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HISTORY OF THE JODRELL LABORATORY AS A CENTRE FOR SYSTEMATIC ANATOMY

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Summary. The botanical studies carried out in the Jodrell Laboratory over the last century are reviewed, with special emphasis on the systematic anatomical work. The routine identifications of wood are discussed in connection with the reference wood and slide collection at Kew.

INTRODUCTION

In order to understand the full significance of the Jodrell Laboratory in the history of British botany, it is necessary to go back to the time of Nehemiah Grew (1641–1712). Grew, as is very well know, was the great pioneer worker in this country in the field of plant anatomy. Although a medical man by profession, Grew was encouraged to take up the study of plant anatomy by certain Fellows of the Royal Society who, by subscriptions amongst themselves, provided funds which induced Grew to move to London where we are told that the Society's microscope was placed at his disposal. Considering the previous lack of knowledge concerning plant structure, Grew's contribution was a very notable one. Furthermore, he was in touch for many years with his Italian contemporary, Marcello Malpighi, and the combined efforts of these two botanists was the main starting point of plant anatomy in England on a scientific basis. I have already told the story of Grew in a previous publication (Metcalfe, 1972) complete with a full series of references to earlier biographical writings about him. It is not, therefore, necessary to repeat this story here, but there is one point about both Grew and Malpighi that I must emphasize, for it has a direct bearing on the significance of the Jodrell Laboratory at the time of its foundation in 1876. The point I have in mind is that both Grew and Malpighi worked in circumstances that gave them no contact with students. In consequence, serious work on plant anatomy ended with their decease and indeed virtually no further progress was made until the period towards the end of the nineteenth century when the Jodrell Laboratory was started. The Laboratory became a very important channel through which knowledge of plant anatomy was reintroduced to the United Kingdom from the European continent, especially from Germany. In saying this, it must be remembered that the distinction between anatomy

and physiology was not very clearly defined during the period that we are considering. Many anatomical investigations were undertaken with a view to shedding light on the relationships between plant structure and the physiological working of the plant. This in fact carried forward Grew's principal approach to plant structure for his main aim had been to relate structure to function. He was only partly successful in achieving this aim mainly because he could not rid his mind of the concept that there must be a heart-beat in plants just as there is in animals. At the same time Grew drew attention to structural differences between plants belonging to different taxa, thereby initiating systematic anatomy as a means of plant identification.

Much of the botanical work in Britain towards the end of the nineteenth century was devoted to systematic botany. It was a period during which a great wealth of specimens, collected from countries that had not until then been more than superficially explored by botanists, were being assembled in herbaria so that they could be named and classified. At the same time, floras that have since become well known classics were being written, special attention in Britain being devoted to countries that then constituted the British Empire. These activities provided plenty of fruitful occupation for systematic botanists, but others who were interested in the life processes, structure and pathology of plants were left out in the cold. Furthermore, as these aspects of botany had largely dried up in England there was very little stimulus within the country to promote much change. There were in Britain at this time some enterprising young botanists who realized the need to revitalize and broaden the prevailing outlook, and they could see that the only way to make a change was to study on the continent. This is what some of them did, particularly in the laboratories of Julius von Sachs at Würzburg and of Anton de Bary at Strasbourg. However, before pursuing the fortunes of these botanists we must see what was happening at Kew.

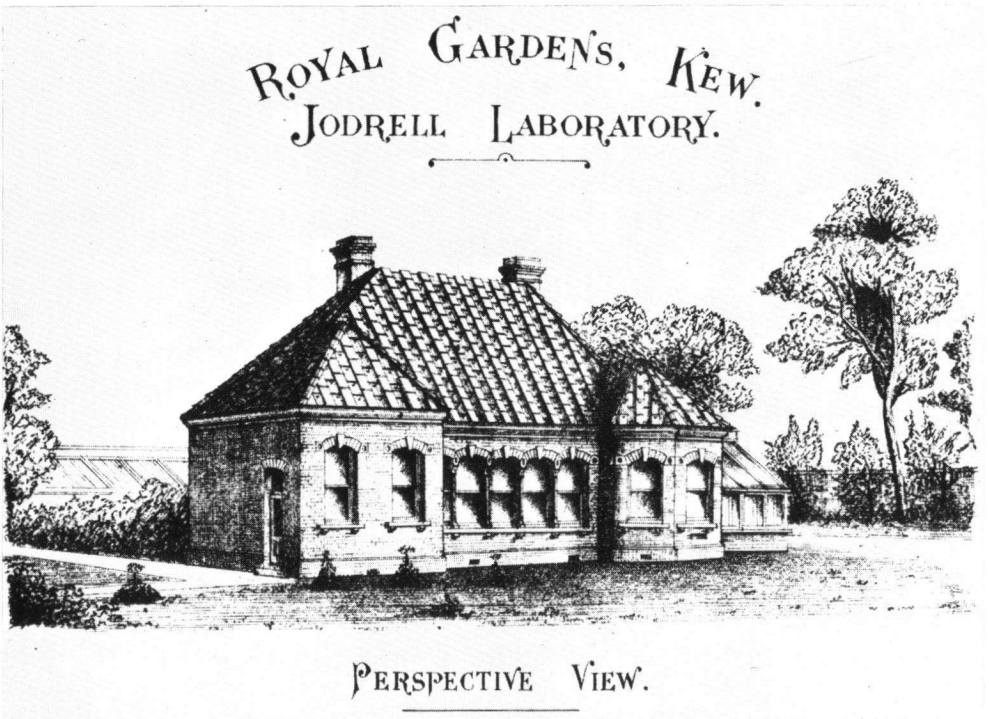
SIR JOSEPH HOOKER, T. J. PHILLIPS JODRELL AND THE FOUNDING OF THE JODRELL LABORATORY

