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# THE PATTERN OF BREWING RESEARCH: A PERSONAL VIEW OF THE HISTORY OF BREWING CHEMISTRY IN THE BRITISH ISLES*

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**In covering the 160 years since the first appointment of a trained chemist to a brewery in Britain, a broad outline of the history of brewing chemistry is hung upon the framework of Irish contributions. Activity is traced through the careers of successive generations of brewers' chemists, from the early practitioners of the 1830s, through the golden age of the late Victorians, into a barren period embracing the two world wars and a second flowering in mid-century. The chronology culminates with the change in attitude to research and decline in open publication of the last decade. A cyclical pattern in the approach to brewing research affecting both the balance and the level of activity is detected and a correlation with social and economic factors demonstrated. The most productive periods are found to occur when an essentially fundamental approach is taken to brewing research thereby complementing the primarily technological interests of the practising brewer.**

Key words: *Brewing science, history, biography, chemistry, research.*

## INTRODUCTION

This paper originated as an attempt to chronicle Irish contributions to brewing chemistry. It has subsequently matured into an appraisal of the general nature and historical pattern of brewing research in the British Isles, particularly as exemplified by work with an Irish connection. In this context we must firstly consider what qualification is necessary in order to justify inclusion as "Irish". A chemist may of course be Irish by birth or by lineage, but the description may also come from association with Ireland through work. Both uses were included by O'Raghallaigh[184], Partington[202], Davis[109] and Thorburn Burns[241] in their respective considerations of Irish chemistry. The example set by these authors will be followed in this paper.

Robert Boyle (1627–1691) who was born in Lismore Castle, Co. Waterford the fourteenth child and seventh son of Richard Boyle, the first Earl of Cork, may fairly be claimed by the Irish. Most of Boyle's life was, however, spent working in London and in Oxford, and this has sometimes led[1] to his being assigned to England. He is best remembered for the gas law named after him, but he has also been described as the "father of modern chemistry"[241]. Certainly he was a pioneer in the use of experimental method, played a large part in the founding of the Royal Society and may best be described by the old fashioned term of natural philosopher. An example of his vision lies in the prophetic words he left us on the subject of fermentation, in his *Essay on the Pathological Part of Physic* written in 1661: ". . . he that thoroughly understands the nature of ferments and fermentation, shall probably be much better able than he that ignores them, to give a fair account of diverse phenomena of several diseases . . . which will perhaps be never properly understood without an insight in the doctrine of fermentations."

This remarkable quotation may almost be taken as a description of the career of a man who lived two hundred years after Boyle—the French chemist and microbiologist Louis Pasteur (1822–1895). Pasteur's work on the nature of fermentation and the diseases of wine and beer leading him on to his even more important work on the diseases of man. In 1876 Pasteur published his *Etudes sur la Biere*, the culmination of his work on the bacteriology of industrial fermentations. In October of that year, in a lecture given in Glasgow[244], John Tyndall (1820–1893), the Irish physicist and polymath[106] who was at the time director of the Royal Institution, recalled his distinguished countryman's prophecy when he had this to say of Pasteur's work.

> ". . . though wine and beer possess so old a history, a very few years ago no man knew the secret of their formation. Indeed, it might be said that until the present year no thorough and scientific account was ever given of the agencies which came into play in the manufacture of beer, or the conditions necessary to its health, and of the maladies and vicissitudes to which it is subject. Hitherto the art and practice of the brewer have resembled those of the physician, both, being founded on empirical observation."

While Pasteur's contributions should not be underestimated, neither should Tyndall's words be taken too literally when he implies that virtually nothing was known of brewing microbiology prior to Pasteur. As I have discussed elsewhere[6], the more enlightened brewers (and not a few others) had deduced the true nature of fermentation some time prior to Pasteur. Indeed the Professor of Botany at Dublin University, George James Allman (1812–1898, Fig. 1) had noted the growth of a bacterium alongside the yeast in a distillery fermentation as early as 1853[4], some years before Pasteur started to work on fermentation. The massive prestige of Pasteur and his place in the history of science have led more recent authors[94,107,226] to compound Tyndall's lionisation of the man and conclude that the application of science to brewing by Pasteur was on virgin territory. If this assumption is mistaken in the case of microbiology, then it is even less justified when it comes to chemistry.

## THE EARLY PERIOD

By the eighteenth century the practice of brewing was moving away from the purely empirical towards the application of scientific principles and the use of measurement[168]. This is heralded both in books on brewing[24] and in chemistry text books[46] published early in the century, and is demonstrated in the introduction of the thermometer[93] and the saccharometer[40,215] to brewing in the mid-1700s. Both instruments seem to have been in common use by the larger English brewers by the end of the century[41]. Used together these instruments brought technical and economic benefits to the brewers in allowing both greater consistency of brewing and more efficient use of raw materials. Such advantages became increasingly important as the scale of production rose demanding greater accuracy. There were also moves towards further innovation with the number of patents taken out by brewers increasing

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FIG 1. George James Allman.

each decade as the 19th Century progressed[95]. These demands are reflected in the gradual recruitment of men with a scientific training into the industry.

In the 1830s the number of practitioners of chemistry in Britain could still be measured in tens[79]. But amongst this small group were chemists working in breweries. The first trained chemist, of whom we have any record, to find employment in a British brewery was Robert Warington (1807–1867, Fig. 2). His chemical education came from the then well known professional chemist and teacher J. T. Cooper to whom he was apprenticed for five years from the age of 15[18]. This was followed by a spell of three years in charge of practical classes at London University (now University College) under the first Professor of Chemistry at that institution, Edward Turner. In 1831 he joined Messrs Truman, Hanbury and Buxton in Brick Lane where he remained for eight years. On leaving the brewery he seems to have held no specific position for three years until being appointed Chemical Operator to the Society of Apothecaries, a position he occupied until within a year of his death[131]. Warington gained some prominence as a chemist, he published over 30 papers in his career and he was elected a Fellow of the Royal Society in 1864. He is also of some significance in the history of chemistry as the moving spirit behind the formation of the Chemical Society in March 1841. He served as Secretary of the Society during the first 10 years of its existence. It is probably through Warington that two brewers were amongst the five "industrial chemists" who went to make up the seventy-seven founder members of the Chemical Society[74]. These were Thomas Hetherington Henry (1814–1859) a former colleague of Warington at Trumans and William Ferguson (1810–1869, Fig. 3) from Reid's Griffin Brewery, in Liquorpond Street (now Clerkenwell Road). At the time, Trumans was the second largest and Reids the fourth largest brewery in London[76,169] and there is no doubt that the three men were well acquainted, all three being members of the local Spitalfields Mathematical Society[247]. Henry had joined Trumans shortly before Warington left[75]. William Ferguson probably also entered brewing in the mid 1830s and may well be the first graduate chemist to work in a British brewery. He possessed a BA degree obtained from Trinity College Dublin in 1833[82]. In the same year, whilst still in Ireland and Operative Chemist at Apothecaries Hall, he published a paper on a new method of determining the specific gravity of fluids[119].

A further seven men who are listed as brewers may be found as members of the Chemical Society in the period up to 1850[77]. The most famous of these is undoubtedly James Prescott Joule (1818–1889) who, working in a laboratory attached to the family brewery in Salford, performed experiments which were to lead up to the enunciation of the first law of thermodynamics[85]. But Joule was hardly typical. In general these men would have been more immediately concerned to apply a knowledge of chemistry to brewing simply to make a living. Some, such as John Wilson (1812–1888) who worked at a London brewery in the early 1840s after studying at University College and under Gay-Lussac and Payen in France[91], came well qualified. As did Heinrich Wilhelm Böttinger, who became "scientific advisor" to Allsopps in 1845 after completing a PhD under the redoubtable Liebig, but for some reason never joined the Chemical Society[8]. At least one, John Furze, was the proprietor rather than an employee of a brewery[124,216]. Others remain more obscure and further research is required to determine their background.

Some measure of how they used their chemical knowledge is available from surviving records. Thus Truman's gyle books of

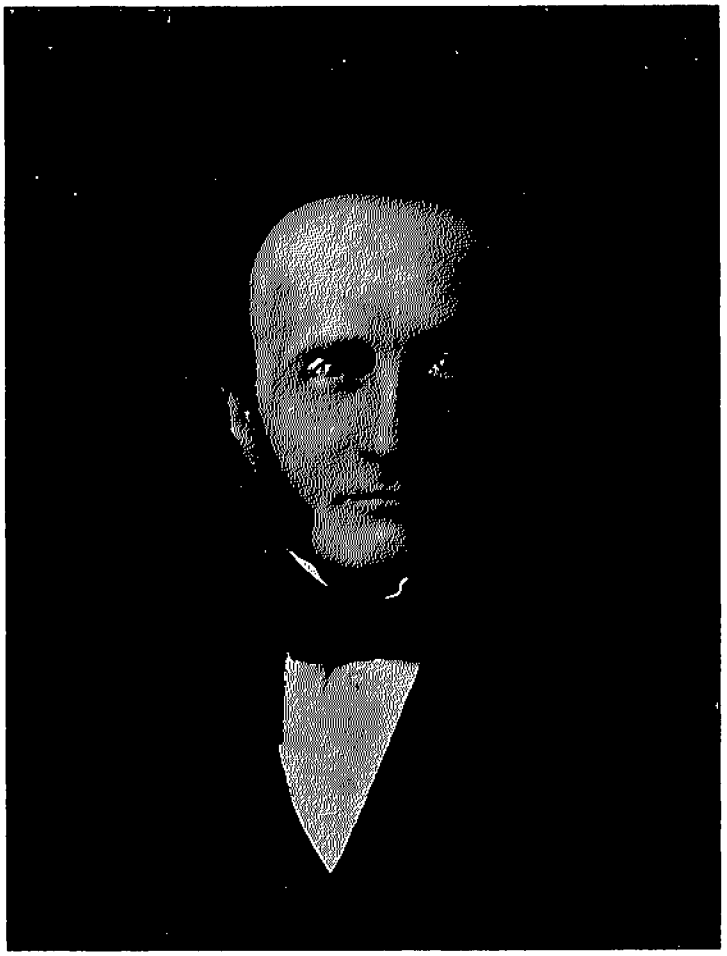

FIG 2. Robert Warington.

the period show the carefully recorded work of both Warington and Henry in monitoring brewing parameters. It is also recorded that Henry carried out investigations on hop and malt quality in the early 1840s[243]. Furze communicated a paper to the Chemical Society in November 1843[125] in which he gave his "Observations on Fermentation". These mainly concerned his attempts to limit the amount of ethanol lost with the carbon dioxide given off. Interestingly he acknowledges the help of his friend Robert Warington in his investigations. Further evidence that Warington kept up his connection with the brewers after he left Trumans comes from a paper of his own, "Observations on the action of animal charcoal" given in March 1845[248]. In this he describes attempts to turn ordinary beer (by which we may assume he meant porter) into pale ale, by treatment with charcoal. He notes that it worked well in removing the colour but also removed most of the flavour and bitterness. He goes on to suggest that this may be a good way of extracting and purifying the substances which cause bitterness. A footnote to the published version of this paper by Warington gives an interesting side-light into the manners of the time. It was then considered bad form for a scientist to start work in a field in which another was already engaged. Warington comments that since giving his own paper to the Chemical Society a translation of a paper by a M. Chevallier had appeared in the April 1845 edition of The Chemist, which showed the Frenchman's priority in aspects of the study Warington himself had undertaken. Warington stated that: "Had I been aware of the existence of this paper at the time, I certainly would not have brought my own experiments forward, and shall not continue the investigation until M. Chevallier has closed his researches."

