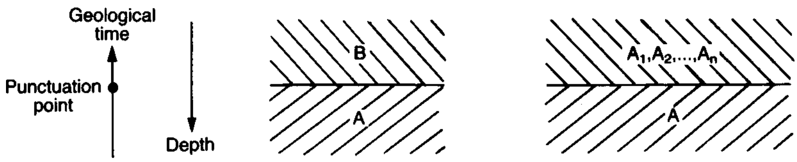

Figure 2 Left: invasion. Right: multiple speciation.

Another typical example is the disappearance of A and its replacement by one or more descendant species A_1, A_2.….A_n (see Fig. 2, right). The interpretation here is of a sudden evolution at the punctuation point, with multiple speciation. The model will explain both processes.

Discontinuities in space

The above examples are of discontinuities in time at a fixed point in space. Similarly these are also discontinuities in space at a fixed point of time, and these can be observed today as abrupt frontiers between different species occupying the same ecological niche (Figure 3).

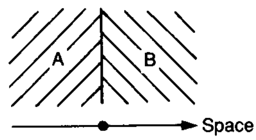

Figure 3 An abrupt frontier between species.

A familiar example is the tree line on a mountain, above which trees are replaced by grass or other plants. In *The Origin of Species,* Darwin draws attention to several examples – going up mountains, down an ocean shelf, or towards cooler latitudes. In the chapter on the difficulties of the theory he argues how intermediate species might be eliminated, but does not explain how such a frontier could form in the first place. Our model will show how a gradual variation of environment can cause the creation of abrupt frontiers.

Discontinuities in form

The problem here is to explain the similarity between individuals of the same species compared with the difference between those of different species. What causes a species to be so homogenous? In other words what causes *canalisation,* the similarity of phenotype (the adults of a species) despite variation of genotype; similar-looking adults can have surprisingly different genes. The immediate answer is natural selection acting on the phenotype. Therefore let us rephrase the question more sharply: if humans and chimpanzees are both descended from a common ancestor about 6 million years ago why is there not a continuous spectrum of individuals running from human form to chimpanzee form? The answer is, on the contrary, that there is indeed such a continuous spectrum in form-time space, going back from the human to the common ancestor, and up again to the chimpanzee, as shown in Figure 4. Here the space of theoretically possible forms is sketched as two-dimensional whereas it should of course be highly multidimensional.

This answer, however, merely throws the question back from the global to the local: how did the bifurcation occur in the first place? To put it another way, what causes *speciation*,

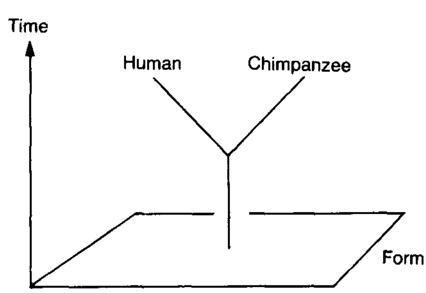

Figure 4 Form-time space.

the formation of different species from a common ancestor? If one replies ‘natural selection’ this raises the awkward paradox that we have now invoked the same cause for the opposite processes of canalisation and bifurcation. The model will resolve this paradox, and also explain the alternative process of catastrophe and multiple speciation at punctuation points.

Mathematical Model

Darwin’s theory of evolution can be summarised briefly as:

(1) Random small variations
(2) Natural selection } ⇒ (3) Evolution of species

Here (1) and (2) are the local slow gradual cause while (3) is the global long-term effect. We want firstly to translate (1) and (2) into mathematical hypotheses, secondly derive mathematical results from those hypotheses, and thirdly interpret the results back into biological conclusions. It is a good idea to keep the mathematical argument as separate as possible from the two modelling processes of translation and interpretation, so that if the biological conclusions turn out to be wrong then the fault can be traced back to one or other of the two modelling processes. So let us begin to translate (1) and (2) into mathematics.

‘Small variations’ suggests representing the individuals of a species by points in some n-dimensional Euclidean space X of theoretically possible forms. What do the coordinates of X represent? They might be particular measurements significant for the specific example of evolution under consideration, such as length of leg or size of beak, or the concentration of some enzyme in some organ, or the timing of some embryological event that affects the eventual shape of the phenotype. We can either choose n small and confine ourselves to a few explicit variables, or else choose n large and allow ourselves an arbitrary number of implicit variables. Although variations in the phenotype must ultimately arise from variations in the genotype, which are of a combinational nature, nevertheless in many cases a continuous model of the phenotype will be adequate, and often easier. Also natural selection acts on the phenotype.

If, further, we want to model the evolution of a symbiotic relationship, or a prey-predator relationship, or an ecology, then a point of X can represent the symbiotic pair, or the prey-predator pair, or a state of the entire ecology.

We translate the word ‘random’ into mathematics by assuming that the offspring of an individual x lie in a small neighbourhood of x. The size and shape of such neighbourhoods will be important for some applications, but we shall not need to consider them at this stage.

Darwin’s hypothesis (2) of natural selection means that more offspring are produced than can survive, so that only those that are more fitted to a given environment will survive. The simplest way to translate this into mathematics is to postulate an *unfitness function* u: $X \to R$ where R denotes the real numbers, and $u(x) < u(y)$ means x is fitter than y. (We use unfitness rather than fitness in order to exploit the intuition of a ball rolling downhill.) Let us postpone discussion on the existence and measurability of u until we have begun using it, so that the usage can then indicate what needs to be discussed.

For simplicity suppose at first that X is one-dimensional, and consider the graph of u shown in Figure 5. (At the back of our minds we continue to think of X as n-dimensional, and later it will be important to have X at least 2-dimensional.) Suppose that

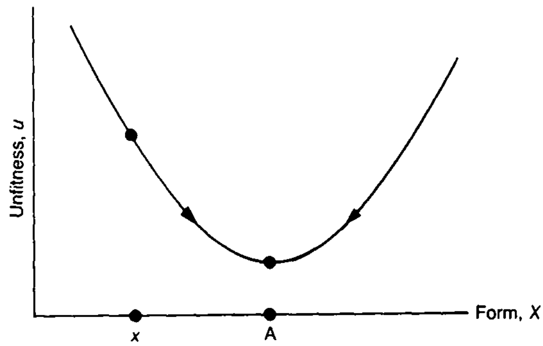

Figure 5 Unfitness function.

the individuals of a species have mean *x*, and are clustered in a neighbourhood of *x*. By hypothesis (1) their offspring will be spread over a slightly larger neighbourhood, and by hypothesis (2) only the fitter will survive, and so the mean of the survivors will be slightly downhill from *x*. Hence the species will begin to evolve by rolling downhill towards the minimum A of *u*. When the species reaches A then it will stabilise, because any small variations will be less fit, and so will not survive. Thus a minimum of *u* represents *a species in stable equilibrium.* Moreover we have trivially explained canalisation, the similarity of phenotype despite variation of genotype.

