COMMEMORATING SIR JOSEPH BANKS — SYMBIOSIS AND THE CONCEPT OF MUTUAL BENEFIT

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Apart from his voyage with Captain Cook, the role of Banks in the founding of Australia owed much to the fact that he was a towering figure in the scientific and national life of late 18th and early 19th-Century Britain. Although he published little of scientific consequence, he achieved a very great deal in helping the scientific endeavours of others and in using his influence with the Government and the King in promoting the cause both of science and of other ventures beneficial to society.

He was President of the Royal Society of London for a record 42 years. Although his Presidency has been criticised in modern times as being autocratic and doing little to improve the Society, this gives a false image of a truly remarkable man whose achievements — Australia apart — were considerable and whose personality was engagingly complex.

It is not easy to assess him as a practising scientist. He published only one serious scientific paper, in which he was the first person to suggest that the Barberry plant can serve as an alternative host to the wheat rust fungus. Although not confirmed by experiment until some 60 years later (by de Bary), this was presumably one of a range of observations which led de Bary to coin the word "symbiosis" for associations (including parasitic) between organisms. Many biologists subsequently restricted the word to only mutualistic associations but a survey of modern knowledge about associations described as "mutualistic" shows that mutual benefit is difficult to define in a way that is experimentally meaningful, and that the concept of mutual benefit should be abandoned.

Although Banks' single scientific paper could, therefore, be said to be an early contribution to symbiosis, he is a classic illustration of the observation that advancement of science depends not only upon those who make original discoveries, but also upon those who select the people and create the conditions under which these discoveries can be made. He differs from many modern civil servants in both having a profound understanding of science and winning the respect of his contemporaries for having this knowledge.

"... a man is never so well employ'd as when he is labouring for the advantage of the Public; without the Expectation, the Hope, or even a wish to derive advantage of any kind from the results of his exertions." — Jos. Banks

BANKS AND CAPTAIN COOK'S FIRST GREAT VOYAGE

In November 1767, the Royal Society of London sent a Memorial to King George III which began:

> "To the King's Most Excellent Majesty. The Memorial of the President, Council and Fellows of the Royal Society of London for improving Natural Knowledge Humbly Sheweth —
> That the passage of the Planet Venus over the Disc of the Sun, which will happen on 3 June in the year 1769, is a Phaenomenon that must, if the same be accurately observed in the proper places, contribute greatly to the improvement of Astronomy on which Navigation so much depends ..."

The Society's memorial continued — rather like a modern research grant application (but in 18th-century language) — with a strong case for support and a proposed plan to send a ship to an appropriate point in the Southern Hemisphere. Finally, the Society estimated the cost at £4000, exclusive of the price of the ship, and concluded its Memorial with almost the same sentiments as it might use today in asking for Government money:

> "The Royal Society are in no condition to defray this Expence, their Annual Income being barely sufficient to carry on the business of the Society."

Contrary, however, to modern practice the Government — or rather the King — responded with speed and generosity. The full £4000 was rapidly granted, and the Admiralty was instructed to purchase a ship. They acquired a Whitby collier, just under four years old, and "308 tuns burthen". Her name was changed from the *Earl of Pembroke* to the *Endeavour* Bark. A warrant officer, Mr James Cook, was appointed to command it. He was little known outside the navy, but had acquired a considerable reputation within the service as a seaman, navigator and cartographer, especially in naval operations in Newfoundland and Canada. Cook was commissioned Lieutenant in May 1768, and the whole expedition set sail three months later, in August 1768.

Two to three months before the ship set sail, the Royal Society made a further request, which the Admiralty accepted, that

> "Joseph Banks, Esquire, Fellow of this Society, a gentleman of large fortune, who is well versed in Natural History, being desirous of undertaking the same voyage, the Council very earnestly requests their Lordships, that in regard to Banks' great personal merit for the advancement of useful knowledge, he also, together with his suite, being seven persons more (that is eight persons in all) together with their baggage be received on board of the ship under command of Capt. Cook."

Joseph Banks was then 25 years old, an ardent botanist who had been elected a Fellow of the Royal Society two years earlier. He came from a wealthy family of Lincolnshire landowners; his personal income at that time has been estimated to be £6000 per annum. The suite of people he took on board the *Endeavour* included the artist Sydney Parkinson, who was to be immortalised by his beautiful sketches of plants and animals encountered on the voyage, and the botanist Daniel Solander, a pupil of Linnaeus who was to serve as Banks' principal colleague and assistant until his death in 1782.

The presence of Joseph Banks on Cook's first great voyage of discovery was to be of profound significance to the later establishment of the first penal settlement in Australia. He was the first scientist of any consequence to voyage and explore in the Southern Hemisphere. He was already an experienced and avid collector of plants, and this was at a time when great importance was assigned to the discovery of new natural resources in the world, especially plant resources. Throughout Cook's voyage, Banks and his team collected plants voraciously, also making numerous beautiful illustrations of them. About 30 000 specimens were collected, comprising 3600 species, of which 1400 were new to Science — and that at a time when only 6000 species were listed in Linnaeus' *Species Plantarum*.