Chemists who did not actually earn their living as brewers also occasionally reported investigations into the brewing process. Thus we have George Septimus Piesse (1820–1882) an analyst and perfume manufacturer reporting in 1841[208], how he could increase the extract yield during mashing by adding a small amount of diastase (actually freshly ground malt) to the 2nd mash. He also advises on the virtue of closed over open fermenting vessels.

Precisely when and to what extent laboratories as such were introduced into breweries in Britain is not clear. In most breweries analyses were probably obtained through the independent professional chemists. The analysis of water[177], a good source of revenue for these men, was particularly popular. But, in a few breweries, analyses were probably carried out on site. Certainly a London vinegar manufacturer had a laboratory specially for monitoring product quality operating in 1842[26]. In the same year the first laboratory was established for the Customs and Excise[90], the government having previously paid for analyses by outside chemists. The laboratory was originally used for tobacco testing but was soon extended to other areas including alcoholic drinks, with men being sent to University College for intensive training in chemical analysis. The extent of the operation may be gauged from the fact that seventy seven officers had been trained in this way by 1854[78]. No doubt some of this increase in establishment by the Excise was due to a change in the law which occurred in 1847 and which also led to employment for brewers' chemists.

It was then that it first became necessary to determine the original gravity of a beer, owing to an alteration in the method of allowing drawback of Excise on beer exported from the United Kingdom. Until that time drawback could only be claimed by the brewer "making oath" that the beer had been brewed wholly from duty-paid malt, and that not less than 2 bushels of malt per barrel of beer brewed had been employed[3].

FIG 3. William Ferguson.

In 1847, brewers were for the first time allowed to use sugar in brewing leading to the introduction of a new system of allowance for drawback. This new system was based, not on the amount of material used, but on the original gravity of the worts before fermentation. Consequently a method of checking the declaration of the brewer at the time of export was required. The first "degrees lost" table, obtained from laboratory analysis of beers using a method based on evaporation appeared in a report produced by the Excise laboratory in August 1847 and was adopted as the official table. The minimum gravity on which drawback was allowed was 1054 and it was important to the brewer to be able to check and prove this. As Bass's chemist John Matthews, who was appointed in about 1850, was to note some years later[171]:

> "We analyse a sample from every brewing of pale ale for export because a drawback is allowed us by the Government officers when certain conditions are complied with."

Further need for laboratory facilities is displayed in some of the "extramural" work of chemists employed in breweries. Thus, Robert Warington, who published papers on such topics as the "Action of chromic acid on silver" whilst employed by Trumans[18], must have had access to a laboratory. In addition to being a chemist, Warington was an accomplished microscopist and it is known that his friend the pharmaceutical chemist Jonathan Pereira (1804–1853), used a microscope housed in the brewery for studying fermentations at Trumans at this time[8]. Similarly, William Ferguson must have been able to carry out chemical analyses whilst at Reids in order to present a paper on the reduction of copper acetate by charcoal in 1849[120]. This paper, one of only two[120,121] which can be traced to Ferguson whilst he was at Reids, is particularly interesting as it relates, somewhat obliquely, to his work in the brewery. He notes that a float gauge on a brewery vat had been charred by steam, yielding acetic acid, which in turn reacted with the copper of the vessel producing copper acetate, only for the copper acetate to be reduced to copper by the charcoal of the charred float gauge.

Whatever the source of these analyses, the time between Warington's first employment at Trumans in 1831 and Ferguson's paper in 1849 saw an upheaval in British chemistry which profoundly affected the nature of the data produced. Simple elementary analysis was replaced by expressions of the nature of the chemical species present. This arose initially through the theories of chemical structure[239] proposed by Jons Jacob Berzelius (1779–1848) the powerful Swedish chemist. These were followed by the theoretical and practical contributions of Justus Liebig (1803–1873) which developed from his studies on organic chemistry and led to much improved analytical techniques and the proposal of the existence of radicals[164]. The full ramifications of the intellectual revolution thus produced cannot be discussed here, but the effect was profound even for the practice of routine analysis as performed for and by the brewers. Thus we have the Professor of Chemistry at Oxford University Charles Daubeny (1795–1877) writing in 1840[108] that it was no longer clear that:

> ". . . the business of the analytical chemist, is limited to the determination of the several elements which compose the substances, and the definite proportions they bear to each other."

The analyst was now required to specify the chemical moieties that made up a substance. These new requirements were met with some disgruntled comment by the established

FIG 4. James Sheridan Muspratt.

professional chemists who served the breweries. Thus we have the observation in 1848[47] of William Thomas Brande (1788–1866), one of the most eminent, that:

> "chemistry is not what it was . . . it is not now as formerly the bare history of the effects of heat and mixture."

This change in attitude is reflected in the writings of one of the more progressive younger chemists of the day, the Irishman James Sheridan Muspratt (1821–1871, Fig. 4). He was born in Dublin the eldest son of James Muspratt the founder of large-scale Leblanc soda manufacture in Britain[135]. The son failed to show the business acumen of his father but after a research training (and a PhD) from Giessen he launched himself on a career as an analyst and teacher, and in 1848 established the College of Chemistry in Liverpool which soon earned the appellation Royal after patronage from Prince Albert. Between 1853 and 1860 Muspratt published as a part-work an encyclopaedic treatise on the chemistry of current manufacturing processes, which included a chapter on beer[180] which appeared in 1854. From this we may deduce the input then current from chemistry into brewing. Numerous examples of analyses are given, ranging from straight elemental analyses of barley and malt to quite detailed analysis of various compounds present in grain and hop ash. Basic organic analyses are also attempted for barley malt and brewers' grains. Water comes in for a lot of attention with examples from Allsopps, Bass and Tetleys analysed by and for the breweries in some detail. Hop analysis is also attempted including figures for the "bitter principle". Saccharometry justifies a section to itself and had by then obviously reached a high degree of sophistication. A method of determining carbon dioxide is described as is the determination of original gravity, alcohol, "saccharine" and "glutinous" matter. The detection of adulterants in beer is also covered quite extensively, which may support the view[197] that one of the principal reasons for initially employing qualified chemists in breweries was the need for the larger establishments to deal with and refute accusations of adulteration. Muspratt does note[181], however, that:

> "This subject, fortunately, is not so difficult to deal with at the present day, as it was about half a century ago; whether this result is owing to the increased morality of the brewer, or to the vigorous measures taken by Government in detecting and punishing sophistications, is a difficult point to determine."

In addition to his detailed discussion of analysis Muspratt thoroughly covers the processes of brewing as seen by the chemists of the day. Although a great deal of his description is quite sensible it is obvious that there is much feeling in the dark for answers to questions which were not available. Perhaps this was the general mood at the time and could well have been the impetus for moving on from what was primarily a utilitarian analytical approach to the application of chemical knowledge to brewing, to the more sophisticated attempt to use of this knowledge in trying to increase understanding of the process which was to be a major feature of the next phase of brewing chemistry.

## THE GOLDEN AGE

If London was where the first brewing chemists were employed in Britain in the 1830s then by the 1860s the focus for brewing chemistry had swung away from the metropolis and towards the small Midlands market town of Burton-on-Trent.

This swing mirrored the movement in public taste away from the porter of the great London breweries—principally Barclay Perkins, Trumans, Whitbreads and Reids[169]—through mild, to the pale ales of the Burton breweries of whom Bass and Allsopp were the leaders[201]. Not that the output from the London breweries did not grow, for it did from 2.2 million standard barrels in 1831 to 5.0 million standard barrels in 1880[250]. But, this rate of growth was slow compared to the Burton breweries where in the same period output increased from 50,000 standard barrels to 3.0 million standard barrels[200]. Thus, even in terms of total volume increases, Burton slightly shaded the London breweries despite the much greater local catchment area of the latter—something which would of course have been impossible without the railway network. In both cases the source of the growth was ale. Many of the London brewers, like Watneys, Charringtons, Courage, and Mann, Crossman and Paulin copied the Burton style—principally either by "Burtonisation" of the soft London water or by setting up new breweries in Burton and elsewhere—and were rewarded with substantial growth[251].

The previously dominant porter breweries were slow in adapting to change both in business practice and in technical development and paid the price. As Wilson notes[251] "Only one of the great porter breweries (Trumans) managed to double output between 1830-1880". Perhaps it is no coincidence that Trumans, who had the best background in chemistry (they had at least three Fellows of the Chemical Society on their staff—Robert Warington, Thomas Henry and George Gow—in the period to the 1860s) should be the established porter brewer to adapt best to the changes that were required.