It is tempting to think of evolution as a gradient differential equation, but we shall see later that if dim*X*$2 then it obeys a rather different kind of dynamics.

Explanation of discontinuities in time

We now introduce elementary notions of catastrophe theory. Suppose that the environment is gradually changing so that another ecological niche appears at B, as in Figure 6(a). More precisely, assume that *u* gradually changes so as to create a new minimum at B, which represents a theoretical form of phenotype best fitted to fill that new ecological niche.

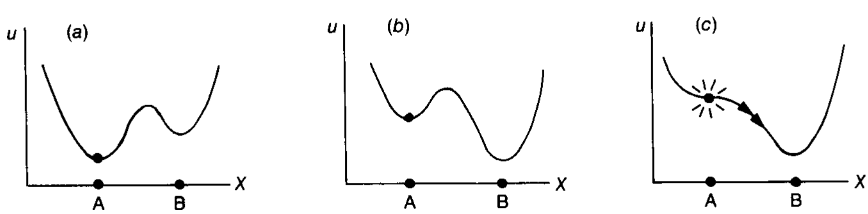

Figure 6 Catastrophe.

Even if the niche gradually becomes more advantageous than A, with a lower minimum as in Figure 6(b), the species is prevented from evolving to B because it cannot climb over the intervening hump towards B; any random small variation of individuals that happened to be towards B would immediately be eliminated because they would be less fit than the existing population at A. This situation persists until the gradual change in *u* causes the minimum at A to coalesce with the maximum, as in Figure 6(c). Then any random small variation towards B will be advantageous, and so the species will evolve until it reaches B, where it will stabilise again. Compared with the periods of stability previously spent at A, and subsequently spent at B, the time taken to go from A to B is likely to be relatively short, perhaps as little as one thousandth as long as the periods of stability. Hence on the geological time scale it will appear as a catastrophic jump, or more briefly a *catastrophe*. In the fossil record the catastrophe will occupy a thin layer of perhaps one thousandth of the thickness of the strata below containing fossils of A, and the strata above containing fossils of B. Indeed the layer may be so thin as not to contain any surviving fossils of the intervening forms between A and B, and hence it will appear as a surface of discontinuity at a punctuation point.

Thus we have shown that *Darwin's two local hypotheses imply punctuated equilibria*. Indeed, Darwin himself had insight into this process because in the summary of Chapter X of the first edition of *The Origin of Species* he writes: 'the duration of each formation is, perhaps, short compared with the average duration of specific forms'; and in later editions he expands this to 'although each species must have passed through numerous transitional stages, it is probable that the periods, during which each underwent modification, though many and long as measured by years, have been short in comparison with the periods during which each remained in an unchanged condition'.

We are not claiming that all evolution takes place by catastrophes; the model also allows for gradual evolution. Figure 7 illustrates the two possibilities, beginning and finishing with the same *u*. In each case the gradual change of *u* is illustrated at successive times 1 . . . 5, and the resulting fossil record in form-time space is indicated below.

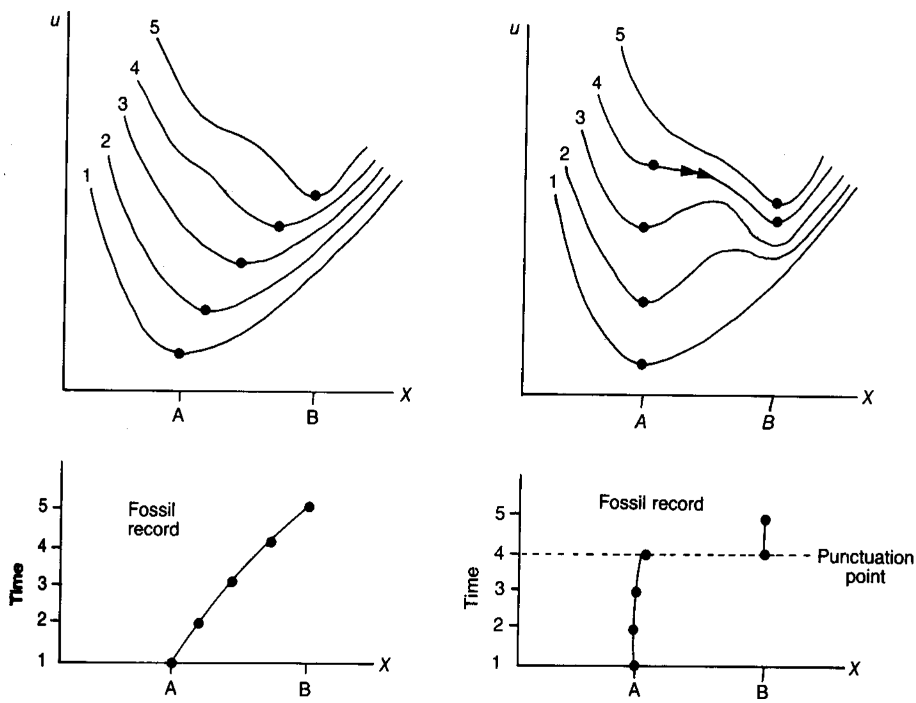

Figure 7 Left: gradual evolution. Right: punctuated equilibria.

Digression on unfitness functions

We have been implicitly using unfitness functions ranging over large changes of form and long periods of time. Are we justified in doing this? The answer is yes for the following reasons. Fitness can be measured locally between individuals living in roughly the same place at the same time in the same environment, for example by counting the numbers of surviving offspring. This determines local unfitness functions, which can then be glued together to give a global unfitness function as required. The glueing together process is non-trivial mathematically, but can be done thanks to a theorem that André Haefliger proved in his doctoral thesis in 1958.

Explanation of discontinuities in space

Suppose that a species S occupies a domain in which the environment varies gradually from one end of the domain to the other. Suppose that one end of the domain favours a smooth gradual evolution of the species into form A, while the other end favours a smooth gradual evolution into form B. What will happen in between?

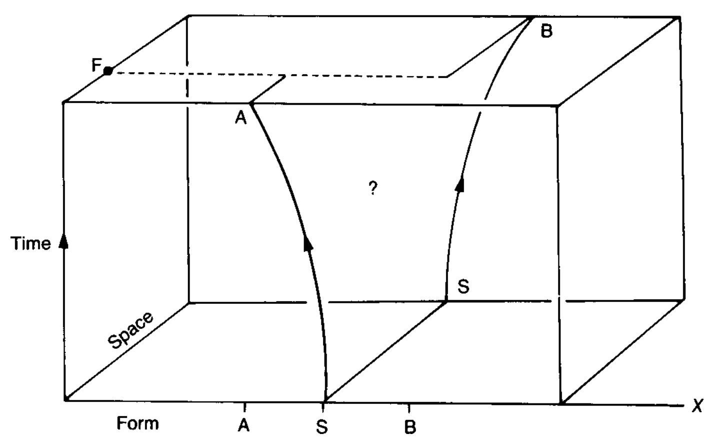

Figure 8 Graph of form as a function of space-time.