The original prime purpose of the voyage, observing the transit of Venus, was successfully and very accurately carried out during a stay on Tahiti, an island whose discovery had only been reported a year earlier in 1768. Nevertheless, the three-month sojourn on Tahiti has probably achieved greater historical memorability for the reported beauty and lax morality of the native ladies than for the astronomical observations.

When Cook set out on his voyage, he was given secret orders by the Admiralty. After observing the Transit of Venus on Tahiti, he was "to prosecute the design of making discoveries in the South Pacific Ocean". He was instructed to proceed as far south as latitude 40. If no land was found he was to go west to New Zealand, explore it (to determine whether it was the northern extremity of the Southern Continent), and then return to England "by such route as he thought proper".

In the event he travelled south, encountered no great continent, and sailed to New Zealand which he thoroughly surveyed, circumnavigating it to prove it was two large islands and not part of Terra Incognita. There was then some debate as to which course to take back to England: to return the way they came by way of Cape Horn, or to go directly to the Cape of Good Hope. Neither seemed attractive because it was the depth of winter and the ship was in poor condition. They therefore decided to go by way of the East Indies, looking at the coast that Tasman and other early voyagers had glimpsed a century or more previously and which was then called New Holland. Banks was firmly convinced of the existence of the Southern Continent, but Cook was very doubtful.

In May the following year, 1770, they first set foot on the coast of what we now call Australia. Cook originally called their first landing place Sting Rays Harbour, after an enormous catch of these fish that was made. Later Cook changed the name to Botany Bay because of the "Great quantity of new plants collected in this place".

The role of Joseph Banks in the later development of Australia owes much to the fact that he was later to become the most powerful and influential scientist in England for almost half a century. Upon his return from Cook's voyage, he was accorded the same kind of adulation that might be given today to the first astronaut to return from the moon. It initiated a close and long friendship with the King, a factor that may have been important in his election to the Presidency of the

Royal Society in 1778. The previous President, Sir John Pringle, had earned the serious displeasure of the king in a rather absurd argument over the correct design of lightning conductors, and Fellows may have felt that the next President ought, therefore, to be someone on good terms with the throne. Banks held the Presidency of the Royal Society for a record of 42 years, a period in which he exercised a dominating influence in many spheres. He had a considerable reputation as a savant, being consulted by King and Government on all manner of questions apart from botany, for example: earthquakes, treatment of garden pests, farms, drainage, docks and canals, tanning and currying, the "tricks of millers and bakers" and the plucking of geese.

Banks, however, was well aware that he owed his fame and position very largely to his voyage with Cook. Some 30 years later, in 1813, when trying to persuade the botanist W. J. Hooker to carry out a botanical exploration of Java, he wrote,

> "... I was about 23 when I began my peregrinations. You are somewhat older but you may be assured that if I had listened to a multitude of voices that were raised to dissuade me from my enterprise, I should now have been a quiet country gentleman ignorant of a number of matters I am now acquainted with, and probably have attained no higher rank in life than that of country Justice of the Peace."

BANKS AND THE FOUNDING OF AUSTRALIA

But if Banks derived his influential position primarily from his voyage to New South Wales with Cook, this position was, in its turn, crucial to the founding of the Australian colony. He first publicly advocated Botany Bay as a suitable place to which convicts could be transported in his evidence to a Parliamentary Committee in 1779. At that time, a crisis had arisen in the British Prison System, considerably exacerbated because the American War of Independence had closed off that country as destination for convicts. Alternatives were being urgently considered for distant places to which convicts could be transported. In his evidence, which would carry additional weight since Banks was a highly successful farmer and landowner as well as influential scientist, he waxed enthusiastic about Botany Bay, stressing its good climate, variety of soil, plenitude of fish and water. The passage of time must have sweetened Banks' memory, since what he actually said in his journal when he first saw the bay was:

> "The country tho in general well enough clothd appeared in some places bare: it resembled in my imagination the back of a lean cow, coverd in general with long hair, but nevertheless where her scraggy hip bones have stuck out farther than they ought accidentle rubbs and knocks have intirely bard them of their share of covering."

As the crisis worsened a few years later in 1785, the Government consulted Banks again, and subsequently received a document, the now famous "Heads of a Plan" to colonise the east coast of New South Wales, at or near Botany Bay; this was not signed by Banks, but surely must have at least been drafted by him. It was decisive in causing the Government to choose Australia in preference to the other options then under consideration (which at one time or another had included Senegal, the Gambia and even Gibraltar). The Lords of the Admiralty then rapidly put into operation this plan to send a fleet of convict ships to New South Wales.

Further, as is well known, Banks exerted a profound influence on the early development of the colony, maintaining a voluminous correspondence with the early governors and using his considerable authority to support their pleas to the Government of the day for help. Without his ever-active assistance and agitation behind the scenes, the colony might surely have failed. Even after the colony was firmly established, he maintained his close interest. For example, it was Banks who had a major role in the detailed planning of the famous voyage of Matthew Flinders in the sloop *Investigator*, put together the brilliant team of scientists and artists (including Robert Brown and Ferdinand Bauer), and paid out of his own pocket for the *Investigator* to be well equipped. It was also Banks who nominated Captain Bligh to be Governor of New South Wales in 1805, even specifying the details of his service. The following year saw Banks trying to get the Government to stop the East India Company blocking trade with the new colony.