But even Trumans were left far behind by the Burton giants, where output by Bass alone topped ½ million barrels in the 1860s and approached 1 million standard barrels in the late 1870s when they became what has been termed[128] "a wonder of the Victorian world" and the largest brewing company in the world at the time[198]. Such growth in output brought with it the benefits of economies of scale, but also greater risks and consequences of error. In order to minimise these the Burton brewers strove to obtain a better understanding of the chemical processes involved in brewing. As we have noted Bass had employed a chemist, John Matthews in about 1850, and in the mid 1860s they employed another who was to become arguably the dominant figure in what was to be a golden age in brewing chemistry. This was Cornelius O'Sullivan (1841–1907, Fig. 5) a native of Bandon, County Cork and a man whom a contemporary Burton chemist Charles George Matthews (1856–1946) was later[170] to term "the Father of Scientific Brewing". On the basis of his scholastic achievements in Ireland, O'Sullivan had been given a scholarship to the Royal School of Mines in London, which he entered in September 1862. At the end of the three year course he became demonstrator under August Wilhelm Hofmann (1818–1892). When Hofman went to Berlin in 1865 to take up the Professorship in Chemistry, O'Sullivan went with him. O'Sullivan returned to England in 1866 to take up an appointment as brewer and chemist to Bass, Ratcliff and Gretton in Burton on Trent, remaining with the firm until his death 40 years later[14,19].

He made his mark with his first paper published in 1872[185] on the transformation products of starch. In this paper he describes how he "rediscovered" maltose—confirming and extending Augstin Pierre Debrunfaut's 1847[112] neglected identification of maltose, rather than the universally assumed glucose, as the major product of the action of diastase on starch. O'Sullivan extended his studies on starch, concentrating on the appearance of dextrins in a series of papers given to the Chemical Society in the 1870s[186,187,188].

O'Sullivan went on to study other carbohydrates in cereals. In 1882 he isolated what he called[189] alpha- and beta-amylan, cell-wall polysaccharides which over a century later are still a fruitful area of investigation, under the name beta-glucans, as potentially *troublesome* agents in mashing. In 1886 he identified raffinose in barley[190]. In 1890 he contributed a massive and most interesting paper[191] on the action of invertase on sucrose entitled—"Invertase: a contribution to the history of an enzyme or unorganised ferment". In this paper O'Sullivan and his co-author Frederick William Tompson investigated the rate at which inversion takes place and how various factors, such as amounts of enzyme and substrate, temperature, alkalinity and acidity influenced it. This paper has been described as a classic or benchmark paper in the history of biochemistry[178], being the first reported investigation of the action of an enzyme by really quantitative means. It should be noted, however, that one of the major conclusions of the paper is in fact erroneous. Thus, it was concluded that the action of invertase on cane sugar showed the same kinetics as simple inorganic reactions i.e. that they were both what we would now call first order reactions; that the rate of reaction depended on the concentration of sugar present[83].

The authors concluded this from the observed similarity between the time curve they obtained experimentally for the progress of inversion and that obtained theoretically by applying A. Vernon Harcourt's work on inorganic reactions[134]. In fact, the fit is far from perfect, as the authors noted at the time, but they discounted the differences as being experimental error. Their conclusion was accepted for over ten years until Victor Henri, in a series of papers published in 1901 and 1902 showed, in part using O'Sullivan and Tompson's own data, that the velocity of inversion of sucrose by invertase was in fact nearly independent of sucrose concentration at high concentrations[141,142,143]. It did not obey Harcourt's kinetics but was, what we would now call, a zero order reaction. Henri having pointed this out, it is worth noting that brewers' chemists of the day were amongst the first to confirm the new interpretation[57,64,110].

It is likely[83] that O'Sullivan and Tompson's wrong interpretation of the data was accepted for so long because it was the answer chemists expected and wanted. It conveniently disposed of any last vestiges of a belief in the participation of a vital force in enzymic reactions and, after all, it must have appeared as only reasonable and common sense that the rate of reaction must depend upon the concentration of the reactant. In fact of course the reality is rather more subtle and it is to the immense credit of O'Sullivan and Tompson that, in their paper, they make an inspired suggestion which in time came to be recognised as central to this subtlety. Thus, from their observation that a solution of invertase will withstand a higher temperature in the presence of sugar than in its absence, they suggested the formation of what we now call enzyme-substrate and enzyme-product complexes. This in time was to lead to the true description of the mechanism of enzyme action. In O'Sullivan's work I think we can clearly see something which was a feature of work in Burton at this time—the utility of brewing related problems in supplying insight into basic science.

O'Sullivan must also have been an interesting man to be around. His son H. D. O'Sullivan, who became a general practitioner in Burton[234], produced a biographical sketch[192] of his father in the 1930s in which he writes of him as a fiery man, not averse to physical violence, with strong opinions on the Irish Question and anti-English sentiments. This picture is however disputed by Henry Edward Armstrong (1848–1937), sometime "Doyen of British Chemistry"[118] and a frequent visitor to Burton in his younger days[160], who had been taught by O'Sullivan at the Royal College of Chemistry and kept in touch with him ever since. Armstrong had this to say[29] of the son's observations, with particular reference to O'Sullivan's anti-Englishness:

> "This may have been, but only after his health curve had begun to run down steeply. Always a true Irishman, he had a pretty good time among us and as long as I knew him in health bore no malice".

Certainly in his later years O'Sullivan had health and domestic problems, most probably compounded by drinking, and this may have influenced his behaviour and/or the son's perception of his father.


FIG 5. Cornelius O'Sullivan.

Whatever the truth of the matter, O'Sullivan was a successful man, rising to head brewer of Bass with his own personal laboratory and a reported[206], almost unbelievably high salary of £5,000/annum by the turn of the century. He saw many changes in his 40 years at Bass. When he joined in the 1860s, brewing was still a seasonal trade and was only carried out in Burton between October and late April[61]. This allowed him plenty of time to pursue his chemical interests. But, as the trade changed with the introduction of "running" beers instead of the old "stock" beers, and all the year round brewing became possible because of better microbiological understanding and the introduction of attemperators and refrigeration plant, so O'Sullivan seems to have changed with it. He became intimately involved in the operation of the brewery until he was in overall charge of production[19]. That he did this successfully must have contributed in no small measure to Bass, in contrast to their great rivals Allsopps, surviving so well the economic difficulties which hit the Burton breweries from the mid 1880s[138]. This is not to claim that other factors such as the relative strengths of commercial management and direction, and the extent of indebtedness incurred in the scramble for pubs (in both of which Allsopps suffered) were not the prime factors in survival[127]; but the relative strengths of production management should also not be ignored. Allsopps also had a star chemist at the time in Peter Griess (1829–1888). But Griess was loath to leave his laboratory and although by the 1880s he operated an analytical service in the brewery[39] his real interests remained in synthetic organic chemistry[246]. Indeed he seemed to resent rather than, as was the case with O'Sullivan, exploit the intrusions of all the year brewing when it came. Thus Griess wrote[92] to a friend in Germany:

> "What would you say if you were in my place? To live in a foreign country in little sympathy with its aims and aspirations, always preoccupied with beer in a town which has little to offer. You must remember that I have almost to steal time, for my research work and have no assistant".

Griess was to get an assistant in the 1880s, George Henry Unwin Harrow (1857–1926) who became his successor at Allsopps[48]. Harrow in turn contributed virtually nothing to the development of brewing science and confined himself in the main to routine analysis[7].

In contrast O'Sullivan with his heavy production responsibilities managed, with the help of assistants such as Arthur Landauer Stern (1867–1956), who was eventually to succeed him as Head Brewer[231], to maintain and apply his research work to providing understanding of the brewing process. By this I do not mean that Bass were more innovative than Allsopps—probably the contrary is true with the latter compounding their inept management by launching into poorly

FIG 6. James O'Sullivan.

market researched ventures into lager brewing[129]. Rather that, with O'Sullivan in charge at Bass, the knowledge gained in the laboratory was incorporated into the practice of brewing in small, unspectacular ways. In 1900 Bass produced about 1.5 million barrels[128] whilst Allsopps had slipped from near parity with Bass at almost 1 million barrels in the late 1870s and early 1880s to around half a million barrels in the 1890s[138]. Not that Bass were immune to the recession which came after 1900. Like most other Burton and London brewers—and many country brewers—they lost volume and suffered declining profitability in the first decade of the century. But even in relative decline they were sound compared to some other breweries who failed to pay a dividend and either merged to try and minimise their over-capitalisation and unit costs, or in extreme cases went into receivership.

But to return to the start of this golden age rather than its end; Cornelius O'Sullivan may have been the most successful chemist to grace the scene, but he was far from alone on the stage in Burton. Peter Griess has already been mentioned and the careers of two other Burton chemists Horace Tabberer Brown (1848–1925) at Worthingtons—who we will meet later in his Dublin period—and his half-brother Adrian John Brown (1852–1919) at Salts, have been well documented in this Journal[6,28,30,61]. These three, together with Cornelius O'Sullivan, all became Fellows of the Royal Society and were the undoubted stars of the period. But they were not alone. Other, perhaps less honoured but nonetheless significant characters in the development of brewing chemistry, were also at work in the town. Amongst these were two Irishmen.

One was James O'Sullivan (1856–1938, Fig. 6) a younger brother of Cornelius who arrived in Burton in 1874 to be trained by his brother, before proceeding in the same year to study under Edward Frankland (1825–1899) at the Royal College of Chemistry. After two years James O'Sullivan returned to Burton and was appointed assistant to his brother in the Bass Laboratory. He became Head Chemist on his brother's death in 1907 and held this position until his retirement in 1922[27,229]. In addition to assisting Cornelius in his work, James published some 20 papers under his own name in his 46 years with Bass[214]. These papers ranged from an analytical study on barley germination in his first paper published in 1890[196] to an investigation of the fermentation of adjunct worts in his last published in 1921[194]. Like his brother, James also studied invertase, but in this case using intact yeast and, in a paper written in 1892[193], reached the same erroneous conclusion that enzymic inversion of sucrose followed 1st order kinetics. He was also like his brother an ardent "home ruler".

As we have already noted Cornelius O'Sullivan had a private laboratory attached to Bass's by the late 1880s and it would appear that there may have been some rivalry between this establishment and the "official" Bass laboratory in which James O'Sullivan worked. Thus, in the recorded discussion of a paper on maltose given by James O'Sullivan to the Nottingham Section of the Society of Chemical Industry in January 1897[195], we find A. L. Stern, Cornelius O'Sullivan's assistant remarking that, in calculating the purity of his maltose, James had:

> "adopted a method which was bound to give apparently good results whether his original specimen of maltose was pure or not."

Stern further expresses his "surprise" that James:

> "still found such low numbers for the cupric reducing power of dextrose as Mr C. O'Sullivan, FRS and himself had recently published a paper in the Journal of the Chemical

FIG 7. John Heron surrounded by his pupils.