Figure 8 shows how to translate this question into a geometric problem of extending to the interior of a cube (or a rectangular box) a graph that has already been given on the boundary of the cube. Here the two independent variables are space and time, where *space* means the one-dimensional direction along which the environment varies. The dependent variable is the form *x*, which lies in a multidimensional space of possible forms *X* (drawn for convenience as one-dimensional).

We want to draw the graph of *x* as a function of space and time. We are given the boundary of the graph on the faces of the cube as follows. At the beginning of the time period under consideration the graph is constant, *x* = S, represented by the line on the bottom of the cube parallel to the space axis. At the end of the space axis nearest the reader the graph shows a smooth evolution from S to A, represented by the curved line on the front of the cube. At the other end of the space axis the smooth evolution from S to B is represented by another curved line on the back of the cube. At the end of the time period the space is occupied by the two species A and B meeting at an abrupt frontier F, represented by the dotted line of discontinuity on the top of the cube. The problem is how to fill in the surface of the graph

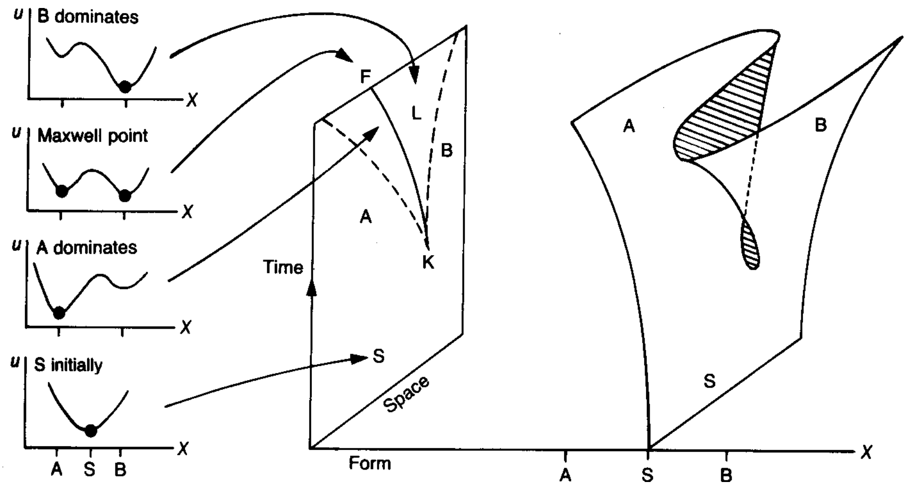

Figure 9 Cusp catastrophe.

inside the cube. Figure 9 illustrates a solution to the problem, and after we have described it we shall explain why it is *the* solution.

The smooth folded surface in Figure 9 is called a *cusp catastrophe*. When the surface is projected (horizontally) onto space-time the images of the fold curves, which are shown dashed, form a cusp at K; hence the name. Examples of the unfitness function *u* at four typical points of space-time are illustrated on the left. For points outside the cusp *u* has only one minimum, which at the beginning is S. For points inside the cusp *u* has two minima near A and B, separated by a maximum (or a saddle-point if *X* is multi-dimensional). The two sheets of the surface labelled A and B are the graphs of the minima near the species A and B, and both these sheets emerge smoothly from the lower part of the surface, labelled S, corresponding to the smooth evolution of S into A and B at opposite ends of the space axis. The folded over shaded part of the surface is the graph of maxima (or saddle-points) in between A and B.

The region of space-time labelled A is where the species A dominates (because A is fitter than B) and similarly the region labelled B is where B dominates. The two regions are separated by the line L of *Maxwell points* where A and B are equally fit. The line L ends at the cusp point K. The graph that we want consists of the dominant species at each point of space-time, and is therefore a subset of the surface, with a discontinuity along L.

L is called the *Maxwell line* after Maxwell's model of phase transition, which has a similar picture. For example, in Maxwell's model the line L represents the discontinuities between liquid and gas of boiling and condensation under gradual changes of temperature and pressure, and K represents the critical point of the phase-transition. In our model the line L represents the discontinuity between A and B under gradual changes of space and time, and K represents the beginning of that discontinuity.

Figure 10 shows a typical Maxwell point M on the Maxwell line L. The vertical line through M shows the fossil record at a particular place, with a punctuation point

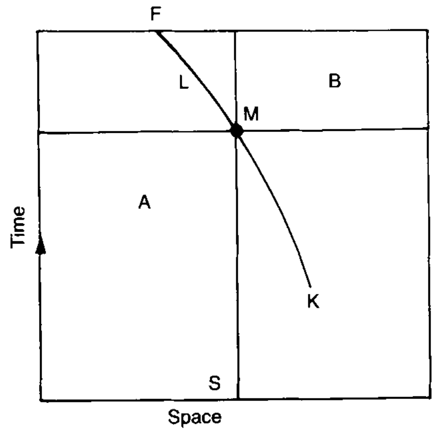

Figure 10 Discontinuity in space-time.

at M where B has invaded A's territory as in Figure 2 (left). The horizontal line through M shows the spatial distribution at a particular time, with an abrupt frontier at M between A and B, as in Figure 3. The point K identifies the time and place where this frontier first appears. The diagram illustrates the interrelationship between these four concepts: punctuated equilibria, invasion of territory, abrupt frontiers and their first appearance. It would be interesting if a Maxwell line could be found experimentally by plotting the punctuation points in fossil records at different places.

Digression on the universality of the cusp catastrophe

Suppose *u* is any smooth generic function on an n-dimensional space *X* with a two-dimensional parameter space P (such as the space-time plane in Figures 9 and 10). The set C of critical points of *u* (that is the minima, maxima and saddle-points) form a smooth two-dimensional surface in *X* H P, as in Figure 9. Call a point of C a singularity if it has a horizontal tangent. The deep theorems of catastrophe theory classify the types of singularity that can occur, and there are only two types, fold curves and cusp points, as shown in Figure 9. Moreover they are robust under perturbations of *u*, and so they are universal models for problems with two parameters. Since there are only two types of singularity, Figure 9 illustrates *the most complicated local shape* that C can have. At the same time it is the *simplest global solution* to our particular problem (where simplest means fewest singularities) because the given boundary conditions imply that there must be at least one cusp. Summarising: the cusp catastrophe is the unique simplest universal solution to our problem.

With more parameters there are more types of singularity: Thom calls them *elementary catastrophes* and classifies them in higher dimensions.

Comparison with allopatric speciation

Allopatric speciation is the name given to the following description of evolution. Although it is a commonly-used description it requires, in fact, five somewhat specialised extra hypotheses as follows. There must be (i) a small peripheral subset of the species that (ii) becomes physically isolated from the heartland of the species in order to prevent interbreeding so that it can (iii) evolve separately due to (iv) adverse conditions before (v) re-invading the heartland.