BANKS AS A SCIENTIST AND AS A PERSON

Banks was a towering figure in the scientific life of late 18th and early 19th-century Britain, but what were his own contributions to the advancement of science? In Sachs' two volume *History of Botany* (1890), Banks merits but a single footnote, and that

PLATE I

Sir Joseph Banks, portrait engraved by H. Robinson after the painting by Sir Thomas Laurance; published by Harding Lepard, Pall Mall East, London 1831; copy by courtesy of the Allport Library and Museum of Fine Arts, Hobart.

only by way of introducing one of his assistants, Robert Brown, who later became one of the most outstanding botanists of his generation. Such an assessment of Banks is not surprising, since his published works amount to very little. There are some interesting notes in the *Journal of the Royal Horticultural Society* — contributions to the latter including items on how to cultivate the American cranberry and the horticultural management of such plants as the Spanish chestnut tree and the onion; some of his notes, such as that on the forcing-houses of the Romans, reveal him to be a man of culture and learning. Banks was undoubtedly a significant influence in the rise of British horticulture, but in terms of contributions to anything which could be called serious science, there is but a single paper of 23 pages, to be discussed later.

Banks did not even himself publish the results of his epic voyage with Captain Cook: he gave his journal of the voyage (over 200 000 words in length) to a Dr John Hawkesworth who published it under his own name; the magnificent set of engravings of plants collected on the voyage are only being published in their entirety (as the Florilegium) this year, in 1988, the year of the bicentennial, and it was left to others to formally describe the numerous new species that were discovered.

It would be grossly unfair to conclude from this, however, that Banks did not care about publishing the results of important scientific discoveries — rather, it was more the case that he was clearly uninterested in attaching his own name to publications, an engaging aspect of his character which would be incomprehensible to most modern scientists. For example, his own writings show that he passed his journal to Hawkesworth to publish simply because he was busy preparing for a second voyage with Cook on the *Resolution* — a voyage from which he later withdrew because of a disagreement over the adequacy of the accommodation for his scientific needs. Banks had a major role in organising the publication of the illustrations and account of Cook's third voyage but publicly it was Lord Sandwich who gained credit for this.

As for the magnificent illustrations from the first voyage now being published, there is considerable evidence that Banks invested much time and effort towards their preparation and originally had every intention of trying to get them published. Benjamin Franklin reported that Banks employed ten engravers and probably spent at least £4500 on the venture, each plate costing him £6. However, his wealth was not limitless and the heavy expenditure on producing engravings probably coincided with other demands — for example, he had recently got married and was having to pay for the complete refurbishment of his country seat at Revesby Abbey. Also, the American War of Independence probably depressed the income from the wool trade. The sheer size of the effort required probably defeated him in the end. Finally, publication of the illustrations may not have been of overriding importance since the actual plants collected from Australia were meticulously preserved in his personal collections which he made freely available to everyone.

Whatever the reason, it is true to say that Banks' reputation depends almost entirely on what he achieved in the management, organisation and administration of science, rather than on personal publication of novel and important discoveries. His authority derived from a powerful combination of a considerable knowledge of science, friendship with the King and other key figures in England, and his very influential position as President of the Royal Society.

BANKS AND HIS ACHIEVEMENTS

Within the Royal Society, the received opinion of Banks' presidency is not kind to him. He is portrayed as autocratic and doing little to improve the antiquated and sometimes chaotic administration of the Society throughout his 42 years of office. Episodes are still remembered such as the time, early in his Presidency, when he caused the unwilling resignation of the Society's Foreign Secretary, the mathematician Charles Hutton, by making what many thought were contrived accusations of inefficiency against him. At the council meeting when Hutton's resignation was accepted, Banks refused to support the formal vote of thanks for services rendered, on the uncharitable grounds that there was nothing to thank him for. The affair caused much dissension among the Fellows, and pamphlets full of robust hostility to Banks were published. Old wounds were reopened and there was, for example, a pamphlet entitled "An history of the Instances of Exclusion from the Royal Society...and other Instances of the Despotism of Sir J. Banks...and of his incapacity for High Office". It contains many abusive passages about Banks, such as

> "...The President is incurably sick with the lust of domination, he imagines himself born to

rule...and cannot perceive he has neither the intellectual nor the moral qualities of a ruler."

But to take the narrow, "Royal Society" view of Banks would be to have a deeply false image of a truly remarkable man whose achievements — Australia apart — were considerable and whose personality was engagingly complex.