Society describing a large number of experiments, which had led them to the conclusion that the old value was materially low, and which was confirmed by other workers."

Hardly the kind of remark one hopes to have directed at you by a colleague after a public lecture. It is possible that Stern was giving voice to the animosity which existed between the O'Sullivan brothers. Diaries of James would certainly suggest that the two men had their arguments[111].

The other Irish chemist to come to Burton in the 1870s was John Heron (1850 1913, Fig. 7). Heron, like the O'Sullivans, was a native of Bandon, County Cork[242]. He graduated with a degree in engineering from Queen's College Cork in 1871, but then developed an interest in chemistry and came to England to study under Frankland alongside James O'Sullivan. He completed two years with Frankland, before joining Horace Brown as assistant chemist at Worthington's early in 1877. Heron spent six years with Brown working mainly on starch before going as chemist to the Anglo-Bavarian Brewery in Shepton Mallet, Somerset. In 1885 he moved to Battersea as chemist to the invert sugar factory of Messrs Garton Hill who also owned the brewery in Shepton Mallet. He stayed in this job until 1895 when, at the age of 45, he set up in London as a brewers' analyst and consultant. He created a prosperous practice[182] which continued until his death in 1913 and which was, in turn, continued by a son (one of John's eleven children) and a grandson. A contributory factor in John Heron's comparatively early death at the age of 63 may well have been his involvement in a disastrous business venture. This comprised, according to his grandson Dick[150], what amounted to exporting home brew kits to India—a venture from which his partner embezzled all the money and left Heron broke in pocket and broken in spirit.

In happier times, however, Heron was a leading light in both the Institute of Brewing and the Society of Chemical Industry. He was primarily an analyst publishing widely on analytical techniques for malt and wort[149], hops[146], beer and caramels[144], etc. His most lasting memorial is the method he devised for determination of the extract of malt. To this day, the method used for this determination in British and Irish breweries is, in all important respects, that first described by Heron in 1888[148] and published in the Journal of the Institute of Brewing in 1895[145]. The method involves mashing 50 g of malt under carefully standardised conditions, making the mash up to 515 ml, filtering and measuring the specific gravity of the filtrate. In order to facilitate this procedure brewers' chemists use specially produced flasks calibrated to 515 ml. This particular volume comes from Heron's experimental determination that the spent grain or residue from the mashing of 50 g of malt occupied 15 ml and that therefore, after making up to 515 ml, each 100 ml of filtrate would contain the extract from 10 g of malt. However, his determination of the volume of spent grain was in fact wrong, it was too high—as was pointed out by a number of other analysts at the time[42,53,123,233]. Heron, however, never accepted this and vehemently defended his figure—specifically in a paper published in 1902[147]. However, there is no doubt that, on average, the actual figure for spent grains should be around 9 ml[44]. Why then do brewers' chemists still use this inappropriately calibrated glassware? The most probable answer is that everyone having bought a set of flasks, they were loath to replace them even though the absolute answer obtained by using them was in error. In fact it was not until 1948 that an equation was formulated which would allow the "correct" figure to be obtained[43,152] using the 515 ml flasks.

So far in considering this golden age we have not looked outside Burton and in fact one of the most perplexing questions

FIG 8. Thomas Bennett Case.

about the late Victorian period is what was the scale of penetration of chemists into the brewing industry at other places? The evidence is conflicting. Edward Frankland when Professor of Chemistry at the Royal College of Chemistry, told the Royal Commission on Scientific Instruction[218] in 1871 that:

> "brewers especially keep almost a constant stream of students passing through the College. They employ a considerable number of chemists in their breweries, some of them have two in the same brewery and they pay them large salaries."

However, as Sigsworth points out[227] the actual evidence produced by Frankland to the Commission showed that from a sample of 366 of a total of 1008 students trained at the college since its foundation in 1845 only twenty were pursuing careers in the brewing industry and of these eleven were known to be connected with three of the Burton breweries. Frankland may therefore have somewhat exaggerated his "constant stream". His remarks should also be taken in context for they were part of his argument in demonstrating the usefulness of the college and the need for more space to be provided for students[80].

Even ten years later in 1882 Charles Graham (1835–1909), Professor of Chemical Technology at University College, was able to tell[219] the Royal Commission on Technical Instruction:

> "Out of 30,000 licensed common brewers (in England and Wales), I think there are only a few where there are . . . chemical laboratories. I know Dr Philip (sic) Griess is at Allsopps and Mr O'Sullivan at Bass's and there is a laboratory at Worthingtons, but scarcely a laboratory anywhere else in England except at Burton."

Here again, however, we should take his words in context for Graham was in the middle of an argument with the Professor of Chemistry at the college at the time over the role of pure chemistry in relation to industry[81]. He may thus again have adapted the facts to suit his own purposes in a plea for the direct teaching of technology rather than science as a way of influencing industry. Graham should, however, have had a fair idea of the true position for he had a large consulting practice which specialised in the fermentation industries[88]. Nonetheless, more objective recently assembled evidence[113] would suggest that the brewing industry in fact did rather well in comparison with other industries in recruiting chemists. An analysis of the distribution of a sample of industrially employed chemistry students across different sectors for the years 1880 and 1900 shows brewing and distilling to be second only to the textile industry and ahead of the mainstream chemical industry in this respect. This still, however, only amounted to 7% of the total number of students in the sample and would have given a very thin spread across the many breweries in existence at the time. Certainly, Alfred Barnard in his tour of the breweries of Great Britain and Ireland—the description of which was published in 1889-90[39]—mentions few laboratories except at the Burton breweries. It may well be then that, at least up until the early 1880s, brewers' chemists were rare outside Burton.

Even in Burton it was not always plain sailing. Horace Brown claimed in his reminiscences[62] that, when he arrived in Burton in the 1860s, the laboratory he introduced was hidden away so as not to offend potential customers. Similarly, the 2nd Earl of Iveagh noted[158] that the first Guinness laboratory was established far from the brewery to avoid public suspicions of "chemical beer". Such reactions, if common, could well have hindered widespread introduction of laboratories. It should be remembered, however, that both Brown and Lord Iveagh were writing 50 years after the events they describe and distance fogs and romanticises recollection.

FIG 9. Guinness Chemist's Laboratory, undated (c. 1910?).

In 1886 of course the Laboratory Club, the forerunner of the Institute of Brewing was set up in London, to be followed by the three provincial Institutes in the early 1890s, federation in 1895 and merger in 1904[206]. This would suggest a spread of chemists around the country, however, the balance between practical and "scientific" men in the early Institute is not clear and a detailed survey of brewery records is really required to obtain a full assessment of the penetration of chemists into the industry. Most breweries probably relied upon the services of consulting chemists, of whom there was no shortage. These men were themselves prominent in the Institute of Brewing. They dominated the pages of the Journal in the early years and were responsible for much of the work in developing analytical chemistry in brewing during this period. From the disputes there were over the possibility of setting up a "central laboratory" under the auspices of the Institute in the 1890s, it is clear that the consultants jealously guarded their vested interests and would attempt to oppose any proliferation of laboratories. Certainly the laboratory at William Younger's was not founded until 1889[165] and Watney's Stag brewery had no laboratory until 1903[89].

Even Guinness, who obtained their first microscope in 1881[158] and were producing over 1.5 million bulk barrels a year by the end of the century[133], did not appoint a qualified chemist until the 1890s. But when they started, following the influence of Christopher Diggles La Touche the then Managing Director[55], they went for the most highly qualified people they could find. Thus, the first chemistry graduate they employed in Dublin in 1893 held a first class honours degree in chemistry from Oxford. His name was Thomas Bennett Case[66] (1871 1941, Fig. 8). Case was the son of the president of Corpus Christi College, a Winchester and Magdalen man[183] and a cricket blue[130].

He was followed in 1895 by another graduate with first class honours in chemistry from Oxford—Alan McMullen (1872 1940) of Rugby and Balliol[121]. The appointment of other chemistry graduates followed regularly. Arthur Jackson in 1897, William Sealy Gosset and E. G. Peake in 1899, Geoffrey Phillpotts in 1900. All from Oxbridge, all Englishmen and all originally employed as brewers or apprentice brewers[67]. These men lived together at the Guinness house for unmarried brewers at St James's Gate and ate and took their recreation together[55]. It must have been rather like a continuation of their college life.

A rather different appointment was that of Alexander Forbes Watson (1872 1909) as chemist in 1896[175]. Watson, after studying at Heriot-Watt College in Edinburgh, had become a lecturer in fermentation following a period in Alfred Jorgenson's laboratory in Copenhagen[174]. He arrived in Dublin at a time when Case was away and took over Case's duties, where he apparently had considerably more impact than Case had managed[69]. On Case's return there was some difficulty in defining the duties of the "scientific brewers" and the "chemists", the problem being resolved with Case's appointment as brewer in charge of the "Brewers' Laboratory" a separate entity from the "Chemist's Laboratory"[69] (Fig. 9). An original member of the Chemist's Laboratory was James Wilson Tullo (1872 1954) who joined in 1899 and was

FIG 10. Horace Tabberer Brown.

appointed Chief Chemist in 1937. He retired on 31st December 1948 aged 76. Another early member was John Andrews (1884–1961) who joined the laboratory in 1900 and became Chief Chemist on Tullo's retirement. Andrews retired four years later at the age of 69. Note that at Guinness the apostrophe in Chemist's Laboratory comes before the s, as no matter how many assistants he may have it is considered that here is only one chemist, the Chief Chemist[205].

A particularly significant development at Guinness occurred in 1901 with the establishment of the Research Laboratory with Horace Brown (1848–1925, Fig. 10) as its Director. Brown, who had risen to the position of joint Managing Director at Worthingtons had left that company in 1894 after a dispute with a fellow director[31] and had been carrying out research in a private capacity in London at various laboratories[176]. He brought with him to Guinness a chemist, J. H. Miller, and a botanist, F. Escombe. These three constituted the Research Laboratory staff with Case and McMullen as Administrators. Brown was to remain with Guinness until 1906, during which time the efforts of the Research Laboratory were concentrated on what was known as the "Nitrogen Question". The aim of this investigation was to gain a fundamental understanding of the composition and function of the nitrogenous materials in malt, wort and beer. The ultimate objective of the work was the definition of those components of beer which encouraged the growth of beer spoilage organisms. Armed with this knowledge, it was believed that adjustments could be made to brewery materials or brewing practice such as to make the beer less hospitable to these organisms and hence more stable[60,176].