In 1876, the year in which the Jodrell Laboratory came to be built, Joseph Dalton (afterwards Sir Joseph) Hooker was Director of Kew. Through his personal friendship with Charles Darwin, Thomas Henry Huxley and the geologist Charles Lyell he was in the vanguard of evolutionary thinking. Moreover, Hooker had the wisdom to see the value of the laboratory approach to botany as a supplement to the taxonomist's approach in the herbarium. Like the young botanists to whom reference is made in our last paragraph, he had an eye on the broad German approach to botany and saw very clearly that botany in this country would be enriched if a laboratory could be founded at Kew. However, he received no encouragement from the Government of the day. At that time, a Commission on Scientific Instruction and the Advancement of Science recommended that opportunities for the pursuit of physiological botany should be afforded in the Royal Gardens. But the recommendation was not heeded and no

provision was made from public funds either for a laboratory or for the remuneration of laboratory staff. We were reminded of these facts by Sir Howard Florey, the then President of the Royal Society at the official opening of the present laboratory in 1965. In making these remarks, Sir Howard was, of course, contrasting the more enlightened understanding that now exists with the parsimonious attitude in 1876. Hooker, however, was forced by the circumstances in which he found himself to seek funds for his proposed laboratory from a private source and in this he was successful. The necessary support was provided by Thomas Jodrell Phillips Jodrell, a public benefactor of those days who was actively interested in promoting scientific research. We know very little about the initial contacts between Hooker and Jodrell. When there is no official backing for an undertaking one has to tread warily and this is doubtless why there is so much obfuscation about what actually happened. Besides being Director of Kew, Hooker was also President of the Royal Society and it may well have been that Hooker and Jodrell first made contact through the Society rather than through Kew.

Jodrell eventually promised a donation of £1,500 which was to cover the cost of the laboratory and its equipment. However, before committing himself he seems to have had his doubts about the wisdom of building a laboratory when no funds were available for the remuneration of those who were to work there. He asked Hooker who, in the circumstances, was likely to work in the laboratory. Hooker replied that he hoped to have a little time to work there himself, but, so far as I am aware, he never did so. Even when Jodrell had agreed to provide the laboratory he seems to have been in no hurry to pay over the money. In the end he made an initial donation of £750 followed some time afterwards by the remaining half of the sum that had been promised. The scheme was very modest and the expenditure involved seems incredibly low by present day standards. The following particulars are recorded in a file labelled Works/16/592. This file is now in the hands of the Public Records Office where I was permitted to consult it. Quotations for building the laboratory were obtained from 6 contractors; these quotations ranged from £745–£1,030. The lowest quotation was from Mr. Jas Elder of Hayes and on December 11th 1875 he was informed, that his offer had been accepted. A quick start with the building operations must have been made for, on January 26th 1876, the contractor was instructed to make the foundations 2 feet deeper than was originally intended, owing to the sandy nature of the subsoil. The extra digging cost £20. A bay on the south side of the building was an afterthought and the building operation was held up pending a decision on whether to spend another £45 for the purpose. However, by February 15th 1876, the price of the bay was accepted. Early in 1876, only £5 remained out of the initial payment of £750, and Jodrell was asked for a further instalment. The work on the building itself was finished on May 7th 1876, about 5 months from the time when the work was started, but the contractor had to wait until August 14th before it was certified that the work had been completed in a satisfactory manner.

There seems to have been delay at this point over the installation of fittings. In December 1876 Hooker said that these should receive immediate attention 'in view



of the approaching lectures to young gardeners in chemistry, meteorology etc. which it is proposed should be given in the laboratory'. This reference to lectures for young gardeners is interesting because, as we shall see, only a few years later Thiselton-Dyer took the line that the Jodrell Laboratory was not to be used by students of any kind, because it had been donated to Kew on the understanding that it would be used only to provide accomodation for fully qualified research workers. Reading between the lines, it looks as if, in December 1876, Hooker was using the forthcoming lectures simply as an inducement to complete the work quickly. On December 29th 1876 Hooker was still asking for furniture to enable the laboratory to be put into operation. In January 1877 Hooker was told that the blinds and floor fittings had been fixed as far as possible but the contractors were unable to complete the work because some of the rooms were occupied by Professor John Tyndall. This gentleman was in fact the first occupant of the laboratory and it is evident that he was installed there before the building was really ready. It seems, however, that the fittings and furnishings must have been completed early in 1877 for Hooker made no further complaints on this score.

From this point onwards in our history it will be convenient to consider the various events that took place under the following headings. I. The pre-Scott era (1876–93). II. The Scott era (1893-1906). III. The Boodle era (1906-1930). IV. The Metcalfe era

(1930-1969). There is, however, no absolute line of demarcation between these divisions, and I feel sure that the reader will understand that many of the events overlap from one period to another.

THE PRE-SCOTT ERA (1876–1893)

Owing to the lack of funds it was suggested that all who worked in the laboratory should contribute towards its upkeep from their private resources. It seems, however, that this scheme was never popular and soon abandoned. Public funds were made available for the maintenance of the laboratory, but the outstanding problem still remained that there was no officer to direct its affairs. From 1876–1892 the management of the laboratory was largely in the hands of William Turner Thiselton-Dyer, who was then Assistant Director of Kew and his interest in the laboratory was continued after he became Director in 1885. Thisleton-Dyer was particularly well qualified to start a laboratory because he had recently collaborated with T. H. Huxley in giving lectures on botany at South Kensington and the lectures were followed by practical classes. T. H. Huxley and Thiselton-Dyer were protagonists amongst those who saw the need to reintroduce the laboratory approach in botany.