By contrast our cusp catastrophe model requires only one somewhat mild hypothesis that different ends of the domain favour the evolution of different forms. Using a universal mathematical model we have then deduced that a frontier will appear in the heartland of the species. It is no longer necessary to appeal to allopatric speciation as the main cause of speciation. Similar catastrophe models can be developed by replacing the space axis with some parameter describing the food supply or the types of predator. If different foods or different predators favour the evolution of the different forms, then this can cause bifurcations with sharp divisions within the species.

Multiple speciation at punctuation points

We have yet to explain Figure 2 (right). For this we must go back to the punctuated equilibrium illustrated in Figures 6 and 7 (right) and analyse the catastrophe when X is multidimensional. It suffices to imagine X as two-dimensional. The catastrophe is triggered by the disappearance of a minimum, or more precisely by a gradual change in u causing the coalescence of that minimum with a saddle point. This can be visualised as a pond on a hillside, whose edge is gradually being eroded until it disappears. Generic pictures of the contours of u in X before, at, and after the moment of catastrophe are shown in Figure 11.

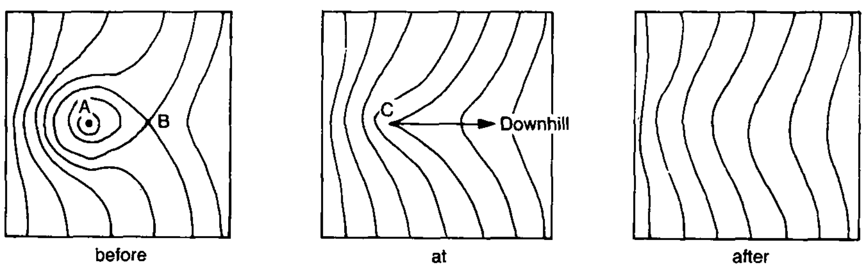

Figure 11 Contours of u before, at, and after a catastrophe.

Before the catastrophe, the species is in stable equilibrium at the minimum A at the bottom of the pond, and B denotes the saddle-point. At the moment of catastrophe A coalesces with B at the point C. The contour through C is a cusp whose interior axis points downhill, and therefore the species begins to evolve specifically in that direction. As the species starts going further downhill the direction of evolution is not so clear, and to determine what happens it is necessary to go back to Darwin's original hypotheses (1) and (2). According to (1) the random small variations will cause the species to spread like a wave in all directions, uphill, downhill and along the contours. Meanwhile the natural selection of hypothesis (2) will prevent it from going uphill, by eliminating the less fit above some contour line. Therefore the species will begin to travel like a solitary wave rolling downhill at the same time as elongating itself along the contours. The wave-fronts will be curves radiating out from C determined by (1), and the wave-backs will be the contour lines determined by (2). Figure 12 illustrates the artificial special case of equal speeds of variation in all directions and parallel contours. At any given time the species will occupy the sector of a circle as illustrated by the shaded areas. After a while the radius will increase and the species will approximate to a strip between two neighbouring contours.

Darwin makes some pertinent comments in *The Origin of Species* in his initial chapter on the breeding of domestic species. A wild breed is stable under natural selection, and will

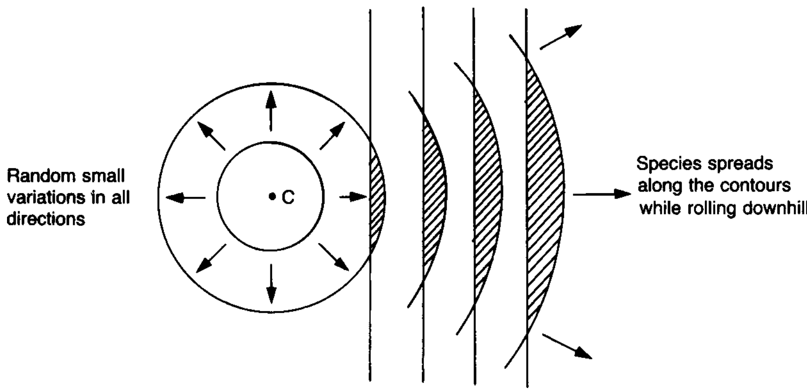

Figure 12 Catastrophic wave.

remain so under domestic selection until the breeder manages to reach the catastrophe point. Darwin then says 'when the organisation has once begun to vary, it generally continues to vary for many generations', corresponding to our wave rolling downhill. Once variation has started 'the whole organisation seems to have become plastic', corresponding to our wave spreading along the contour lines. Furthermore, recall that X is really n-dimensional for some very large number n, and so the contours are no longer one-dimensional but (n-1) dimensional; hence the species will begin to fan out continuously in every direction but one. Eventually the species will finish up distributed amongst a number of minima at the bottom of the u-landscape. Individuals in most of these minima are likely to be eliminated by those in fitter minima. The few surviving minima will represent the stable descendant species A_1, A_2 ... A_n as in Figure 2 (right). Hence multiple speciation.

Summarising: if there is only one parameter, namely time, then there is only one type of singularity, namely the fold point where a minimum and a saddle-point coalesce, triggering a catastrophe, with rapid evolution and multiple speciation. The result will be recorded as a punctuation point in the fossil record as in Figure 2 (right). This explains why *multiple speciation rather than bifurcation occurs at those punctuation points where there are descendant species*.

We now explain why speciation and canalisation into the new species are likely to occur in mid-evolution, before those species eventually hit their minima and stabilise.

Going back to Figure 12, in general there will be severe problems in measuring the rates of variation and natural selection in terms of measurements of the phenotype. We would not expect the speed of variation necessarily to be the same in all directions, nor would the contours of u necessarily be parallel. For example, consider what will happen if those contours develop some curvature as in Figure 13. The straight dotted lines represent the wave-fronts determined by random small variations (1), and the curved continuous lines represent the wave-backs along the contours of u, determined by natural selection (2).

The effect of the curvature of the contours is firstly to separate the species into disconnected pieces in the valleys between the ridges (speciation) and secondly to act like a lens focusing each piece into a small droplet rolling down the middle of the valley (canalisation). In fact, the effect is enhanced if account is taken of the fact that the wave-

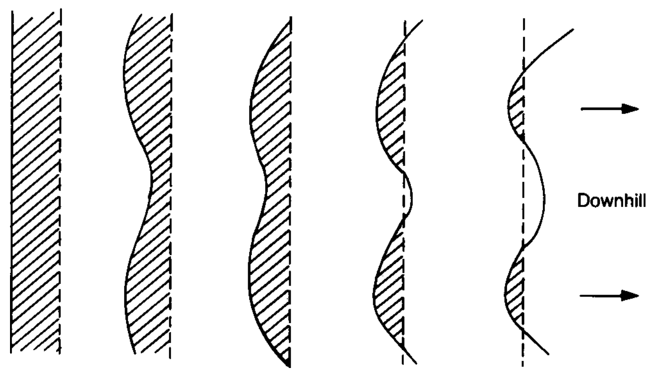

Figure 13 Speciation and calanisation.

fronts tend to go slightly faster down the steeper slopes of *u*.