The results of the work were published as 350 pages of Transactions, privately printed by Guinness, and the gist of the material was presented by Brown in a 63-page paper in the Journal of the Institute of Brewing in 1907[60]. Much effort had gone into method development in the work and there had been a clear demonstration of the gross properties of soluble and insoluble nitrogenous materials in wort and beer, and even the identification of the amino acids leucine, tryptophan, tyrosine and aspartic acid in malt. We can now appreciate that Brown's objective of an infection-resistant beer was misguided but, because he was such a good scientist, his methodical approach still paid dividends. However, as Brown himself stated in his introduction to the 1906 volume of Transactions, in reference to the detailed composition of nitrogenous materials[59]:

> "a vast amount of patient and continuous work is required before we can get a clear insight into these questions."

But this was not to be, for it was at this stage that Guinness called a halt to Brown's work. His research was discontinued and he left the company. The attempt to transplant the Burton spirit in Dublin had failed. The swansong of the golden age had ended.

## THE BARREN PERIOD

According to Horace Brown[63] his departure from Guinness was "partly through the mistaken idea that it [the work] had reached finality." "Partly" indeed, for there were other reasons. A somewhat frosty exchange[249] between Brown and Alexander Forbes Watson following a 1909 paper by Brown on the Nitrogen Question at which Watson asked "what experimental evidence Dr Brown possessed that assimilable nitrogen left in the beer was really a matter of practical importance", suggests that there was some dissent within Guinness over Brown's theories. It is also the case that Guinness retreated into secrecy at this time and would not have welcomed an obligation to

continue publishing Brown's researches. Thus, when in 1908 William Sealy Gosset (1876–1937), whilst in charge of the Experimental Brewery at Guinness, came to write a paper on significance testing, "The Probable Error of a Mean", he had to publish it under the pseudonym Student[236]—hence Student's t test—because of the Guinness Board's aversion to publicity. It has even been suggested[204] that a textbook Gosset wrote on experimental sampling was not published because "the rather secretive Board of Directors of Guinness did not allow such publication." Certainly the scientific work which continued at Guinness after Brown's departure was kept under wraps. This is referred to by H. E. Armstrong, who in 1921[32], when berating the breweries over the decline of the scientific spirit within the brewing industry since the great Burton days, wrote:

> "The worst case is that of a leading firm which is known to have a highly organised scientific department—but this is closed to the world. How greatly this might have contributed to knowledge is obvious from the publications which were issued while the Laboratory was under the direction of Horace Brown."

An obvious reference to Guinness. Thus, I would contend that the reasons for Horace Brown's departure from Guinness in 1906 were really quite complex, involving scientific differences, personalities and changed company policy.

Not that the Guinness Research Laboratory in fact disappeared with Brown. Charles Joseph Newbold (1881–1946), another of Guinness's early chemists, this time a Cambridge man and an England international rugby forward who joined to the company in 1904 and became Managing Director in 1941[230], had this to say in a reminiscence[183]:

> "After the initial work had been completed the Guinness Research Laboratory was removed to other quarters. The character of the work changed somewhat to meet the special requirements of the Guinness products and their manufacture."

What was this work? Well it is very difficult to tell, as the Guinness ban on the publication of papers by its staff under their own name was not lifted until just before the second world war[104]. We can however obtain some idea of the general research interests at Guinness from more general reports which appeared before and after the ban. The young Oxford and Cambridge graduates taken on at the turn of the century spent two years as a junior under the instruction of a senior brewer and were then put in charge of a section of the brewery and research work[55]. Case and McMullen were involved in barley and hops and the study of these materials seems to have been one of the major interests at Guinness over a long period[65]. Initially concerned with methods of analysis the two men moved on to consider sources of supply, the relative merits of different varieties and the effect of conditions of drying and storing on the malting value of barley and the brewing value of hops. In this they were assisted by an experimental maltings first used in 1902 and 12-barrel experimental brewery which put through its first brew in 1903[68]. With hops the main preoccupation was in their preservative properties, which seem to have been regarded as even more important then bittering power. A long series of trials were carried out in the experimental brewery from 1907[72], comparing on the one hand American and English hops and on the other Fuggles and Goldings, after both cooled and uncooled storage. Guinness showed particular interest in varieties and cultivation of hops and enjoyed a long relationship with Wye Agricultural College most notably at this time with Ernest Stanley Salmon (1870–1959) famous for his work on hop diseases and hop breeding[5]. The company were to go on to become one of the largest hop growers in England[56].

Another famous name to become associated with Guinness at this time was Edwin Sloper Beavan (1857–1941) the breeder of Plumage-Archer barley[163]. In 1904, when Guinness became interested in barley breeding, Beavan, who was a maltster in Warminster, became a commission maltster for the company and in 1919 was made Guinness's buyer of all imported barley. Guinness also collaborated with the Irish Department of Agriculture in studies on the improvement in quality and yield of malting barley. Herbert Hunter (1882–1959) was appointed by the ministry to take charge of these experiments[151] and Guinness brewers including Case, McMullen and Jackson toured the experimental plots on numerous occasions[56]. Barley grown in these plots was followed through malting and brewing to the final beer using the experimental facilities at Guinness to give a comprehensive set of data[172]. It was Hunter who created Spratt-Archer barley by a cross made in 1908. In the 1920s and 30s, 90% of the barley grown in Ireland was Spratt-Archer as was most of that grown in England[139]. W. S. Gosset was involved in all of this hop and barley work, either directly through his work as Experimental Brewer, or through statistical design and analysis of the results of the agronomical work. It was in coming to terms with problems that arose in brewing work that he developed much of his statistical research. In all "Student" published 22 papers[54], the first of which was entitled "On the error of counting with a Haemocytometer" and appeared in 1907[235] and his last "Comparison between balanced and random arrangements of field plots" in 1938[237]. He had no statistical assistant until 1922 and whilst later a statistical department was set up, much of the calculation was still done by him—much of it apparently on the "backs of envelopes"[173]. In 1935 he went as Head Brewer to the new Guinness brewery at Park Royal but died at the age of 61 in 1937[171].

It would appear that much of the scientific work carried out by Guinness at this time was rather slow in finding direct practical application in the brewery. The work on hops is a good example of this. In line with observations made elsewhere that hop resins were responsible for both the bittering and preservative properties of hops, analysis of soft resins was carried out by Guinness from the end of 1897 onwards[71]. By 1909 Gosset was able to state that "soft-resin was closely correlated with the life of the resulting beer and promises to be of very considerable use." But it was not until 1925 that the company started to buy hops on the basis of soft resin content[73]. Similarly, despite extensive Experimental Brewery work it was not until 1923 that any hop variety trials reached the main brewery. This resistance to change has been attributed to the influence of T. B. Case himself[70]. Case had risen through the company becoming an Assistant Managing Director in 1919 and Managing Director in 1927. But Case was very much the conservative when it came to matters technical. He also had the ear of Edward Guinness the first Earl of Iveagh, which effectively put the block on innovation at Guinness. This was apparently much to the disappointment of Alan McMullen who had also risen in the company but not so far as Case. In 1909 McMullen was put in charge of the Chemist's Laboratory and became Second Brewer in 1923. According to J. F. Brown in his book Guinness and Hops published in 1980[65]:

> "McMullen was technologically far more able and progressive than Case, but was frustrated in much by his senior colleague until he became Head Brewer in 1931 and was at last in a stronger position to put into practice some of the things he would like to have done for at least 20 years."

Nonetheless if Guinness were conservative in their attitude to change it would seem that they held maintenance of quality in proper respect. Stella Cunliffe, a statistician at Guinness from 1947 to 1970 noted[105] about the company when she first joined that they:

> "never stopped experimenting to try to produce the product as a constant one, from varying raw materials, varying because of weather, soil, varieties of hops and barley, as economically as possible."

This does not tell us much about what actually went on but does tell us quite a lot about the ethos of the company. Miss

FIG 11. Guinness Brewers 1923.
Left to Right: FRONT ROW: E. G. Peake, A. McMullen, E. L. Phillips, A. H. C. Barker, A. Jackson. MIDDLE ROW: G. Buttanshaw. M. S. Heycock, J. W. F. Crawford, G. S. Phillpotts, H. Peel, W. S. Gosset, C. J. Newbold. BACK ROW: C. K. Mill, R. S. Wix, G. F. E. Storey, Hn. Paul L. R. Shildrick. Those mentioned in the text are underlined.

Cunliffe also gives us a picture of the awe the brewers were held in when she recalls how, on arrival at St James Gate as a newly-hired statistician, she was told that if she were lucky enough to meet a brewer in the corridor, on no account was she to recognise him, but should lower her eyes until he had passed. With such treatment it is hardly surprising that a certain arrogance showed itself in the attitude of the company[105]. Not that they hadn't much to be arrogant about. It must undoubtedly be the case that their team of chemists turned brewers (Fig. 11) would have outclassed their contemporaries elsewhere. They also assembled a large team of practising chemists; a photograph taken in 1935 (Fig. 12) shows sixteen at a time when even the largest breweries elsewhere in the British Isles would be unlikely to approach half that number. If we have only an imperfect idea of what the "chemist brewers" got up to then the activities of the practising chemists in the Guinness laboratories are even harder to get at. The techniques developed by Horace Brown during his time there were utilised and comprehensive quality control schemes introduced, but what of research activity actually in the laboratory? J. H. Miller, Brown's assistant, stayed on after Brown left and we have it on the authority of C. J. Newbold that research continued[183], but we don't know what it involved. Only occasionally has the curtain been lifted. As, for example, when R. B. Gilliland presented a paper on "The flocculation characteristics of brewing yeast during fermentation" at the 1951 EBC Congress at Brighton[126]—a paper which was to lead to the adoption of the "Gilliland types I–IV flocculation types". In fact, as Gilliland reveals in his paper, the classification had been devised *some thirty* years previously by J. W. Tullo at Guinness but had remained unpublished.