Mystery surrounds the question of how botanists were chosen to work in the Jodrell Laboratory at the time when it was first opened. The general principle underlying their selection was that they were to consist of experienced research workers who were to be admitted to the laboratory in the same way as visitors were admitted to the Herbarium. I suspect that the early workers were personal friends of Hooker and that he made contact with them through the Royal Society. When the laboratory was ready for use, Hooker must clearly have felt the need to have somebody of eminence to occupy it at the earliest possible moment. Jodrell would have felt that his gift was not appreciated if it had not been used and it was also necessary to convince the critics of the scheme that the laboratory had indeed been worth building. It was at this stage that John Tyndall DCL, LLD, F.R.S. was installed in the laboratory. He was interested in putrefaction. An account of his work on this topic was published by the Royal Society (Tyndall, 1877). The investigation was undertaken at Kew in the expectation that the air there would be purer than near the Royal Institution where Tyndall had previously been working. He wrote 'I was able to transfer my apparatus to Kew Gardens. By the enlightened munificence of Mr. Jodrell, a new and very complete laboratory had just been erected there, and in it I sought a purer air than I could find at home'.

As the varied nature of the early researchers at the Jodrell Laboratory has been described in my more general history which has just been written, and as a complete list of publications from the laboratory has been prepared by Mary Gregory (Gregory, 1976) for our centenary celebrations there is no need to follow them in detail here. It will suffice to say that they included investigations with a mainly physiological back-

ground and others were concerned with plant pathology. An event of considerable practical significance was that Charles Frederic Cross and Edward J. Bevan made use of the laboratory for some of their earliest researches on cellulose which led ultimately to the establishment of the rayon industry in this country.

THE SCOTT ERA

Scott's training

As we shall see, the influence of Dukinfield Henry Scott in raising the status of the laboratory was very profound. Indeed, the Scott regime has become so well known that, with the passage of time, we are apt to forget that the laboratory was in operation for 17 years before Scott came on the scene as Keeper. In order to understand the full significance of the part played by Scott, we must first take a look at his botanical career before his Keepership began.

D. H. Scott (1854-1934) was the second son of the well known architect Sir George Gilbert Scott. At the time when he first attracts our attention for the purpose of this narrative he had just read classics at Oxford. At this stage, George Gilbert Scott hoped that his son would become an engineer (Walton, 1959). The son was interested in railways, so it is perhaps not surprising that he obtained work at Euston station in London. For three years he pursued his intention to become a railway engineer.

Then, there came a complete change in his career at the age of 25, for he discovered that his real bent in life was to study the anatomy and physiology of plants. This change was inspired by the writings of German authorities such as Nägeli, von Mohl and Hofmeister. Scott also derived much benefit from reading Griffiths and Henfrey's (1875) Micrographic Dictionary. Owing, as we have already seen to the fact that physiological investigations with a microscopical background were then being pursued more actively in Germany than in Britain, it is not surprising that he decided to study in Germany. Two other young botanists, who subsequently became leading authorities in their respective fields, namely Sidney H. Vines and Frederic Orpen Bower had already taken this course. According to Walton (1959) it was J. D. Hooker who advised D. H. Scott to adopt the same course, but I have also seen it suggested that Thiselton-Dyer provided the primary influence. It may well be that Scott received the same advice from both Hooker and Thiselton-Dyer.

Scott started by teaching himself, in a matter of only a few months, enough German to enable him to follow a lecture. He then proceeded to Würzburg to study under the renowned Julius von Sachs at the Botanisches Institut. What happened to him there we are told by Scott himself (Scott, 1925). Scott describes the institute as 'an old fashioned but fairly roomy building adjoining the Botanic Garden'. Here he worked with a microscope that lacked any coarse adjustment beyond a sliding tube; he used water immersion objectives for the higher magnifications and in his account he adds 'I never saw a microtome'.

Scott tells us that the elementary lectures began at 8.15 a.m. and lasted for 45 minutes. Concerning von Sachs himself Scott says he was the best lecturer he ever heard. Following the 8.15 a.m. lecture Scott and his fellow students were expected to work until 8.00 p.m. On one occasion when Scott dared to leave the laboratory at 6.30 p.m. he met von Sachs who enquired whether Scott was taking a holiday! S. H. Vines (1925) has also given his recollection of von Sachs and the Botanisches Institut and, apart from a few minor details, his recollections agree very closely with those of Scott.

From the experiences of Scott and other young botanical research workers who visited Germany at this time we can see that this was a period when great progress was made in our understanding of physiological processes in terms of anatomical structure. Luckily an eye witness's account of these happenings is preserved for us by Bower (1938). It should be noted that the botanists concerned worked in simple laboratories using simple equipment. The progress that was made arose from the high mental calibre of the botanists. High mental capacity alone would not, however, have been completely effective without a tremendous capacity for working at high intensity for very long hours. Bower told me personally that this was so. In those days there was no loss of prestige if one worked in a laboratory that was small and, by modern standards, ill equipped. Simple as they were, the facilities and equipment of the Jodrell Laboratory at the time of its foundation are said to have been equal to those in continental research laboratories. The 9.00 a.m.–5.00 p.m. mentality was then completely unknown and a 5 day week would have been unthinkable. It was, at the same time, an age when a qualified investigator could be expected to make a new discovery on almost any day. This produced an atmosphere of great intellectual excitement which served to stimulate the spate of research activity.

Before returning to England, Scott was awarded a Ph.D. *'summa cum laude'* for a study of laticiferous elements. This can have been no small achievement when we remember the relatively late age at which he became interested in botany, and the fact that his studies were in a foreign language. Oral examinations for a Ph.D. were very formidable confrontations in Scott's time, as they still are in some continental universities to-day. In his reminiscences Scott amusingly recalls that he had to wear morning dress and a silk hat for the occasion and that he was confronted by all of the Professors in the Faculty.