Notice that the curvature of the contours below the initial catastrophe point C in Figure 11 (centre) also has the effect of focusing and emphasising the initial direction of the evolution, before it begins to fan out along the contours.

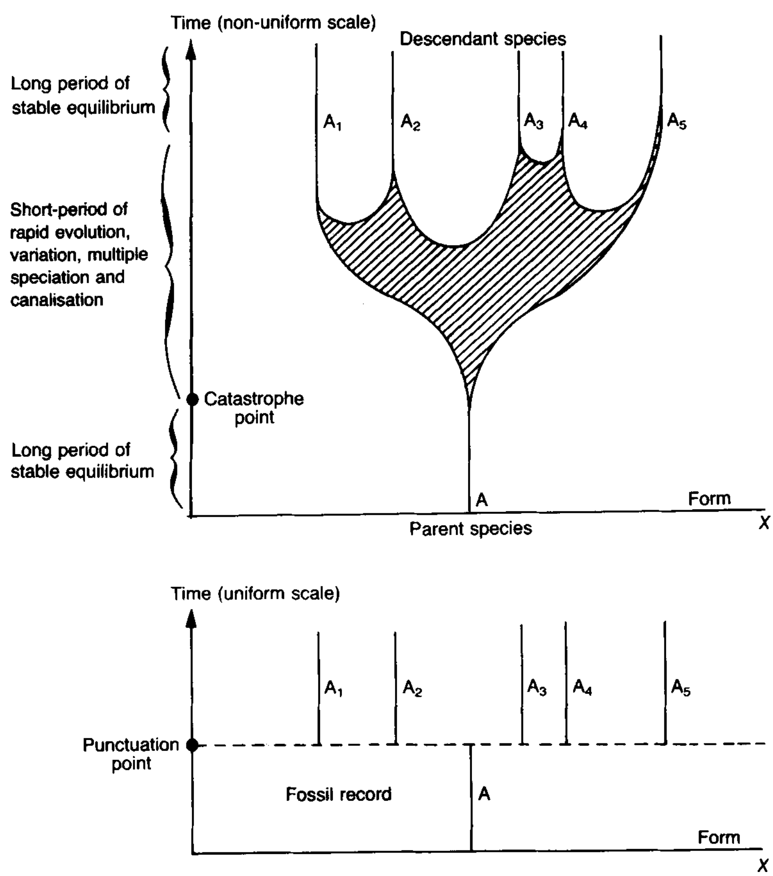

Figure 14 Multiple speciation and canalisation.

Figure 14 shows the path of the species in form-time space, with the resulting trace in the fossil record. In the expanded non-uniform time scale of the top picture the rapid evolution begins as a continuous variation of individuals within the species still capable of interbreeding with one another, and then as the variants diverge they gradually begin to lose that capability and become separate sub-species. In the fossil record, however, all this subtlety of variation, speciation and canalisation is lost in the collapse of the short period of rapid evolution to a single punctuation point on the uniform time scale of the bottom picture.

Remarks about dynamics

The familiar concept of the evolutionary tree as a one-dimensional graph has the disadvantage that it contains no dynamics, and therefore offers no opportunity for causal explanation; it is also misleading in suggesting that bifurcations are generic. Modelling evolution with an ordinary differential equation is no good because it cannot explain the central phenomenon of speciation. I do not know whether it is possible to use a partial differential equation; the difficulty lies in modelling natural selection, because a differential equation is essentially a local concept whereas a contour line is global. It might seem desirable to try to incorporate both processes of (1) random, small variations and (2) natural selection into a single equation, but in fact keeping them mathematically separate has helped to clarify our model. Sometimes it can be useful to combine them, as for instance when studying the speed and cross-sectional shape of an evolutionary wave as it rolls downhill.

Conclusions

We have used a catastrophe model to show that Darwin's local continuous hypotheses of random small variations and natural selection imply the global discontinuities of

- (i) punctuated equilibria;
- (ii) speciation and canalisation;
- (iii) multiple speciation at punctuation points;
- (iv) abrupt frontiers;
- (v) the creation of frontiers; and
- (vi) invasions of territory.

We have also shown that bifurcation is no more generic than multiple speciation.

Further Reading

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Gould S.J. 1977. *Ever Since Darwin*. New York: W.W.Norton

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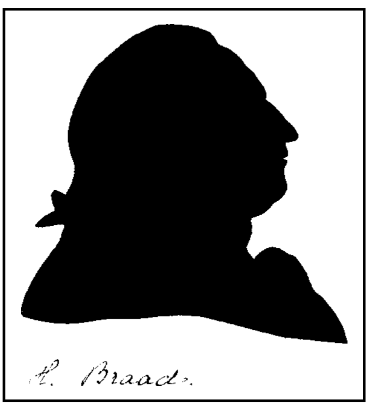
Reports to the Swedish East India Company: The Indian & eastern years (1748-62) of Christopher Henrik Braad (1728-81)

3. Under orders by land and sea: India 1753-58

To recapitulate: Braad added in 1767 two notes to one of the two copies of his 1750–52 Surat journal; their handwriting is so similar that they must have been made on the same occasion. The first has been discussed. In translation, the second reads:

> Our [i.e. *Götha Leijon's* 1750–52] supercargo's envy was much the cause of all obstacles put in the way of my gaining any knowledge. The first [supercargo], a Scot, John Irvine, born in India, but favoured by his fellow-countryman Col. Campbell in Göteborg, otherwise an idiot but whom possessed all Scots arrogance who showed through his behaviour how little he was worthy of the charge of Swedish effects and people he had been entrusted with. I spare the names of the others as they have both been informed of and (in part regretted?) their misunderstanding. My stay in China has similarly not been so unwatched and (many collections testify to it?).



Silhouette portrait of Braad, courtesy of the National Museum of Finland.

Götha Leijon was the first Swedish vessel to visit an Indian port since the 1734 *Porto Novo* affair, the catastrophe with which the second company voyage ended, as one of the participating officers had shrewdly if vainly predicted it would.[1] The purchase of the vessel, the engagement of the officers and their orders were very largely the work of Colin Campbell. He and his brother Hugh were engaged in the lengthy negotiations between the Swedish company and the British and Swedish governments that more-or-less cleared up the mess. A settlement was reached in 1740: the company undertook to engage as trading officers or supercargoes no more British subjects but only Swedes; it was allowed to keep its British supercargoes. The matter was bedevilled by the presence of many Jacobites – Campbell was active in Sweden during the '45 – in the Swedish company.