Banks was educated first at Harrow, then at Eton. His school record was unremarkable, but as a teenager at home in Lincolnshire, he suddenly developed a consuming passion for collecting and studying plants. He went up to Christ Church, Oxford, in 1760 to read Botany, but encountered the problem that the Professor of Botany, Humphrey Sibthorp, did not give lectures (or is at least reputed to have given but a single lecture during the entire 35 years in which he occupied the Chair). (When I was the Sibthorpian Professor at Oxford, I was required to give a minimum of 36 lectures in a single year — such has been the nature of academic inflation over the last two centuries.) With Sibthorp's permission, Banks visited Cambridge to hire his own lecturer in Botany, one Israel Lyon, and brought him back to Oxford. After three years at Oxford, Banks left, following the rather common practice of not bothering to take a degree. He moved to London and became a member of a kind of social set of the leading young intellectuals of the day. His passion for collecting plants developed and, instead of following the tradition of his aristocratic contemporaries and going on the Grand Tour, he made a notable trip to Newfoundland and Labrador for the better part of a year. He transformed the knowledge of the vegetation of those countries and gained invaluable experience of how to conduct scientific exploration, learning to endure the physical hardships of working in the field in inclement climates; incidentally it was on this trip that the artist Sydney Parkinson was first initiated into drawing plants.

In 1776, three years after leaving Oxford, Banks became a Fellow of the Royal Society. One might have imagined this was due to his good social standing and personal wealth rather than his scientific interests and discoveries but, although only a minority of Fellows at the time were practising scientists, the signatories to Banks' certificate were not aristocrats but Fellows with serious botanical interests, such as Sir William Watson.

It was his election to the Society (together with his friendship with Lord Sandwich, soon to become First Lord of the Admiralty) which enabled him to fulfil his passion for scientific exploration and get himself attached to Cook's famous voyage. Banks attended the Royal Society Dining Club weekly during the period when the Society was preparing its Memorial to the King, and this must have given him an excellent opportunity to prepare the ground for the Society's later proposal that he be attached to the voyage.

When Banks returned from Australia, he became instantly lionised in society — and to a far greater extent than Cook — but, as his reputation rapidly grew, he was not tempted to indulge in any self-aggrandisement of his personality; instead he began to devote himself wholeheartedly and completely to the cause of science and of scientific institutions. His personal integrity was unimpeachable, and undoubtedly contributed to his influence. For example, later in life some of his detractors scorned his wearing of the ribbon of the Order of the Bath, perpetuated in the portrait by Phillips and the target of a malicious cartoon by Gillray entitled "The great South Sea caterpillar, transformed into a Bath Butterfly". But few also cite the fact that he had refused this coveted Order on an earlier occasion for fear that it would be seen as being tinged with political overtones since, at the time, he was doing his duty as High Sherriff of Lincolnshire and raising troops of militia. Notably, when the King first raised the possibility of this order with Banks in 1789, he made it clear that it was partly for the flourishing state of the Royal Society under Banks' Presidency.

While Banks exercised great and pervasive influence, it is remarkable how often that his efforts resulted in the scientific cause, rather than his own name, achieving prominence. A list of some of his major achievements will illustrate this:

(1) Kew Gardens. He became the scientific adviser to the King (who owned the gardens) in 1773, and in the next 40 years completely transformed them into the gardens we know today. He recruited and sent out, often at his own expense, a series of highly distinguished plant collectors to all parts of the known world to send back the collections which make it the premier botanic garden of the world that we know today. About 7000 species of new exotic plants were added to the garden during his time.

(2) He founded the Royal Horticultural Society, and helped found the African Society (which later became the Royal Geographical Society), being instrumental in organising and financing the expeditions of a number of famous explorers such as Mungo Park and Burkhardt. Banks played a key role in the founding of the Royal Institution, chairing the meeting at which it was inaugurated and dealing sensitively with the temperamental

Count Rumford whose philanthropy triggered its establishment. Likewise, he played a significant role in the events leading to the formation of the Linnean Society, supporting it from his position as President of the Royal Society, although he was not present at the inaugural meeting.

(3) He arranged for Breadfruit to be introduced into the Caribbean. The ill-fated first attempt resulted in the famous Bounty mutiny, but less well known is that the second attempt was so successful that Captain Bligh was voted a reward of £1000 by the House of Assembly in Jamaica. Banks tried to persuade the East India Company to introduce the China tea plant to India, and the area he recommended, Assam, was later to prove ideal for this crop.

(4) In collaboration with the King, he introduced merino sheep from Spain into Britain, resulting in a permanent improvement in the quality of British wool. Initially, Spain prohibited the export of merino sheep, so that Banks had to be a party to organising the smuggling of them out of Spain. Some of these sheep provided stock from which the foundation of the Australian sheep and wool industry developed.

(5) For nearly four decades, he was a dominant figure in the Board of Longitude, a body perhaps as important to improving 18th-century navigation as is NASA to space exploration today. A further illustration of his integrity and passion for defending science occurred when politicians overrode the views of the Board and awarded the prize for a chronometer to a T. Mudge. Banks challenged the Prime Minister (William Pitt):

> "...to rescue Science from the discredit she must fall into if public awards are given to those who have the greatest political interest in preference to those who have most merit."

He also had a long association with the Royal Mint, which began with his management of the Royal Society Cook Medal in 1780 and continued through his involvement in its complete reorganisation, as a member of the Committee of Coins.