On returning to England, Scott spent about 3 years (1882–1885) first as an assistant and later as a lecturer at University College London. In 1885 he became an assistant Professor of Botany under T. H. Huxley at the Normal School at the Royal College of Science at South Kensington. From here he took his advanced class to work at the recently opened Jodrell Laboratory.

One would have thought that with his background Scott and his advanced students would have been welcomed at the Jodrell Laboratory, but this apparently was not so, at least in the early stages. Thus in 1887 (Works file 16/592. Jodrell Laboratory 1875–1887) we find Thiselton-Dyer taking a high handed line when answering a request that students from the Normal School under Scott's supervision should be allowed to work

at the Jodrell Laboratory. He agreed, as a very special concession, that the 4 students should be allowed to come in that year (i.e. 1877) but he went on to say that this permission could not be repeated because experience had shown that 'the use of the laboratory by students under instruction is incompatible with the purpose for which the laboratory was built by Mr. Jodrell—namely to afford accomodation to persons engaged in independent research'. The 4 members of Scott's class were Miss Agnes S. Calvert, Miss H. V. Klaasen, Mr. L. A. Boodle and Dr. W. R. Gregg. Miss Klaasen subsequently became Mrs. Scott and L. A. Boodle succeeded Scott as Assistant Keeper of the Jodrell Laboratory.

It looks as if Thiselton-Dyer may afterwards have realized that he had rather overstepped the mark in trying to prevent Scott from bringing his class to Kew for we find that he wrote in a subsequent report 'The instruction in Botany at the Normal School is the only course of a comprehensive and adequate character on the subject given in London'. Concerning Scott himself he said: 'Dr. Scott (son of Sir Gilbert Scott) is a gentleman of private means who at a small salary has devoted himself with assiduity and success to the work and nothing can be less troublesome than the mode in which he conducts his instruction at Kew'.Thiselton-Dyer went on to say that if accomodation for instructing students could be provided, he would be very willing to co-operate. He pointed out that some students from the Normal School were very outstanding and he cited Harry Marshall Ward (afterwards Professor of Botany at Cambridge) as an example.

Scott accepts the Honorary Keepership

In 1892 Scott was offered and he accepted the Honorary Keepership, the post which he held with such distinction until 1906. F. W. Oliver (1935) who actually worked in the laboratory at this time pays an outstanding tribute to Scott's leadership in these words:- (Scott) 'always shared our ordinary daily interests and difficulties as if they were parts of his own botanical investigations, as indeed they were. There were no formal consultations about the work, and he never went over notes, or the written paper, as far as I can remember. When I see more modern methods in 'organization of research' I feel how good the Jodrell way was, and how much we all owed to Scott's influence and help that never suppressed independence. We all adopted him for life as a chief—even when we had another, and through the years he remained the same and never failed us in his interest and help on our work. Scott was a great botanist and a great investigator, and his influence on British botany was wide. But those who had the good fortune to work under him at the Jodrell Laboratory had, I think, the cream of his influence'.

It is not surprising that Scott's presence at the laboratory attracted a great many research workers. When he first became Keeper his primary interest was still in plant anatomy, but, by this time, he had become fascinated by the possibility of using histological characters to supplement those of external morphology both as an aid in identi-

fying vegetable material and as an aid in taxonomy. Here again we can see the influence of his training in Germany for, in that country, as also in France, the taxonomic value of histological characters had long been recognized. Indeed in such important works as Engler's 'Pflanzenreich' and 'Pflanzenfamilien' it was and still is customary to give selected histological as well as external morphological characters for the plants.

During the latter part of his time at Kew, Scott became interested in palaeobotany, through the influence of William Crawford Williamson. Williamson was Professor of Botany at Manchester, but, when he retired, he moved to London and collaborated with Scott at the Jodrell Laboratory. This put the laboratory in the forefront of palaeobotanical research, a position that was maintained until Scott left Kew in 1906.

Visitors to the Jodrell Laboratory in Scott's time

Apart from visitors to the laboratory during Scott's time who have already been noted in this narrative, we can picture him whilst engaged on his own diverse anatomical and palaeobotanical researches, surrounded by the happy band which included Bower (Pteriodphyta); Boodle (Pteridophyta and miscellaneous studies); Brebner (Pteridophyta). T. G. Hill worked on *Triglochin* and began his work on seedling structure; F. E. Fritsch studied the systematic anatomy of various plants and did some of his early work on Algae. We can also catch a glimpse of Worsdell (teratology and Cycadaceae); W. H. Lang (sporangia of ferns and Cycads); Harvey Gibson *(Selaginella)*; D. T. Gwynne Vaughan (polystely in *Primula*); Reynolds Green (pollen grains and tubes); Thiselton-Dyer (Haustorium of *Loranthus*). Although the publications by these botanists may be relatively unfamiliar to day they were in their time regarded as being of great interest and importance. Much of the knowledge to which they gave rise has since become embodied so inextricably in the general corpus of botanical wisdom that the means by which it was acquired has long been forgotten. It was also during this period that Horace T. Brown and F. Escombe made use of the laboratory for part of their classical researches on photosynthesis and the diffusion of gases through stomata. A considerable amount of work on mycology and plant pathology was also undertaken. Full particulars are recorded in the list of publications from the laboratory (Gregory, 1976).

Ample evidence that the work from the Jodrell Laboratory during the Scott period was fully appreciated is provided by the fact that Royal Society medals were awarded to 6 of the botanists concerned. The medalists were Burdon Sanderson (electromotive properties of *Dionaea* (1883); Marshall Ward (embryology and mycology; 1893); Walter Gardiner (continuity of protoplasm; 1898); Horace T. Brown (assimilation of carbon; 1903); D. H. Scott (palaeobotany; 1906); Bower (morphology of cryptograms; 1910). In addition a Davy Medal was awarded to E. Schunck for his researches on chlorophyll. (Of these medalists the work done by Burdon Sanderson was completed before Scott became Keeper, and Bower did not receive his medal until after Scott had left Kew).