Irvine and Braad personified the conflict of interest inherent in the settlement, and as the *Porto Novo* voyage had revealed Campbell's talents for managing men, the conflict duly broke out. Braad allows one to suppose it had been resolved before he began his next (third) voyage to the east but it was not. (The last sentence of his note, being rather obscure in the Swedish, is not addressed here.).

1. *Kristof Glamann* "En Ostindisk Rejse eller Thomas på Galejen" *('A Voyage to the East Indies or Thomas Thomson in the Galley')* Sjöhistorisk årsbok *1953–54, 13–47. C.Gill "The Affair of Porto Novo: an incident in Anglo-Swedish Relations", in* The English Historical Review *(1958) 73, 47–65.*

He sailed in early April 1753 for Surat and Canton. One notes he was once again subordinated to John Irvine and two of the supercargoes from his previous voyage. On arrival in Canton he received orders from Sweden, sent directly there, that required him to return to India and travel in ‘southern Asia’ for the company. I know of no other instance of a Swedish Company servant being ordered to travel by sea other than in a company vessel or on land, in an exotic – in other words, an unhealthy – part of the world; let alone when prior discussion of such orders was impossible. Linnaeus’ apostles who had died in the course of travel (e.g. in the eastern Mediterranean) had died as volunteers. I interpret these arrangements as follows.

The orders were sent clandestinely to reach him in Canton because, had they become known, they would have disgraced the company. Thus they were not mentioned to him before he left Sweden. But in Canton what could he do or say? He had only to obey them.

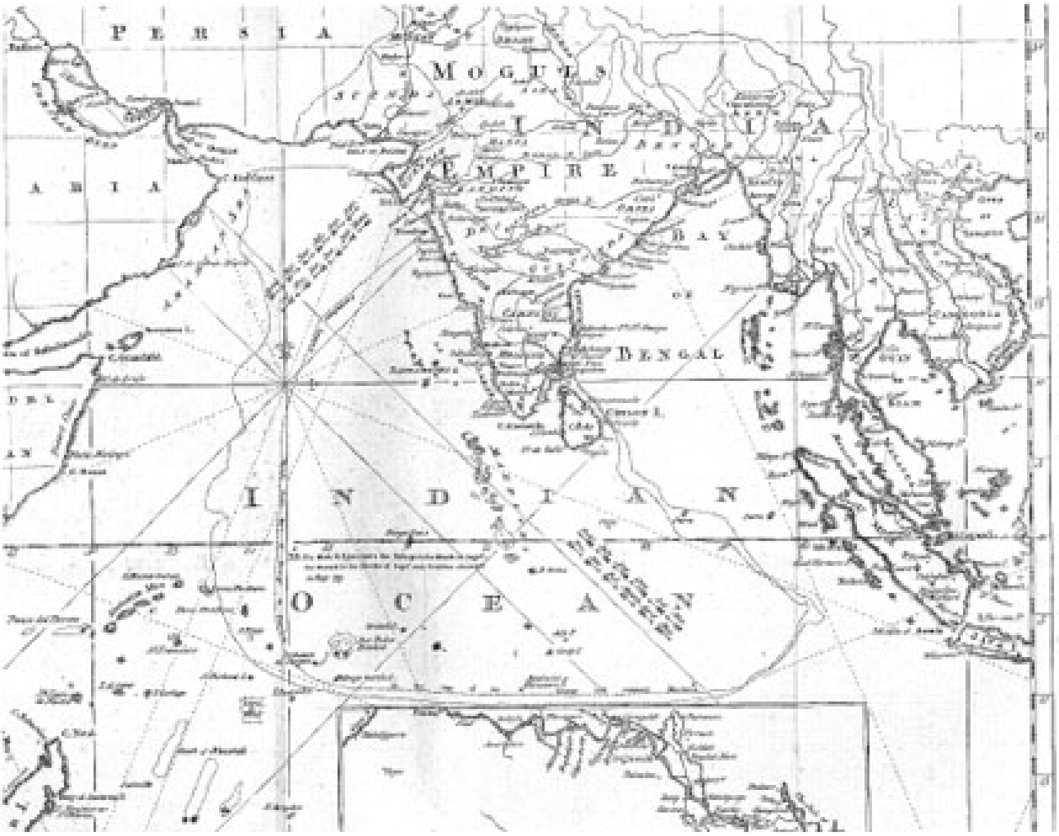
As supercargo, Irvine had probably delivered a set of these orders (original and copies) to a European port (e.g. Dover, Cadiz, Funchal) for transfer to vessels sailing directly to Canton; (no Company vessel left Sweden for Canton until December 1753). He probably knew their contents but would plead ignorance should Braad comment or complain. Had he died on his travels, would Campbell and Irvine have known anything of any orders?

In the event, as Braad made clear in his 1780–81 autobiography, he saw the risks, decided to face them and sailed in a country vessel from Canton to Calcutta. His account of the voyage includes a description of how the Dutch sent troublesome company servants to an insalubrious establishment in the fever-ridden swamps of Sumatra, where they soon died. Between its lines he was saying he’d seen the purpose of the underhand Jacobite trick that had been played on him.

So reaching Bengal in 1754, he observed the Europeans a year or two before the English emerged from the latest squabble – “this revolution”, as he called it – in effective possession of the province. His remarks on mortality suggest he was careful of his own health. His worst suffering was to lose almost all his papers from 1754–58, and some earlier ones, in a shipwreck on his return voyage to Europe in 1758. He got back to Sweden in summer 1759 and wrote his account of Bengal that autumn, when the outcome of events in Bengal was still uncertain. Writing from the pragmatic point of view of a potential trader, he was serving no specific national, religious or ethnic interest. His account reinforces the impression given by the Surat journal: virtually every Indian prospect pleased him and the only man who was vile was Mr. Jack Lamb, the English director in Surat, of whom he was to find in 1760 the well-informed Capuchin mission in the town had entertained just as poor an opinion.

His account fulfilled the orders he’d received in Canton six years earlier in a way that would have disconcerted Colin Campbell had the two men met. But Campbell was fortunate to have died in 1757.

The company promoted Braad to supercargo and sent him once again to Surat. He sailed early in 1760. As a trading venture the voyage failed. Surat was controlled by the British who had been more skilfully unscrupulous than either Mughal grandee (the governors of the town and fortress had been at war for decades) or any other European grouping. Braad was personally – but no more – in good standing with the British. His friends in Bombay told him in the



On the voyages from or to Europe in 1750–52, 1753–58 and 1760–62, Braad visited ports on most of the northern shores of the Indian Ocean, including the Straits of Malacca, Ceylon and the Persian Gulf, but seemingly not the Coromandel coast.

nicest way possible that he would be wise not to return as a trader. Having driven off the French and Dutch, they had put an end, to their own advantage, naturally, to the endemic armed squabbles in Surat, to say nothing of the rest of India, between rival Mughal and other grandees and their supporters among the separately competing European interests.