But if Guinness were secretive about their researches (in which trait they were probably joined by Heineken[20]) and conservative in their application, they were ahead of the other brewers. The rest of the industry in the British Isles would seem to have adopted a very narrow approach in the period between Brown's departure from Guinness in 1906 until after the Second World War. Gone were the days when brewing would make a contribution to main-stream science as in the work of Cornelius O'Sullivan. Instead, as Professor I. A. Preece (1907–1964) of Heriot-Watt noted in an essay written in 1963[211]:

> ". . . the bulk of brewing scientific work over a period of 40–50 years up to 1950 . . . devoted itself to the study of ad hoc problems, to the study in fact of the gross behaviour of the materials; so that—with innumerable variables involved—the results, though interesting and often of the greatest value in a particular set of circumstances, lacked ultimate definition."

In other words the work had no fundamental or lasting value. By this time many breweries had basic QC laboratories of some sort but few went further than routine analyses and were not very well equipped[212]. Immediately practicable technology, rather than the pursuit of understanding through science, was the prime interest of even the more progressive British breweries in the 20s and 30s. This is exemplified in the original published papers of a Dublin born man who was Chief Chemist at Truman Hanbury and Buxton in London between the wars. This was Arthur James Curtin Cosbie (1884–1951) who studied at Trinity College Dublin and Birmingham University, before joining Trumans in 1924 and going on to link up with Harold Heron, John Heron's son, in consulting

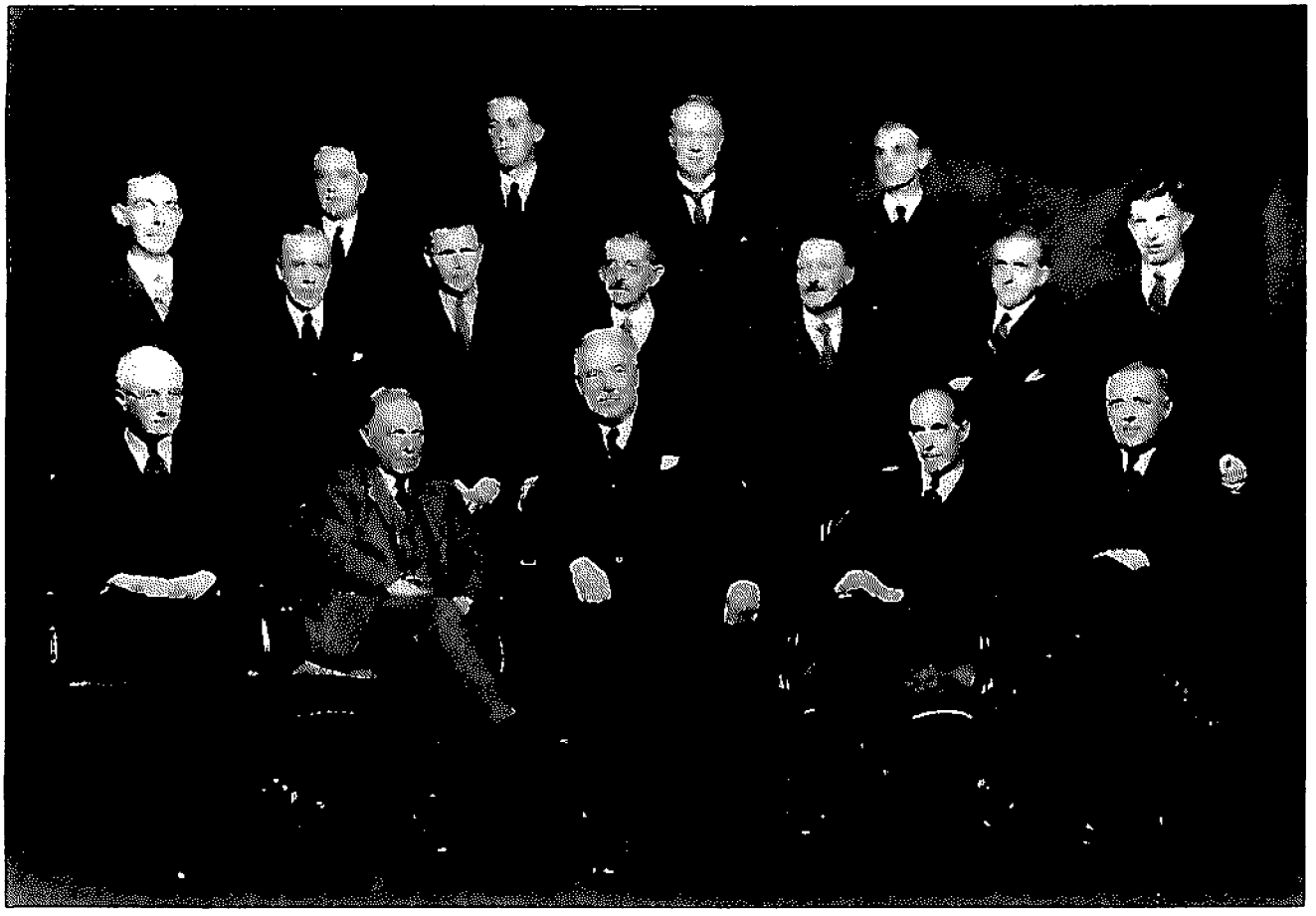

FIG 12. Guinness Staff of Chemist's Laboratory 1935.
Left to Right: FRONT ROW: R. Marshall, J. W. Tullo, J. H. Millar, R. Coleman, J. Andrews. MIDDLE ROW: (FIVE) W. White, J. I. Webb, W. Reilly, H. Tapley, W. J. Stringer. BACK ROW: W. Brunty, D. McCluskey, J. M. O'Donnell, J. McDonnell, T. Wright, W. Toner. Those mentioned in the text are underlined.

practice in 1941[11,143]. Cosbie was a significant figure at the time, at the forefront of brewing science, lecturer in brewing technology at Sir John Cass College, council member and examiner for the Institute of Brewing. He was chosen to give the Royal Society of Arts Cantor Lectures on Brewing[101] in 1942—the first time brewing had formed the subject for this event for nearly 30 years—and contributed erudite general articles to the Journal of the Institute of Brewing on matters of current scientific interest in the 20s and 30s[96,98]. Cosbie did some basic work in microbiology in conjunction with T. K. Walker in the 1940s after leaving Trumans[102,103] but his original communications whilst at the brewery were of a more severely practical kind, with such titles as "Bottling technique and plant"[100], "The effect of temperature of drying on the value of hops"[97] and "Sterilising filters"[99]. No doubt these papers met with interest at the time and in Preece's words "were of value in particular set of circumstances", but they have very little of a research element in them. They are very much descriptions of technology rather than contributions to science.

There were, however, one or two exceptions to this prosaic approach and here I would make special mention of John Lester Shimwell (1901–1964) Head Brewer at the Beamish and Crawford brewery in Cork between 1932 and 1939. Shimwell had joined Mitchell and Butler's brewery in 1919[12,87]. From there he was sent to Birmingham University where he obtained his degree in biochemistry, returning to Mitchell and Butlers until 1927. Then he moved to the Crown Brewery in Barry and went in 1931 to Beamish and Crawford, becoming Head Brewer in 1932. For 30 years onwards, he published a whole series of papers[220,221,222,223,224,225] which put brewing bacteriology on a firm basis and, as Cyril Rainbow wrote[213] in his obituary of Shimwell, "established order out of chaos." Shimwell was awarded a DSc by Birmingham in 1937. In 1939 he left Ireland and joined Whitbreads (who had started a yeast research laboratory in 1937)[240] as a research chemist. In 1943 he left Whitbreads and worked from home as a consultant before joining British Vinegars in 1950 to take charge of their Research Department. He was a prolific writer of technical articles with a distinctive lucid style. He was also very much his own man, often the centre of acrimonious scientific exchanges; he did not suffer fools gladly[86]. In 1950 he was offered a post as head of a department at the new Brewing Industry Research Foundation but turned it down because of a disagreement over the conditions under which he would be working[12]. His talents may have been more on the interpretative than the practical side, much of the practical work whilst at Beamish and Crawford being carried out by his assistants[122]. Nonetheless it is doubtful if the contributions of this essentially introspective man were fully realised at his sad death in 1964[86].

But Shimwell, as has been noted, was an exception with very little work contemporaneous to his studies in Ireland going on anywhere else in the British Isles. There was an Institute of Brewing Research Scheme from 1920 onwards, it having been recognised that the record of research activities at the time in brewing was, as an editorial in this Journal noted[33], "not one with which a great and important industry can be satisfied." But this only amounted to a few initially scattered workers around the country, so that even in 1934 the editor could again note[34]:

"We are only on the threshold of exact knowledge concerning the many processes involved in brewing, the advance is

painfully slow owing to the few workers who are doing anything in this country on brewing research, and it will be many decades before operations in the brewhouse will be carried out, or comparable with, the exactitude of those of some other industries."

These sentiments must have had a bearing on the decision to centralise the effort at Birmingham University in that same year. This went some way towards achieving critical mass in bringing together a number of scientists[207]. The first amongst equals of this group of quality research workers was Laurence Robert Bishop (1903–1988). A proper appreciation of Bishop's work which spanned all aspects of brewing is not possible within the context of this paper and requires separate treatment[22]. Suffice it to say that Bishop has a strong claim to being regarded as the premier brewing scientist of this century—regardless of nationality. But without adequate funding[207] only so much could be achieved even by a man of Bishop's abilities. Had it not been for the war, improved resources may have come sooner but in all events it was not until the late 1940s that we begin to leave the tunnel of the barren period.

## The Second Golden Age

As the war drew to a close there was a new spirit in the air, people wanted change and to throw off the perceived failures and disappointments of the 20s and 30s. A belief in the utility of science in bringing about improvement was widespread. The mood of the times is demonstrated by Julian Levett Baker (1873–1958) in his Horace Brown Medal lecture "British Brewing in Retrospect and Prospect", published in this Journal in 1948[35]. Baker, editor of the Journal from 1920–1949 and hence responsible for the critical editorials already cited, had been Chemist at Watney Combe Reid & Co. since the turn of the century and was well placed to review the scene[89]. Despite putting a brave face on things he was unable to point to much in the way of scientific or technical progress in British brewing during his time in the industry. The work of Beaven and Hunter in producing the barley varieties Plumage-Archer and Spratt-Archer drew appreciative mention, as did the work of Professor Salmon on hops and the work of the Institute Research Scheme. But, Baker was unable to cite anything of significance emanating directly from breweries. He even admitted that his own researches on starch were slight and "assist to only a limited extent in the fundamental problem of the make up of the starch molecule"[36]. He goes so far as to imply criticism of the Institute Research Scheme when he talks of the "modest sum at its disposal"[37]. Baker, with his great experience of the industry, clearly saw the way forward as investment in long term research. In referring to the research scheme launched by the Brewers' Society on 1st October 1947 he says[37]:

> "With so many of what may be regarded as minor problems connected with brewing which in the opinion of some require immediate investigation, there is a possibility that efforts to solve them may claim more time and attention than ought to be allowed compared with what should be regarded as the main work of the Research Scheme."