Translation of Solereder's 'Systematishe Anatomie der Dikotyledonen' into English

This translation was of very great significance in the subsequent history of the Jodrell Laboratory. It is therefore curious that our records give very little information about the circumstances in which the translation came to be written. Solereder's book was then the only comprehensive work recording the anatomical characters of the vegetative organs of dicotyledons family by family. Some botanists may have felt the book to be unsatisfactory because it attempted little more than to record a summary of the characters that are exhibited by the plants, although the taxonomic significance of the characters was discussed at the end of the 2 volume work. Solereder's presentation of the facts was cumbersome and this in itself may have created a feeling of frustration and mental indigestion amongst its readers. However, the cumbersome style may not have aroused so much opposition as we should now expect when we remember that in those days little or no attempt was made to make scientific writing palatable. Indeed, the idea seems to have prevailed in Germany that a ponderous style enhanced the scientific value of the printed word. It is clearly evident, however, that in spite of its imperfections the treatise was a key work in the field of systematic anatomy. It carried forward a point of view established by Radlkofer who was the botanist who initiated Solereder himself into systematic anatomy. There was thus a direct line of evolution starting with Radlkofer, continued through his student Solereder, whose work was made known in England through Boodle and Fritsch's translation with some additions by Scott.

This in turn led on to the much more recent work initiated by Metcalfe and Chalk and which is now being expanded again with the help of a number of collaborators. Because Solereder's book was a pioneering attempt to bring together the very scattered information that previously existed, it would have been nothing short of a miracle if the best possible book had been produced at this first attempt. At the beginning of the 20th century the translation of German texts into English was very much in vogue. Consequently, when Boodle and Fritsch, with their deep knowledge of the German language, were available to undertake the translation, it is easy to guess that Scott took advantage of the situation to get the work done. But why so little was said about it at Kew remains a mystery. We must be grateful for the fact that the translation was achieved and that the English translation was published in 1908, just after Scott had left Kew.

In his editorial preface to the English translation Scott wrote as follows: 'The Systematic Anatomy forms an indispensible work of reference to all engaged in systematic studies, and serves at the same time as by far the best source from which students may gain an idea of the objects and methods of this young and vigorous branch of Botany. The present translation will, it is hoped, much facilitate the introduction of modern anatomical methods into the daily work of the Herbarium and the Economic Museum. One of the advantages of the study of systematic anatomy is that it brings together the work of the laboratory botanist and the taxonomist, each of whom has hitherto remained too much isolated in his own department. The work of translating so extensive

a treatise has naturally been extremely arduous; the translators, Mr. Boodle and Dr. Fritsch are to be congratulated on the successful completion of their labours. The translation, first begun by Mr. Boodle, was carried out jointly by him and his colleague up to the end of the Natural Orders; the work of translating the addenda and concluding remarks fell to Dr. Fritsch alone.'

THE BOODLE ERA (1906–1930)

The retirement of Scott must have presented the Kew authorities with a problem for it had been stipulated that when he left Kew he was not to be replaced. However, a very simple remedy was found when they decided to appoint an Assistant Keeper. Nobody had said that an Assistant Keeper should not be appointed and so this seemed a way out. Although Boodle in effect took control of the laboratory as soon as Scott retired, he was not in fact accorded the title of Assistant Keeper until several years later. At the same time, it was decided to make the Assistant Keepership a salaried post, and when Boodle was first appointed, he received a modest salary of £90 per annum.

In order to understand the position of the Jodrell Laboratory during Boodle's term of office, it is necessary to know something of the character of the man himself. As I had the good fortune to know this quiet, scholarly man, I can from my own experience say something about him. Boodle was a botanist, and especially an anatomist of very great ability. This is shown by his publications, especially those which appeared during the time that Scott was still there to spur him on. At the same time he was of a shy and retiring disposition. He found it very difficult to make effective intellectual contact with those who came to see him. He set himself such a high level of exactitude that he disliked committing himself in print and, when the influence of Scott was no longer behind him, he tended to hide his very great ability behind a timid exterior. For this reason, many people, including A. W. Hill, never fully appreciated him, because of the feeling that he was letting down the side after the inspiring innings of Scott.

I was lucky enough to be one of those who succeeded in breaking through the unapproachableness with which Boodle surrounded himself. I found him to be a true scholar in the highest sense of the word. He was a highly cultured man who loved listening to good music and attending the theatre. He was a linguist of no mean ability, with a good knowledge of German, French and Italian. Indeed, it was he who told me that I would never make any progress in plant anatomy without some ability to read German, and how right he was. He had an impish sense of humour which was seldom revealed except to his closest friends. I was told that this sometimes found expression when he wrote parodies of well known publications in botanical journals. I was never privileged to see any of these documents, but I am sure they must have been outstandingly good. His knowledge of botanical literature, particularly German literature was unbounded, and he retained his bibliographical knowledge in his head. I was always

impressed when he used to tell me that the answer to a question that I had put to him was to be found in a book on a particular shelf in the herbarium library and he would end by giving the approximate page number of the reference concerned. Unfortunately, his knowledge of the herbarium library was seriously impaired by a big change round of the books in the early 1930's, after which it was a great source of sorrow to him that he could no longer tell me where to find the books I wanted.

Probably Boodle's greatest claim to scientific fame rested on his ability to determine the botanical origin of archaeological specimens, especially from the tombs of ancient Egypt. Among the Egyptologists of his day, he had a high reputation for work of this kind but his ability was not well known or fully appreciated even by most of his colleagues at Kew. Boodle's temperament in some respects recalled that of Sherlock Holmes, and he had a flair for establishing the botanical source of miscellaneous fragmentary material. As the years went by, increasing quantities of timbers, fibres, medicinal plants and other miscellaneous items were submitted to Kew for identification. Boodle went on dealing with this material with consumate skill, day in and day out, year by year and his efforts were almost unnoticed except by the recipients of his reports.