(6) Throughout a prolonged period of hostilities with France, he made persistent efforts to ensure that French and British scientists remained in contact and stayed above hostilities. During the War of the French Revolution, for example, the Kingdom of Naples wrongly imprisoned the distinguished French geologist, Dolomieu; Banks made strenuous attempts, in a personal capacity, to obtain his release, lobbying William Pitt, Lord Nelson, Lady Hamilton and others. He also engineered the return to their rightful owners of the important plant collections of the botanists La Billardière and Deschamps, which had been captured from the French. His efforts were long remembered with gratitude in France. Indeed, he was elected an associate of the Institut de France before the Peace of Amiens was signed. Unfortunately, the French immediately published his letter of acceptance before the war was over to show that France had been rehabilitated, and this earned Banks opprobrium from some sections of public opinion who felt he was something of a traitor.

(7) He had a long association with the British Museum, starting with his first reader's ticket in 1764, and ending with his death in 1820, when he ultimately bequeathed his magnificent library, herbarium and other collections to help form the basis for what would later be the Natural History Museum. Throughout his life, he and his various assistants maintained close and detailed contact and collaboration with the Museum.

But perhaps most influential of all was his role as the informal centre of science in this country for four decades. He purchased a large house in Soho Square, London, where his magnificent library and collections were freely available to all reputable scientists. He had a small private staff of librarians and curators, some of whom themselves later became outstanding scientific figures. The latest scientific correspondence and treasures were always on display, there were frequent scientific receptions on Sunday evenings, and his breakfasts were famous informal occasions for meeting guests. Every foreign scientist of note who visited England visited Soho Square. Indeed, Banks and his house fulfilled some of the roles carried out today by International Conferences. Further, much of his personal wealth was channelled into science (and he probably contributed more than the King to the costs of Cook's first voyage). He paid the salaries of quite a number of botanists and plant collectors. For example, he paid George Caley, whom he sent out to make notable collections in Australia, 15/- per week out of his own pocket, since he did not feel he could ask the Government to pay for someone who lacked formal training; later, he even paid Caley, a good collector but a difficult and complaining fellow, a pension of £50 per year. He also paid George Suttor, who was the first successful market gardener and viticulturalist in New South Wales, 15/- per week for collecting, maintaining and transporting out to Australia a variety of fruit trees and other plants. (Just over 100 years later, George Suttor's grandson, Sir

Francis Bathurst Suttor, became the first President of the Sir Joseph Banks Memorial Fund.)

Banks also helped others in a variety of ways. After an angry mob burnt down the house of the chemist Joseph Priestley, it was to Banks that he turned for help in replacing all his chemicals and equipment. In 1782, Banks secured a pension from the King for the astronomer Herschel. (Banks himself made a present of shoes, allowing for seven pairs of socks on cold nights of astronomical observations.) He tried to look after the widows of scientists, lobbying government for a pension for them, or even paying out of his own pocket on some occasions. His benevolence could also be to the country as well as to people. In 1798, the Treasury instructed him to provide such fruit trees, useful plants and seeds as were wanting in His Majesty's colony of New South Wales, but there was no allocation of money and he bore all the expenses himself. He paid for a gift of plants from the King to the Emperor of Russia, and it was three years before the Foreign Office reimbursed him (the dilatory civil servant got a £400 snuff box).

In a sense, therefore, Banks functioned as a kind of one-man benevolent Research Council. Perhaps one of his greatest qualities was his ability to pick first-class scientists as his assistants. Apart from Solander and Robert Brown, they include Dryander, who became librarian of the Royal Society and of the Linnean Society, and others who also became Fellows of the Royal Society, such as Charles Konig and John Sims who founded the Annals of Botany, John Tiarks who left in 1818 to join the American Boundary Commission sponsored by Banks and the Astronomer Royal, and John Lindley who later, in 1838, produced a report which rescued the Royal Botanic Garden at Kew for Science.

BANKS AS A PERSON

While friendship with the famous features prominently in the life of Banks, he was just as kind and caring in his dealings with humbler persons, as witnessed by his copious correspondence with aspiring plant collectors, little-known horticulturalists and seamen with whom he had voyaged.

Indeed, the one area in which he did not receive untarnished success, and curiously the area of which he was most proud, was as the long-serving President of the Royal Society. At the time he assumed office, the Society, like many other British institutions such as the Church and the Universities of Oxford and Cambridge, had sunk into a lethargic state, in need of reform. But the spirit of the age was against reform. One suspects that the episode of Banks engineering the resignation of the Society's Foreign Secretary was a clumsy attempt at reform, and the reaction to it characteristic of the pervasive spirit of resistance to change. Less well publicised were his successful attempts to wrest the nomination and election of Fellows away from the nepotistic influence of the Secretaries. Quite probably, almost anyone else as President would also have found it difficult to carry out major reforms. So, throughout his long Presidency the rules and conduct of business remained antiquated, and the keeping of minutes and the state of accounts remained chaotic. Paradoxically, this was quite out of keeping with all other aspects of Banks' life. He was a meticulous classifier, and his collections, his books, and all matters to do with his busy and extensive estates were quite impeccably organised and filed, likewise his stupendously voluminous correspondence. (It is estimated by some that he wrote 70 000 letters, all in his own hand, during his life, an average of 50 letters a week!) His enemies in the Society may have portrayed him as autocratic but his far more numerous friends respected his firmness, straight-dealing and fairness. There are numerous examples, in the correspondence, of his gift of being able to disagree openly with people on specific issues without in any way impairing his strong friendship with them.