Braad did not come home empty-handed. Having spent time during autumn 1760 with his friends in the Capuchin mission in Surat, he had with him what is perhaps his most important manuscript: a 20,000-word set of extracts from the confidential diary kept by the mission since the 1650s. The celebrated medical clinic through which it offered European and Indian medical drugs and treatment at no charge to whoever sought its help was, I suspect, the cover under which it gathered some of the juicier items of information in Braad's extracts. After all, one of the earlier fathers had advised his fellow missionaries to be *prudent sicut Serpentes & Simplices sicut Columbae* 'as wise as serpents, and as innocent as doves'; what could be more essential to survival than the earliest intimations of some new trouble or more innocent than a visit to the clinic?

It is an academic question whether Braad would have referred to the diary in 'communicating' his travels in Asia; I'd like to think he wouldn't have revealed what he had learned in confidence. In 1840, however, when this manuscript and others were bought at auction by Uppsala University library, and the Capuchins' survival in India no longer hung on delicate threads of intelligence, the situation was quite different. Only a brief examination would have been needed to set on foot enquiries that, pursued diligently and discreetly, could have led to the discovery and preservation of its source that, eighty years later, seems to have vanished without trace.[2]

The extracts indicate the diary documented details of events and persons during the time when the port city of Surat was at, and then declined slowly from, the height of its splendour and importance. Internal evidence suggests it filled seven or eight volumes, and the 600-work bibliography to Henry Yule and A.C. Burnell's irreplaceable *Hobson-Jobson. A Glossary of Colloquial Anglo-Indian Words and Phrases* suggests nothing remotely like it, except perhaps Nicolao Manucci's memoirs, has been known to historians of the sub-continent in its early modern 'pre-British' period. The extracts are, incidently, perhaps the most convincing evidence of the respect that Braad won during his years in India.

Conclusion

According to Holden Furber, "the great East India companies were always ready to encourage the scholarly work of their servants and to subsidize its publication."[3] Lately resuscitated in a 21st-century form, the Swedish Company has thus an opportunity to distinguish itself by distinguishing the work, as discussed briefly above, of perhaps its most scholarly servant.

Postscript

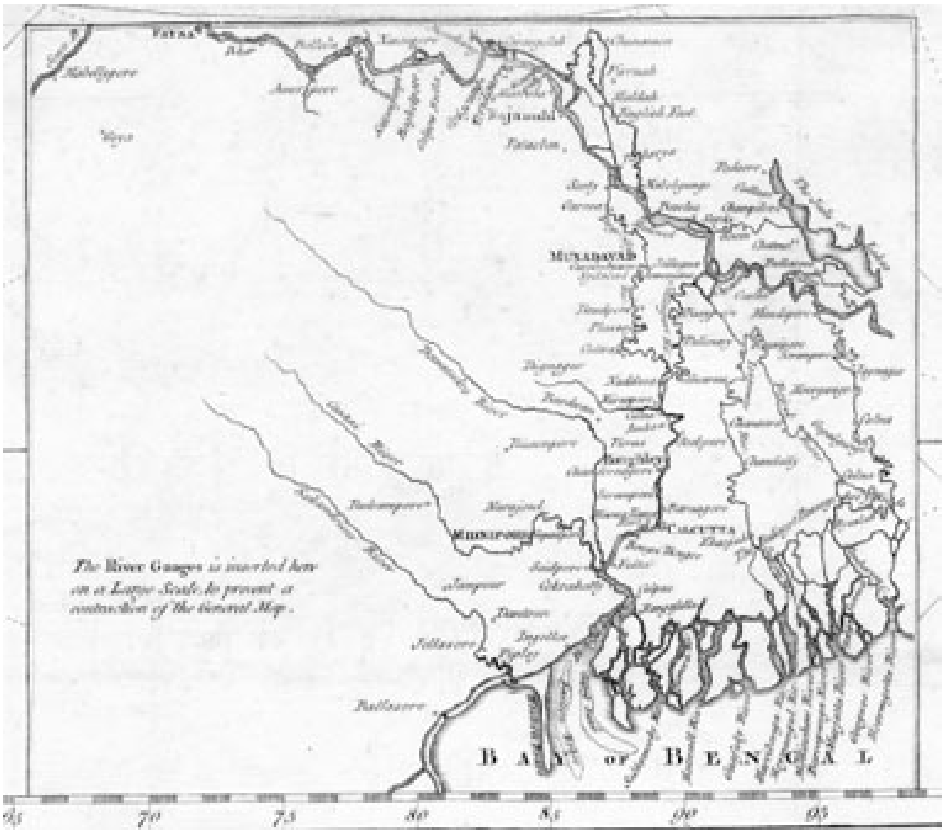
The preceding three articles include my thesis that one may err who writes on mid 18th-century Swedish travel and travellers in ignorance of the contents of the Braad papers. The articles were scarcely complete before a manuscript that had not been mentioned in print since the 1860s came to hand, 'like a letter in the post', as one says in Swedish of a timely arrival. Revising the articles in light of it would have hidden their errors but I have chosen to let them be and discuss them here, so they may confirm the thesis.

The manuscript is Braad's "*Curriculum vitæ* or short account of the principal events … during [his] travels and life [between 1728 and 1762]". I should like to thank Matthias von Wachenfeldt of Linköping City Library, for kindly sending me a copy of the facsimile that this library holds; the original has been held by the Royal Library, Stockholm, since 28 March 1844.

Braad began it in June 1781. It gives an account of his parents; describes his upbringing, education and 15 years' service with the Swedish East India Company; and ends with his decision to retire after his first voyage as supercargo that, as he put it, earned the company over forty barrels of gold at a cost of about twelve and himself – his commission on this fine result added to his reward for salvaging the trading funds of the company's *Fridric Adolph,* abandoned as a wreck near Canton – enough to retire on.

2. P. Giangrisostomo da Lugo *Elenco. Dei Missionari Cappuccini ... de Pandichery, Surat e Madras dal 1639 al 1804 ... ...* (Cawnpore, 15 August 1927).

3. Holden Furber, *Rival Empires of Trade in the Orient 1600–1800* (Minnesota, 1976), 325.



Reaching Bengal from Canton in January 1755, Braad informed himself about and/or visited most places on and near the Hugli and Ganges up to Patna later that year and in 1756.

The detail of dates, sequences of events, and names of persons and vessels in its 35,000 words suggests he used the diaries mentioned in his sixth note to his earlier, shorter autobiographical account. If, as I hope, these diaries still exist, they may among other things further justify my thesis. However, I want to concentrate on the Linnean significance of this text, except to note its significance to Braad's surviving papers.