He goes on to say[38]:

> "Doubtless able directorship of our Research Scheme will establish an appropriate balance between the two policies of 'long-' and 'short-' term research."

From this we may deduce that discussions were going on as to the form research into brewing should take. Direct support for the long term view comes from another leading brewing scientist of the time Bernard Meredith Brown (1889–1976) head chemist at Whitbreads[45] who, within two months of Baker's lecture, gave a paper entitled "Research and the Brewer" in which he noted that in the activities of an industrial research organisation[58]:

> "Some liberty I think should be allowed to the workers to carry out fundamental researches upon the materials and organisms appertaining to our industry even if no application can be foreseen, partly because our knowledge should exceed our immediate needs, partly because we might well be proud as an industrial body of scientific knowledge, as indeed workers in the industry have done in the past."

That the "fundamentalists" won is evident from the eventual appointment of Sir Ian Heilbron (1886–1959) as director of the embryo Brewing Industry Research Foundation later in 1948[114]. Heilbron was at the time Professor of Organic Chemistry at Imperial College and had just been nominated as President of the Chemical Society. His aim in accepting the post as director was expressed some years later when he stated[116] that he hoped that he:

> "Would be able, not only to create an organisation useful to the Brewing Industry, but one which through its fundamental studies, would possibly take its place upon a broader stage and become the British equivalent of the Carlsberg Laboratories in Copenhagen."

Thus Sir Ian's approach was much in keeping with the aspirations of leading scientists in the industry. Research at last came to brewing in Britain on a sizeable scale and BIRF soon came up with the goods. Original research papers poured out from 1955 onwards such that by the late 50s output from the Foundation, as it soon became known, made up nearly half of the total number of papers published in the Journal of the Institute of Brewing[203].

The pace also quickened in research activities at the University of Birmingham and at Heriot-Watt College—even though these institutions continued to receive little direct funding from the industry compared with the amount spent on BIRF. The new enthusiasm spread to the breweries. On 1st July 1955 Sir Ian Heilbron officially opened the new Guinness laboratories at Park Royal Brewery[115]. There had been a laboratory at Park Royal since the brewery opened in 1936 but this was now found to be inadequate. The new laboratory suite included research laboratories. It was in these laboratories that Guinness, more than 50 years after parting company with Horace Brown, were to return to the "nitrogen question" and publish some notable work on the pattern of amino acid excretion by yeast[161]. The opening address by Rupert Edward Guinness, 2nd Earl of Iveagh, then aged 81 and newly created a Knight of the Garter who, as a youth, had bicycled around the Kent hop fields with Case and McMullen, makes interesting reading. He notes that[117]:

> ". . . there never was a time in our history when the public were more conscious of the important part being played by the scientist in industry. Until comparatively recent times brewers had seemed somewhat scared to allow other brewers to know what they were doing inside their own breweries. There was, for long enough, a general idea that the brewing of Guinness was a deep and strongly guarded secret."

He goes on to say that now:

> "Whenever we find the answer to some particular problem we should not keep the information to ourselves, . . . it should be made available to the industry and to the world."

Quite a change in philosophy; a public recantation of the doctrine of secrecy.

This second flowering of brewing research continued to spread, with major brewers such as Bass and what was to become Allied Breweries opening new research laboratories in the late 50s and early 60s. New techniques undreamt of by previous generations became available to the burgeoning number of chemists and other scientists taken on by the industry both in quality control and research. These men and women, in addition to their own efforts, brought with them the ability to appreciate and utilise academic work which impinged on the industry such as that on yeast in the Zymology Laboratory at Bath University and elsewhere[217].

The span of research work carried out prevents any attempt

at a detailed description of activities in the period within the confines of this paper. To do this period justice really requires a separate study. Such a study should encompass not only a proper appreciation of the multifarious lines of research that were followed, but also a consideration of the socio-economic context and changing market and industry structure in which the work was done. It must be admitted that the writer is ill-equipped to do full justice to such a task even if space were available. Nonetheless a few observations may be permitted. There can be little doubt that the technically and scientifically moribund state of the British brewing industry in the early post-war years made it ripe for improvement. It is also evident that the men and women who attacked the many areas that required investigation did so with a vigour that well merited the successes they achieved. Literally no area in which science could be applied to brewing was left untouched by the work carried out from the early 1950s on. The scale of activities dwarfed all that had gone before it. Fig. 13 shows the number of papers published in *EBC Congress Proceedings* and in the *Journal of the Institute of Brewing* from 1950–1990 by BRF and British/Irish breweries. This may be taken as a reasonable guide to the original research output from the industry. It is seen that, after a sharp rise in the early 1950s, the level of publication by the British industry stabilise at between 50 and 60 papers in each two year period for the years between 1954 and 1986. There are only two exceptions, one in the late 50s and the other in the early 60s. The unprecedented level of research activity this represents reflected the explosion of science generally and led to a transformation in the understanding of brewing chemistry.

Analytical methods were improved beyond recognition, the chemical structure of hop components was to a large extent unravelled and their significance appreciated, the physiology and biochemistry of barley germination and thus the pattern and nature of malt modification were pieced together (and vigorously debated), the complex biochemistry of the mash tun was delineated, yeast nutrition and growth and hence fermentation became better understood, pathways of flavour compound synthesis were extensively studied and their production at all stages of the process made were amenable to control, the microbiology of beer spoilage was clearly described, the chemistry of haze development became more clearly defined; foam, gushing, hop and barley breeding, were all grist to the mill—the list is practically endless.

The lion's share for most of the period came from the Brewing Industry Research Foundation which, following the lead given by successive directors Sir Ian Heilbron and Arthur Herbert Cook (1911–1988), adopted the basic philosophy "knowledge first" in the conviction that this would necessarily lead to benefits[23]. Research needed no justification because it was of its nature bound to lead to greater understanding and hence improvements. Attempts to define these further would necessarily be fruitless and in Cook's philosophy were basically ridiculous[23]. Whether or not one accepts the validity of Cook's analysis, its utility was demonstrated in an evaluation of the cost/benefit of 25 years of brewing research carried out in 1980. The results of the survey were published by A. D. Portno in this Journal[210]. The figures showed the considerable savings that had been made because of the findings of research scientists in that period, and in highlighting the role of the Foundation noted: "BRF's research is relevant, applicable and highly cost effective".

Whilst I have intimated the importance of the Brewing Industry Research Foundation in the prosecution of research in this period—an importance which transcended national boundaries—universities and individual brewing companies in Britain also had a considerable impact, the weight of the latter becoming increasingly felt as the decades passed. To single out individuals in these areas necessarily runs the risk of being invidious. However in addition to Laurence Bishop, who has already been mentioned, two names stand out from the many as much for their all round scholarship as for their considerable achievements in research. They are Anna Macgillivray MacLeod (1917– ) and Cyril Rainbow (1913–1980), the 1976 Horace Brown Medallists.

But nothing, no matter how apparently firmly based, remains the same for ever. Even as these awards were being made a change in mood was becoming discernible in the brewing industry's attitude to research. In the late 1970s the industry was swept up in the international enthusiasm for the "new" biotechnology and there was a questioning of the relevance of the fundamentalist approach to research in achieving the advantages that beckoned from its exploitation. As we have seen, the benefits that had accrued to the industry from its investment in research over the preceding 25 years were recognised[210], but there was a widespread belief that the time was ripe to place the emphasis on work of a more applied nature capable of direct commercial application. This was to grow into a perceived need for greater accountability and monitoring of research which mirrored the national mood in other industries and in government. The changed approach necessarily led to the requirement to show more immediate pay-off from investment and was coupled to an increasing sensitivity regarding the commercial advantage to be gained from research. With this reasoning becoming the new orthodoxy, a swing from science to technology, from an emphasis on research to an emphasis on development was inevitable.

Such a sea change soon showed its effects. The activities of the renamed Brewing Research Foundation were more tightly regulated and brought under the influence of industry research panels[49]. The old Institute laissez-faire Research Board was replaced by a leaner committee[153,155]. Education and training in the industry were reviewed and measures put in hand to "educate for practice".[154] After 88 years, support was withdrawn from the Brewing School at Birmingham[156] and activities concentrated on Heriot-Watt, with a new training initiative in the "Brewster" courses[154]. Guinness closed their Park Royal research laboratory and concentrated development activity in London with research housed in Dublin. Allied Breweries reduced staffing levels in its central technical department, including its research laboratory, went for a decentralised structure and redistributed responsibilities.

Not that the trend was necessarily one of reduction in facilities. Whitbread, with their new technical centre at Luton[166] and Guinness, with their new laboratories in Dublin[157] invested heavily. Bass, with Delta Biotechnology in particular widening horizons[232], and Allied Breweries, in extending their pilot brewing facilities[10], also spent money. Heriot-Watt benefited with the establishment of the "International Centre for Brewing and Distilling" at the Riccarton Campus[154]. But a trend towards obtaining more immediately quantifiable pay-back was evident. This change in emphasis was not immediately obvious at the beginning of the decade. Thus the BRF Annual Report published in 1980[49] states in relation to the review of the Foundation's activities over the past year:

> "A main feature of internal change has been a reduction in the effort devoted to development work, and an increase in the more fundamental work to accord with the original concept of the establishment."

By 1982, however, new priorities had been formulated with less stress on fundamental work. Thus in the Annual Report published in that year[51] we have:

> "BRF researchers have the responsibility for clearly establishing the aims of their projects, the probable level of achievement in the prescribed time and, assuming success, the possibilities for industrial implementation. The foregoing modus operandi clearly indicates a targetting approach to the researches at Lyttel Hall while not neglecting the responsibilities of the Foundation to develop the fundamentals of brewing science."