Despite the large amount of letters and other contemporary material concerning Banks, there are aspects of his character that remain enigmatic. His copious writings, including the journal of his voyage with Cook, contain very few comments of a personal nature, so we know very little of his inner thoughts or feelings. One unusual but attractive feature is that he had a dislike of leaving a reputation behind him. At his own express request, he was buried in an unmarked grave in the churchyard at Heston, Middlesex. In a letter to someone who wished to present his portrait to his old college, Christ Church, he wrote that he was "not much addicted to posthumous fame". When selecting his personal seal, he chose the lizard, saying (in his own words)

> "I have taken the lizard, an animal said to be endowed by nature with an instinctive love of mankind, as my device and have caused it to be engraved as my seal, as a perpetual remembrance that a man is never so well employ'd as

> when he is laboring for the advantage of the public; without the Expectation, the Hope, or even a wish to derive advantage of any kind from the result of his Exertions."

This, more than anything else I have read about Banks, epitomises to me his true character; a fitting epitaph to a great and remarkable man.

BANKS AND SYMBIOSIS

The remit I was given for this lecture was to make some assessment of Banks, especially as a scientist, and then to give some account of my own research, which has been in the field of symbiosis. At first sight, there would seem to be absolutely no connection between the life of Joseph Banks 200 years ago and my own interests in biology today, which are in the experimental study of symbiosis.

However, there is a remarkable but convenient coincidence that the one really scientific paper written by Banks concerns an aspect of symbiosis. In 1805, he published a private pamphlet on the diseases of wheat which suggested that the fungus which causes rust disease may be the same as a fungus which also occurs on barberry plants. Over 450 copies were issued, and it was later communicated to the Board of Agriculture. It was also printed in the *Philosophical Magazine, Annals of Botany* and *Journal of Philosophy.* Today it is very well known that the wheat rust fungus has a complex life cycle, alternating between wheat and barberry as hosts, and this knowledge is the basis of a classical method of controlling the disease by eliminating all barberry plants near wheat fields, but when Joseph Banks first put this revolutionary idea in writing, it was attacked by many. Thus, an anonymous reviewer in the *Farmers Magazine*, published in Edinburgh 1805, said,

> "...we are free to say that if the author were not a man of high rank, and at the head of the Royal Society, his publication would be disregarded by every farmer in Great Britain."

In fact the idea was not proven by experiment until the work of German botanist, Anton de Bary, 60 years later. One of the most distinguished 19th-century students of fungi, de Bary was the outstanding expert of his day on fungal diseases of plants and is also well known as the person who invented the term "symbiosis". It was probably his interest in associations between organisms which led him, in 1867, to coin this word to describe organisms which made a common life together, whether as host and parasite or as organisms appearing to derive benefit from associating with each other.

It is the meaning of the word symbiosis and how it is defined which forms the theme for the second part of this lecture. De Bary defined symbiosis simply in the phrase "...des Zusammenlebens ungleichnamiger Organismen..." — the living together of differently named organisms.

However, within a couple of decades of de Bary's original paper, many biologists had come to restrict the term symbiosis to cover only those kinds of association in which all the organisms concerned appeared to derive benefit, and this is the sense in which the word has entered everyday English language. The question to be addressed is whether it is a valid or useful concept in biology that two organisms can live together for their mutual benefit, or whether there ought to be a return to the simple definition of de Bary. If the latter were possible, it would make Banks' one serious scientific paper an early contribution to symbiosis.

An influential factor causing the change in meaning so soon after de Bary invented the word was undoubtedly the discovery of the true nature of lichens a few years before de Bary coined the term symbiosis. For hundreds of years previously, lichens had been regarded as simple plants, and classified as such. Under the microscope, they have a filamentous structure, with a layer of spherical green objects embedded near the surface. These objects were thought to be reproductive spores until, in 1867, the Swiss botanist Simon Schwendener published the revolutionary theory that lichens were not simple plants, but an intimate association of two quite distinct plants, a fungus and an alga (a possibility that de Bary himself had hinted at in an earlier paper). The discovery of the true nature of lichens gave a powerful stimulus to the concept that two organisms could live together for their mutual benefit. It became accepted that there were two kinds of intimate association, parasitic and mutualistic, and most biologists equated symbiosis only with mutualistic associations.

For over half a century afterwards, the nature of the interactions between organisms living together in mutualistic symbiosis was never investigated by rigorous experiment and, during this period, it became embedded in the minds of most biologists that, if an association was termed "symbiotic", then all the partners must derive mutual benefit from the association, even though there was no evidence for this assumption. It is only in the last few decades, when these interactions have been properly investigated, that it has become clear that "mutual benefit" is a vague concept, difficult to define in a biologically meaningful way, and almost impossible to prove experimentally as occurring in nature. To illustrate the problem I will describe some of the more modern experimental work on mutualistic symbiosis.