Because Boodle was so much of a recluse, it is scarcely surprising that the laboratory became relatively unknown during the period when he was Assistant Keeper. Moreover, his period at Kew covered the duration of the first world war when very little happened at the laboratory. Because he hated standing up for his own legitimate demands the equipment of the laboratory deteriorated, and by the time of my arrival in 1930 there was very little effective equipment left and there was even a shortage of bottles for chemicals and distilled water was almost unobtainable.

THE METCALFE ERA (1930–1969)

Early difficulties

My chief difficulty on coming to Kew was that I had been trained as a plant pathologist and had to convert myself into an anatomist at short notice with very little guidance. Boodle was a great help at this stage. The change from plant pathology to anatomy was forced on me by the lack of employment in plant pathology owing to the economic conditions of the early 1930's. The change caused much heart burning as I was genuinely interested in plant pathology. My second problem was due to the lack of scientific equipment at the laboratory which had arisen for reasons that have already been mentioned. The third difficulty was that there was no set policy for the laboratory, and so it was perhaps inevitable that I became involved in a wide range of miscellaneous problems which are more fully described in my general history of the laboratory. I was in danger of becoming a botanical jack of all trades and master of none. My own inclination was to take up the study of wood structure from the taxonomic standpoint, as it seemed to me that this would fit in very well with the routine identifi-

cation of woods which it was clearly evident would constitute a fair proportion of my work. But even in this direction I was given rather luke warm support from A. W. Hill, but was more actively encouraged by Thomas Ford Chipp who was then Assistant Director and by W. Dallimore the Keeper of Museums.

The writing of Anatomy of the Dicotyledons

With the welter of activities mentioned above it may seem to be a matter for wonder that it ever became possible to embark on any large undertaking such as the writing of a reference book in two volumes. The decision to do this really stems from an occasion when Dr. A. G. Lowndes, who taught me biology in my school days at Marlborough College, came to see me at the Jodrell Laboratory. After talking for some time, and as we emerged from the front door of the building, Lowndes expressed the view that it was time for me to embark on some big undertaking rather than to disperse my energies on so many diverse activities. This, undoubtedly, was the moment at which the seed was sown that led to publication of 'Anatomy of the Dicotyledons' and later to the series of volumes on Monocotyledons. The scheme did not become formulated immediately after Lowndes's visit, but his comment set me thinking. It seemed to me evident that, although we relied so much on Solereder's 'Systematic Anatomy' in our daily routine work, the book was out of date. A research programme supplemented by a survey of the literature would be needed to modernize the book. This led to discussions with Dr. L. Chalk at Oxford. Hill gave the scheme his blessing, an agreement was reached with the Clarendon Press and the work was started.

I can remember in the early stages that the pessimists shook their heads, made discouraging noises, and indicated that the publication would never be finished. And yet it was finished and the book is widely used throughout the botanical world, and we are currently working on a second edition still with assistance from Chalk.

It would be wrong to leave 'Anatomy of the Dicotyledons' without paying tribute to L. Chalk's collaboration. Ours was, and still, is a very close relationship and it was a real achievement to secure and maintain this degree of co-operation. Chalk was supported in the early stages by Margaret Chattaway, and I was helped later by Leighton Hare who provided many of the illustrations and examined and made notes on countless microscope slides from our reference collection. Others also assisted, for example Enid Slatter, and the work would never have been achieved without the help of our very skilled and devoted technicians. But every word of the text, apart from a few passages, was written by Chalk and myself.

Routine identifications

It cannot be too strongly emphasized that the contribution to systematic anatomy from the Jodrell Laboratory has been on a broad front, both in its taxonomic extent and its histological content. It has not been confined to wood structure, and, although the

taxonomic importance of wood anatomy is fully recognized, it must be remembered that the histological approach to systematic anatomy does not lie wholly in this field. This may sound rather unpalatable to specialists in wood anatomy, but it should be realized that from 1950 until the present time the anatomical work of the Jodrell Laboratory has been mainly devoted to Monocotyledons i.e. the division of angiosperms which do not possess any secondary xylem. In spite of the lack of this tissue, our investigations have given very rewarding results and there is every prospect that they will continue to do so.

Nevertheless, the identification of wood from its microscopical structure, initiated at the Jodrell Laboratory by Scott has been continued as a routine ever since. The secondary xylem that we have had to examine has not always consisted of timber in the forester's sense, but it has included many vegetable products of economic importance as well as forensic and archaeological material. In recent years, there has been a steady interest in the identification of the roots of trees and shrubs particularly when they cause damage to property by undermining the foundations of buildings. These root identifications are achieved mainly by studying wood characters, but it must be remembered that the wood of roots usually differs in certain respects from the wood in stems, branches and trunks.

It is in the field of routine identifications that the main contribution to the study of wood structure has come from the Jodrell Laboratory. Owing to the very varied sources from which woody material has been received for identification, the investigations have called for much ingenuity. I have recently looked through some of the note books in which a record was formerly kept of the material submitted for identification, and the number of wood specimens and the range of sources from which they have come are truly remarkable.