Having supposed Braad lost in the shipwreck in 1758 a putative original of his Surat Journal, I now know he lost *inter alia* the papers from which he had made in Norrköping in 1752–53 'the clean copy of my account of travel in *Götha Leyon*' that he signed on 5 March 1753 and presented to his directors soon afterwards. Göteborg University now holds it and I at least will no longer call it the 'first copy' of anything.

That title belongs properly to what I have called the 'KVA copy' (i.e. the one held by the Royal Academy of Sciences, Stockholm). The company's secretary, Magnus Lagerström, had it made and sent to the Academy, probably after Braad's departure for the east on 8 April, which is a timetable consistent with its illustrations' hurried look, and the absence of any signature by Braad on it.

I had supposed Olof Torén's inertia in 1750–52 followed a putative failure to resolve a moral dilemma over pornography. The inertia and pornography were real enough, being documented by, respectively, his published letters to Linné and Braad's reading notes, but the *Curriculum vitæ* documents the cause of the first as dipsomania. Braad records that during their four years (1748–52) together he saw this otherwise agreeable pastor drink himself into no fit state for sensible company at sea and into an early grave on land.

This document has thrown a clearer light on the orders Braad received in Canton in 1754 to risk his life for the company and to gather natural-history data. Linné's prior knowledge of these orders is consistent with his reception of Braad in Uppsala six years later, or about a year after Braad had "lost … two chests with many rare natural-history specimens of all the realms of nature [of] Asia" in the shipwreck. Another of Linné's visitors was Peter Forsskål. Drawing on his own experience of good health in Canton, Bengal, Gujerat, the Persian Gulf and Mocha, Braad warned him of some putative dangers to health in Arabia, where Forsskål died the following year.

The *Curriculum vitæ* has shown me I had been right, however, in the early 1990s to infer his potential as a writer from how his sharp eyes in Canton in 1748 stimulated a mind broadened by wide reading. Writing at the age of 20, he noted that poor boat people working in the rain in coats of rushes put him in mind of the wild Americans' knee-length feather capes described in some travellers' accounts. The present text is not only a coherent temporal and thematic whole (it omits, for example, his later wish to publish his travels that is discussed in my first article) but shows – but only between its lines – how much Braad enjoyed himself. His account of foxing inept Governor Drake of Calcutta into letting him pursue his not wholly innocent researches is a comedy, but one with a dark undertone. A little later the man as ineptly brought on the catastrophe of the Black Hole of Calcutta out of which, so to say, British India emerged.

In 1754, Braad's presence in Calcutta led the governor to suspect him of being an agent of the Swedish company and to put two red-turbaned spies on his tail. One evening Braad gulled them with a demonstrative but quite fallacious interest in snakes. On the next, among Drake's dinner guests, who had much good-natured fun at the expense of 'the Swedish Philosopher' – how soon would he not extirpate the snakes of Bengal! – he let them so dissipate their suspicions that thenceforth "I could go freely wherever I liked and ask whatever I wanted without anyone taking notice of what I was doing."

To sum up what these errors signify, I'd suggest it calls for Torén's letters to Linné and his decision to publish them in Swedish (1757) and German and English (1771) to be re-assessed. One reason is that their readers have been or are not equally well informed.

Of the readers of the Swedish, the group of those who knew Torén as a befuddled pastor must have wondered – had they read Braad's far longer account of the same voyage or had spoken with those who had – whether Linné was justified in conferring this distinction on a set of short, possibly incoherent original texts. The second group of those who read only the German and English editions could have viewed Torén only as a scientist whose promise was extinguished by death met selflessly in a noble cause.

After the Royal Library in 1844 had bought *Curriculum vitæ*, its unpalatable revelations must have led some of its readers to choose to share, or at least not to obstruct, the second group's view. By the end of the century, this was adopted, willy-nilly, by the distinguished figures of Henry Yule and A.C. Burnell, the compilers of *Hobson-Jobson* (1st ed. 1886), and the editor of its second (1903) edition, William Crooke. Can one doubt – had Braad's texts been in print – but that they would have joined the first group and caused the bibliography of the second edition to include Braad's name?

Things are now much as they were then, except that work published in the 20th century includes more than Stellan Ahlström's 1961 edition of Torén's letters, that would be different, or might well not have been undertaken, had Braad's work been in print. It may be familiar to the present writer but is not yet accessible to those who are better fitted to take a fully informed view of Europe's perceptions of itself and its interactions with the Indian Ocean world in and since the mid 18th century.

Acknowledgements

Having worked on the Braad papers for ten years, it's a pleasure and a privilege to have this as a first opportunity to acknowledge my debts of gratitude. For financial support that's let me work at home and in distant archives I am indebted to, respectively the Torsten and Ragnar Söderberg Foundations and the Helge Ax:son Johnson Trust, all of Stockholm. Those in Australia, Britain, Denmark, Finland, France, Germany, Holland, India, Italy, Portugal, Sweden, the United States and the Vatican who've helped me in many ways will excuse me, I hope, for putting off a final settlement until there's space to thank each by name. This won't do, however, for three in Sweden: Tomas Anfält in Uppsala; Philip K. Nelson in Norrköping; and Bo Ralph in Göteborg, to whom I'd like to offer my warmest thanks for support and guidance in especially the intitial years of my work. Finally my gratitude to my wife for her affectionate forbearance in putting up Braad as our lodger is more than all the rest: I'm happy to acknowledge it but to thank her adequately for it is quite another matter.

JEREMY FRANKS

The Linnean Society
Programme

2005

9th Sept.		A CELEBRATION OF GRASSES † Dave Simpson FLS (Part of a two-day meeting jointly organised with RBG Kew)
15th Sept	6pm	THE ASIAN VULTURE CRISIS: CAUSE AND SOLUTIONS Debbie Pain
17th Sept.		London Open House
20th Sept.		GILBERT WHITE AND BIODIVERSITY (A one-day meeting in Southampton) † Gilly Drummond
22-24th Sept		THE PARADOX OF ASEXUALITY: AN EVALUATION Three-day conference with ESF-PARTNER † Hugh Loxdale FLS
29th Sept.	6pm	THE ANALYSIS OF FLOWER SCENTS Robin Clery
15th Oct.		CONVERSAZIONE at Chester Zoo hosted by The President
tba Oct		TRANSPLANTS FOR TOMORROW Dublin Event † Mary Griffin FLS
26th Oct.		NEW DISCOVERIES IN OLD COLLECTIONS Linnean Society Palaeobotany Group † Jason Hilton FLS
14th Nov.		CELL DEATH AND THE PROTOZOAN PARASITE British Society for Parasitology one-day symposium † Sue Welburn
17th Nov.	*6pm	THE ORIGIN OF MODERN HUMANS Chris Stringer FLS FRS

† organiser * Election of new Fellows

Unless stated otherwise, all meetings are held in the Society's Rooms. Evening meetings start at 6 pm with tea available in the library from 5.30. For further details please contact the Society office or consult the website – address inside the front cover.

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