LICHENS

The conventional view of the lichen symbiosis which persisted for many years was that the alga supplies the fungus with carbohydrates produced by photosynthesis and that "in return" it was supposed to receive mineral nutrients and some form of physical protection. There is no doubt that the alga does indeed supply the fungus with substantial amounts of photosynthetically produced carbohydrate, and this has been demonstrated by experiments on over 40 different species (Smith 1980).

Much more problematic is whether any nutrients move from fungus to alga. This has never been demonstrated experimentally. In practice, lichen algae grow far more slowly in the lichen than in laboratory culture, hardly an indication of being well nourished. Most of the products of photosynthesis of lichen algae are lost to the fungus instead of being allocated to their own growth, and, again, it is difficult to construe this as "benefit".

Most of the symbionts and their fungal hosts only occur naturally in lichens and hence are mutually dependent on each other, but mutual dependence is not the same as mutual benefit. Many domestic animals are wholly dependent on man for survival; it is a moot question whether such dependence is "beneficial" to them. In the absence of a generally acceptable, rigorous and biologically meaningful definition of the term "benefit", the question remains unanswerable.

ALGA/INVERTEBRATE ASSOCIATIONS: GREEN HYDRA

There are numerous examples of symbioses between algae and aquatic lower invertebrates, ecologically the most important of which are the reef-forming corals, estimated to occupy 90 million km^2 of the earth's surface. However, the symbiosis which has proved most satisfactory for experimental research has been green hydra, an animal which belongs to the same phylum as corals. This coelenterate is widely distributed throughout the world in freshwater habitats. The digestive cells in the endodermis contain a population of about 12–30 cells of the unicellular green alga *Chlorella*, each alga being enclosed in a host membrane. Hydra can be grown in large numbers in controlled laboratory conditions in a simple mineral medium and fed every one or two days on freshly hatched *Artemia* nauplii.

Numerous experiments show that products of photosynthesis move, in the form of the disaccharide maltose, from the alga to the animal host. However, it is equally clear that the host will not grow unless it can also feed, even if it is placed in permanent illumination.

This raises the question of the role of symbiont photosynthesis in the symbiosis. This can be studied directly because, by artificial means, hydra can be freed of their algae, so that host growth with and without algae can be compared. In permanent darkness, green hydra grow more slowly than aposymbionts, showing that symbionts impose a measurable "cost" on the host, presumably deriving nutrients from the host. In the light, green and white hydra grow at the same rate unless the supply of food is reduced to starvation conditions, whereupon green hydra survive much longer. Since food supplies are indeed severely limited in natural habitats (Ellard 1987), it is very likely that the growth of the animal benefits from the presence of algal symbionts.

However, it is very difficult to argue that *Chlorella* "benefit" from the host. In symbiosis, they grow much more slowly than in isolated culture. They lose a considerable amount of carbon to their host, and there is no evidence that they receive a rich nutrient supply from their host; indeed, there is now persuasive evidence that the animal restricts the growth of symbionts to a very low level by severely limiting the supply of nitrogen to them (Rees 1986). *Chlorella* symbionts cannot survive in the wild away from the host, so it is again difficult to see what benefits they derive.

ASSOCIATIONS INVOLVING HIGHER PLANTS AS HOSTS

Mycorrhizas

These are associations between fungi and the roots or other underground organs of green plants. This is probably the commonest type of symbiosis in the world, since the root systems of the great majority of plants are mycorrhizal in natural vegetation. The fungi involved are mostly incapable of prolonged existence independently from their hosts, but their mycelia often ramify from the root extensively into the surrounding soil, in some respects appearing to function as if they were an extension of the root system.

There are a very large number of pot experiments which show that on nutrient-poor soil, plants infected with mycorrhizal fungi grow more vigorously than uninfected plants, and they also have a higher content of nutrients such as phosphorous and nitrogen; on nutrient rich soils, infection has little or no effect on plant growth or nutrient status. In vesicular arbuscular mycorrhizas, experimental evidence shows that the beneficial effect of infection on host vigour is because the fungal mycelium appears to exploit a greater volume of soil for nutrients than the host root system, these nutrients being transferred to the host plant. There are also many experiments showing that the fungi acquire photosynthetically fixed carbon from their hosts.

Thus, results of simple pot experiments might justifiably be taken as good evidence that the relationship between host and symbiont is "mutually beneficial", host plants "gaining" mineral nutrients in exchange for providing fungi with a carbohydrate source. However, we know very little about interactions in natural vegetation and there are sufficient experimental results to suggest again that relationships between host and symbiont may not be as simple as they seem. In field situations, the soil is densely occupied by root systems of different species. Mycorrhizal fungi have very low specifity, and the same mycelium may frequently interconnect roots of different species. Pot experiments in which the roots of two different plant species are connected by the same fungus show that organic and inorganic nutrients may pass between the plants along the interconnecting mycelia (Francis & Read 1984, Finlay & Read 1986); the receiving plant might thus be considered as parasitic on the donor. Fungal mycelia are more efficient at absorbing mineral nutrients from dilute solutions than roots, so that in soil densely packed with roots, it may be more a question of the fungi "outcompeting" plants for nutrients rather than exploring "unexploited" volumes of soil. Plants gain access to nutrients "sequestered" by the fungus only by mycorrhizal infections, in the course of which they lose photosynthate to the fungus. Experimental evidence on the effect of infection upon the vigour of host plants in the field is very limited, and what there is provides conflicting results (e.g. Fitter 1986).