Wood identifications have been made possible partly through the availability from the Gardens of material in cultivation. But of much greater importance have been the wood specimens in our museums collections. These specimens are of very mixed origin, and the starting point for assembling our reference material really began when Sir William Hooker (father of J. D. Hooker) decided that the herbarium collections should be supplemented by botanical specimens of economically important plant products to be stored in a museum. The first Museum of Economic Botany was opened in 1847, and it showed manufacturers, traders and craftsmen the useful products of the vegetable world and where they came from. The Museums at Kew also became depositories for specimens that were so bulky that they could not readily be preserved on herbarium sheets. One has only to think of such items as palm fronds, or the subterranean portions of bamboos as examples of these bulky objects. However, for our present purpose the most important items are wood specimens. Many of the first to be received were sent in response to a circular letter from Kew requesting forestry departments and others who were interested to send material for display. Many of these specimens were in the form of large planks sent to Kew from the British overseas dependencies and they included very representative collections of the timbers that were at the time regarded as the most important from the economic standpoint. I

can, for example, remember the Australian wood anatomist H. E. Dadswell inspecting our collection of timbers from New South Wales in my early days at Kew. The specimens in question were at the time stored in the orangery which in those days served as one of the museums. Owing to lack of space they were fixed to one of the walls, so high above floor level that they could be approached only from a somewhat rickety gallery. Dadswell's reaction was immediate for he said he had not seen such a comprehensive collection of New South Wales timbers anywhere in Australia, and he was horrified by the inaccessible position in which they were kept. Besides these large demonstration planks the worldwide wood collections included hand specimens of mixed sizes including the small specimens that made up Gamble's Indian collection. This valuable collection comprised the specimens on which Gamble's classical 'Timbers of India' was based. Here again I remember in my early days at Kew being visited by Samuel J. Record of Yale University who remarked that if we did not really value these specimens he would be only too pleased to provide a home for them at Yale.

The present reference museum near the Jodrell Laboratory was the first building at Kew to be developed for the storage of economic plant products. Furthermore the building is of historical interest because it was the first museum of economic botany not only at Kew but in the country as a whole. The other museums at Kew came later. It is not my purpose, however, to follow the history of the Kew museums in detail, but rather to show how they came to provide such an important background to the wood identifications at the Jodrell Laboratory. When I arrived at Kew in 1930 the museum facing the pond near the Cumberland Gate was devoted to Dicotyledons and it was here that most of the smaller hand specimens used as reference material were stored. Most of the material in this museum was and still is kept in glass fronted cabinets, of which many still exist, and it was arranged by families according to the Bentham and Hooker sequence. The wood specimens were not stored separately from other economic products, so all of the cabinets contained a very mixed collection of items, amongst which the wood specimens had to be sought. The difficulties of doing this were increased by the fact that there was no electric light in the museum, so that searching for reference specimens on a foggy winter morning was quite a problem. To add to our difficulties the doors of the cabinets were frequently difficult to open and the locks defective. There was also a collection of wood arranged geographically.

The early wood specimens at Kew have been much criticized because they were not backed by herbarium material from the same sources. I readily concede that this was in fact an important weakness. However, at the time when these specimens were being assembled, the need to have supporting herbarium material was scarcely realized. Many of the timbers were well known and the botanical identity of the trees that produced them presented no problem to the forestry departments of the day. Moreover, many of the specimens that came to Kew were collected by well known botanist who, in fact, sometimes submitted herbarium specimens as well, although there was no precise correlation between one particular wood specimen and one herbarium sheet. I do not believe that many serious errors were made in the naming of these wood specimens, and, after working with the collection for many years, I have never found any reason for revising this

opinion. Indeed, even in these more enlightened days when the need for supporting herbarium specimens is fully recognized, mistakes in identification can still be made for one reason or another. For example, the herbarium specimen numbers and the corresponding numbers on the wood specimens can and do become mixed up. Even when working with correlated material, it is necessary to be continuously on the look out for specimens that are wrongly named. The validity of the name on a wood specimen that is correlated with a herbarium specimen depends on the ability of the botanist who named the herbarium specimen. As herbarium botanists are just as prone to make mistakes as other mortals, it follows that 'authenticated' wood specimens can be wrongly named. After a time one gets to know which are the most reliable specimens in a collection and this valuable information becomes the stock in trade of knowledgeable wood anatomists. No one would dare to put this information on record otherwise than mentally. In the early days there were some errors that were repeated so frequently that their inaccuracy was not realized at the time. As an example Brazilian Tulip Wood was for a long time stated to be derived from *Physocalymma scaberrimum* Pohl of the family Lythraceae, whereas in actual fact it is the wood of a *Dalbergia*. Amongst the reliable wood specimens at Kew I can remember some that were kept in a specially guarded cardboard box. These had been assembled by Boodle in the Jodrell Laboratory to assist in identifying certain critical taxa and timbers that were commonly confused. But I must emphasize that very great trouble was taken to avoid mistakes, and it required somebody with the ability and knowledge of Boodle to ensure accuracy. Furthermore, it must be remembered that timber identification was a regular routine at the Jodrell Laboratory long before more recent institutions that deal with the same problem came into existence.

The techniques for examining wood specimens adopted by Scott and later extended by Boodle were painstaking and crude by modern standards. With great patience transverse, tangential and radial longitudinal sections were cut with 'cut-throat' razors directly from the reference specimens in the museums. Botanists selected razors which were found by experience to give good results, and those that gave the best results were highly guarded and treasured possessions. The sections were usually mounted in dilute glycerine. They were small in area, and not even remotely uniform in thickness. Nevertheless, by diligent searching, especially along the thin edges of the sections, the necessary diagnostic characters could be made out. When an identification had been made the slides were thrown away. Fresh sections were made whenever a wood came in to be identified and there was no attempt to maintain continuity by building up reference collections of microscope slides.

Soon after coming to Kew, I had the good fortune to meet Dr. Laurence Chalk who had then been in charge of the wood structure department at the Imperial Forestry Institute at Oxford for several years. Dr. Chalk had initiated a scheme for the systematic sectioning of authenticated wood specimens in order to build up a reference collection of microscope slides. These were filed in the familiar aluminium slide holders, which, at the time of which I am speaking, were made locally in Oxford, but they were based

on an American prototype. It was immediately evident that Chalk's methods had tremendous advantages over the use of temporary slides, and I suggested that these methods should be introduced to the Jodrell Laboratory. This was achieved in spite of considerable initial opposition. The slide collection at Kew never consisted exclusively of sections of wood, unlike the slide collections at Oxford, Princes Risborough and Yale to mention but a few of the collections that at once come to mind.