Leaf nodules

Several genera of plants bear leaf nodules containing bacteria which do not fix nitrogen. The recent study of Miller & Reporter (1987) on leaf nodules of *Dioscorea sansibarensis* deserves particular mention in any consideration of "mutual benefit". *D. sansibarensis* invariably possesses leaf nodules in nature. Plants free of nodules can be produced artificially, and these show depressed vigour compared to nodule-bearing plants; they grow more slowly, leaves are paler and only one is produced per node instead of two. In a straightforward comparison, it appears as if infected plants "benefit" compared to uninfected. The explanation of the apparent "benefit" is obscure. It is not due to nitrogen fixation, and Miller & Reporter suggest the possibility that the bacteria might provide a growth regulator; if this were the case, it presumably replaces the source of regulator provided in the ancestral host plant.

Is it justifiable to describe as "benefit" the improved growth of *D. sansibarensis* caused by bacterial infection in the leaf nodules, especially when those other *Dioscorea* species which do not have leaf nodules have morphologically normal growth? Bacteria and *D. sansibarensis* have become to a large extent mutually *dependent*, but it is difficult to call the relationship mutual *benefit*.

The situation is in some respect reminiscent of Jeon's (1980) work on *Amoeba proteus*. A laboratory culture of this amoeba originally became infected with a pathogenic bacterium which had demonstrably deleterious effects on host growth and survival. Within 200 host generations, the association had evolved to a state where host growth had returned to normal, but the amoeba had become dependent on the bacteria and could not exist without it, probably because the bacteria produced some compound essential to host survival, possibly a protein (Jeon 1980). No measurable *benefit* was conferred on *A. proteus* compared to uninfected cultures, yet bacteria and host had become mutually *dependent*.

SYMBIOSIS AND THE CONCEPT OF MUTUAL BENEFIT

The examples above should illustrate the problems involved in the concept of mutual benefit. The conventional view of symbiosis is that the interactions between the partners are those of conferring benefit, yet it has become quite clear that very often, benefits are accompanied by costs.

For most hosts, benefits seem to outweigh costs, but for many types of symbionts, it could be argued that costs might well outweigh benefits. Also, perceived "benefits" in laboratory experiments may not be so readily manifest in the field.

Nevertheless, there remains a clear difference to many people between symbioses which are termed parasitic and those termed mutualistic. In the former, hosts are undoubtedly harmed in the association because they are exploited by their parasites. In mutualistic associations, it often seems as if the host is exploiting the symbiont.

In the light of these considerations, A.E. Douglas and the author propose a new definition of symbiosis for those associations described as mutualistic, which avoids the concept of mutual benefit yet continues to allow them to be distinguished from parasitic associations. Their definition is

> "Persistent and intimate associations between organisms of different size in which the larger organism (the host) utilises novel or enhanced properties possessed by the smaller partner(s) (symbionts)."

This definition unifies all those associations which are mutualistic, and it is experimentally testable.

SIR JOSEPH BANKS IN RETROSPECT

There is an evident connection, albeit tenuous, between Banks' scientific work and my own interests in symbiosis. The key link is de Bary, who both proved the one major scientific hypothesis which Banks formulated about the life cycle of wheat rust, and coined the term symbiosis to cover situations like fungal diseases of plants.

Banks' single scientific paper was, however, but a tiny fragment of a life devoted to the cause of science. He is a classical illustration of the proposition that advancement of science depends not only upon those who make original discoveries but also upon those who select the people and create the conditions under which these discoveries can be made. He differs from many modern civil servants and administrators in having both a profound understanding of science and the respect of his contemporaries for having this knowledge. He was also fortunate in having sufficient personal wealth and a very good standing in society. At a time when such attributes are the occasional target for social criticism, it is perhaps unfashionable to recall that they can also "confer benefits".

However, it would be unfair and simplistic just to regard Banks' achievements as those of some very superior civil servant. Probably, one of his most important hidden influences was on the subsequent conduct of scientific exploration. He set very high standards for the scientific explorer, not only in how he behaved himself on scientific expeditions but also in the way he insisted on the thorough training of his collectors. Quite possibly, some of the later voyages of scientific exploration owe something to Banks' example.

Finally, there is one ironically beautiful paradox about Banks' life. As we have seen, he did not crave posthumous recognition, he is not remembered for any great scientific discoveries, and he is but a small footnote in the history of botany, the subject he loved. Yet he achieved much in his life, especially in the momentous consequences which his voyage with Captain Cook had for the later settlement of Australia. How fitting, then, that his pioneering work in scientific exploration is commemorated in the naming of over a dozen geographical features around the world, such as bays, capes and inlets. But perhaps the finest tribute is that his name will be remembered forever by that Australian genus of beautiful plants, *Banksia*.

For myself, I remember him most for the quotation that appears at the head of this lecture —

> "...a man is never so well employ'd as when he is labouring for the advantage of the Public; without the Expectation, the Hope, or even a wish to derive advantage of any kind from the results of his exertions." — Jos. Banks

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