Following the inauguration of the Jodrell slide collection, the task of identifying timbers was considerably expedited and simplified. The growth of the slide collection still goes on, but, as with all slide collections, we still have a long way to go. Many of the recent additions have been prepared from authenticated wood specimens and the reference specimens in the museums are now being effectively indexed. The strenuous labours and helpful collaboration of colleagues on the staff of the Kew museums are very greatly appreciated.

There is no need to give particulars of the technique of establishing the identity of timbers, as the diagnostic characters in current use are very well known, and the methods employed are very much alike in all departments where timber identfication is undertaken.

Soon after I arrived at Kew an International Botanical Congress was held at Cambridge. It was a particularly eventful one for the history of wood structure as it was the occasion on which the International Association of Wood Anatomists was initiated mainly through the strenuous efforts of Samuel J. Record, the world famous authority on timbers at Yale University. I became a foundation member of the I.A.W.A. although I was given little encouragement to do so by the Kew authorities. The aims and objects of the I.A.W.A. did not then appear to be very well understood at Kew, and, indeed, there seemed to be a definite prejudice against the Association for reasons that I never clearly understood.

It will also seem strange that there was also opposition to my cutting pieces of wood from the reference specimens in the museums so that they could be sectioned. It was pointed out that Boodle had been able to identify wood specimens without cutting pieces from them so why could I not continue in the same way. Besides, I was told it would make the specimens unsightly. This last problem arose because the wood blocks in the Museums served for exhibition as well as for reference. Eventually, it was decided that every specimen of which I wished to obtain sections would have to be approved by the Keeper of Museums. He marked with a pencil outline the positions on the individual specimens from which pieces could be cut. The cutting was entrusted solely to the Museums Preparer, Mr. L. J. Harding, who was luckily interested and very willing to help. It was not often that permission for sections to be cut was actually refused, although I remember an occasion when I was not permitted to examine one particular specimen because it had been presented to Kew by the Prince of Wales. However, with the passage of time a more normal and common sense approach to the problem was evolved and has been maintained ever since.

Slides for the Jodrell collection are made to be as endurable as possible, but it is

inevitable, with the passage of time, that replacements are sometimes needed. Furthermore as more material becomes available it is possible to obtain preparations that are more typical or of better quality. However, in spite of the difficulties concerning the initiation of the collection it is now one of our most valuable aids to microscopical identification of vegetable material and it is increasing in value all the time.

The literature index

Our routine and research work have also been greatly assisted by our very comprehensive index to the literature of plant anatomy which is now so ably maintained by Mary Gregory. Boodle had a notebook in which he recorded important references to anatomical publications, but, although this was useful, it had serious limitations. Many years ago I started the modest card index which was the unassuming start of our index which now occupies a large bank of card index cabinets. In view of its present importance, it seems strange that there was opposition to my mentioning its initiation in an annual report on the grounds that it was an event of trival significance.

CONCLUSION

The story that I have told shows that J. D. Hooker had great foresight in initiating the Jodrell Laboratory. If he were alive to-day, I suspect that he would be pleased that the unassuming laboratory which he initiated with Jodrell's financial assistance had expanded into the much more impressive building which we have to-day. I think he might be surprised that a laboratory which was intended primarily to serve as a centre for physiological investigations developed so vigorously in the fields of systematic anatomy and more recently of cytology and biochemistry as a supplement to herbarium taxonomy. Meanwhile, physiological investigations have been transferred to Kew's satellite garden at Wakehurst Place. The Jodrell Laboratory is extremely well situated for studies in systematic anatomy, but the work can be done so effectively only because our herbarium colleagues are available for consultation. In the special field of wood structure we receive much assistance from colleagues in the Museum and Gardens who provide us with reference material. The unrivalled library facilities at the Herbarium are also available. In other words the effectiveness of the Jodrell Laboratory as a centre for systematic anatomy depends on its position as an integral part of Kew. I suspect that although J. D. Hooker thought of the Jodrell Laboratory as a physiological rather than a taxonomic laboratory, he would not have been disappointed by the laboratory's evolutionary development.

REFERENCES

BOWER, F. O. 1938. Sixty years of botany in Britain (1875–1935).

GREGORY, M. 1976. Jodrell Laboratory Publications 1877–1975. Notes Jodrell Lab. 8 (available from the laboratory on request).

GRIFFITHS, J. W. & A. HENFREY. 1875. Micrographic Dictionary.
METCALFE, C. R. 1972. Nehemiah Grew in Dictionary of Scientific Biography (ed. Amer. Council Learned Societies) 5: 534–536.
METCALFE, C. R. & L. CHALK. 1950. Anatomy of the Dicotyledons.
OLIVER, F. W. 1935. Dukinfield Henry Scott 1854–1934. Ann. Bot. 49: 823–840.
SCOTT, D. H. 1925. German reminiscences of the early eighties. New Phytol. 24: 9–16.
SOLEREDER, H. 1908. Systematic anatomy of the dicotyledons (translated by L. A. Boodle and F. E. Fritsch, revised by D. H. Scott).
TYNDALL, J. 1877. Further researches on the deportment and vital persistence of putrefactive organisms from the physical point of view. Phil. Trans. R. Soc. 167: 149–206.
VINES, S. H. 1925. Reminiscences of German botanical laboratories in the seventies and eighties of the last century. New Phytol. 24: 1–8.
WALTON, J. 1959. Palaeobotany in Great Britain. Vistas in Botany (ed. W. B. Turril) 1: 230–244.