The report goes on to describe steps taken to extend development facilities by setting up biochemical engineering and

chemical engineering facilities and restructuring the existing sections. Development rather than research was now taking over. This trend continued to gather momentum during the 1980s[50,167], not just in brewing but across the spectrum of British industry, so that today what its adherents would call the new realism and what its opponents would call short-termism is the norm. For how long it will remain the norm can only be a matter of conjecture. Certainly there are signs that the fundamentalists are making a comeback. On the national stage the House of Lords Science and Technology Committee has recently berated both the Department of Trade and Industry and industrial companies for their short-termism and lack of investment in research and development[25]. The academic establishment periodically gives out dire warnings of the imminent collapse of basic research in this country[209]. Closer to home, *Ferment* carried an editorial in its April 1991 issue expressing concern at the lack of fundamental research being carried out in the brewing industry at present.

Such concern receives support from an examination of the level of research publications currently issuing from the industry. Both the absolute (Fig. 13) and relative (Fig. 14) numbers of papers published in the primary research outlets for the British industry by UK/Irish breweries and BRF is at a lower point over the period 1989/90 than at any time since 1951/52. The dramatic swing away from publication in this Journal is partly offset by an increase in publication in the EBC Proceedings. Most of the latter comes from the introduction of posters at the EBC Congress in 1981 thus expanding the available outlets for publication. Even this is, however, unable to counteract the decline. It is also questionable whether publication in a conference proceedings which receives no peer review is an adequate substitute for publication in a refereed journal. Future historians must be left to judge, but by the criterion of open publication[203], the Second Golden Age of brewing chemistry died in the 1980s. Whether it will lie down quietly is another matter.

## Discussion

There have been a number of fairly distinct periods in the history of brewing chemistry. These periods follow a cyclical pattern.

1. The Early Phase from the 1830s to the 1860s when practical chemists first found employment in the brewing industry. These men were not particularly concerned with the advancement of chemistry but were more interested in making a living by applying their chemical knowledge to immediate production necessities.

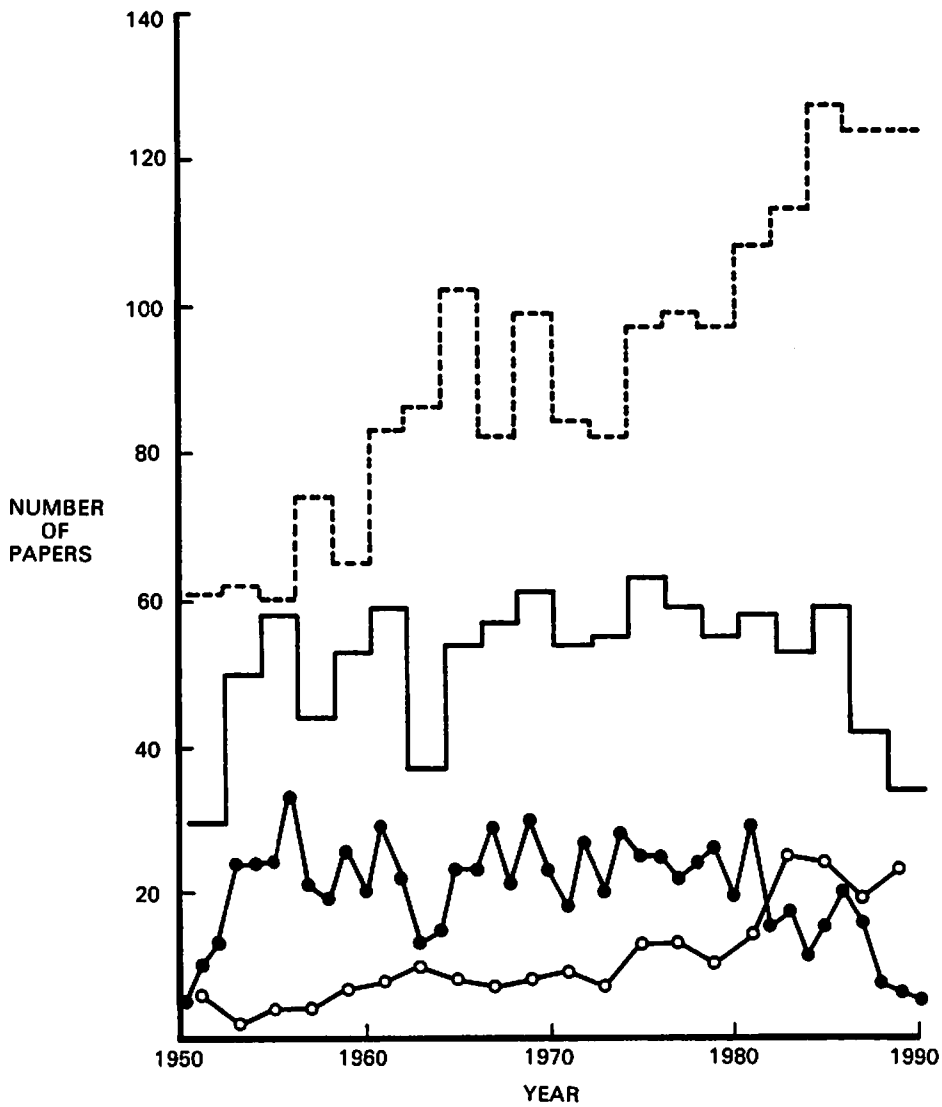


FIG 13. Number of papers published in EBC Congress Proceedings and in the Journal of the Institute of Brewing, 1950–1990. ●, total in the Journal of the Institute of Brewing from UK/Irish breweries and BRF; ○, total in EBC Proceedings from UK/Irish breweries and BRF; (——), total in both publications from UK/Irish breweries and BRF; (– – –), total in both publications from all other sources.

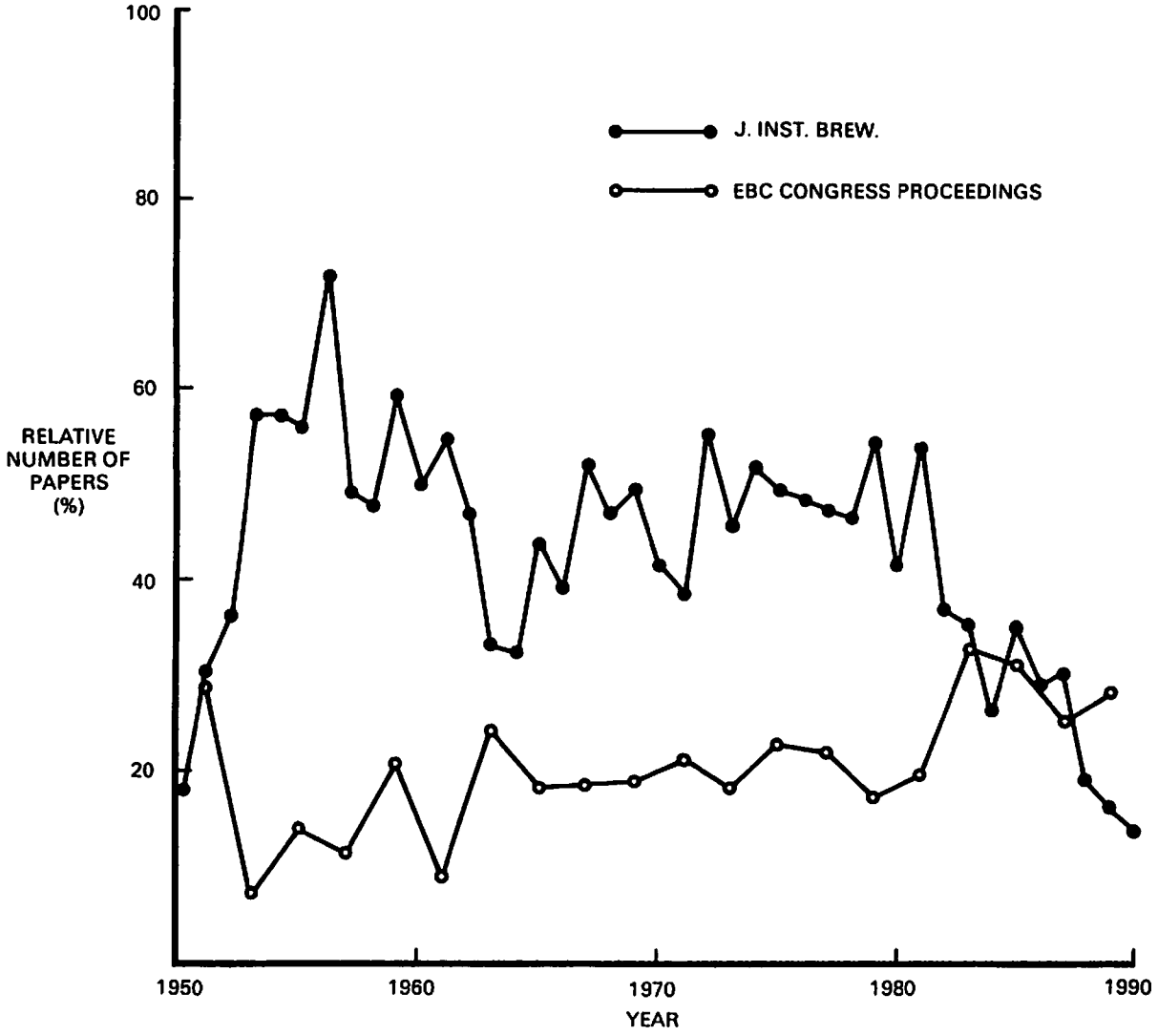


FIG 14. Number of papers published in EBC Congress Proceedings and in the Journal of the Institute of Brewing by UK/Irish breweries and BRF, 1950–1990, as a proportion of the total number of papers published in those journals.

2. The First Golden Age centred on Burton running from the 1870s to the 1890s, with Horace Brown's sojourn at Guinness as something of a swansong in the early years of this century. Here the great names from the past and their numerous acolytes put much store by the need to get at the underlying science of a problem.
3. The Barren Phase stretching from the early 20th Century to about 1950. When, apart from a few individual efforts, and with the possible exception of what went on behind the closed doors of Guinness in Dublin, little attempt was made at advancing knowledge. Many breweries ran laboratories and employed chemists, but these men resumed a role not unlike that of their mid-19th century predecessors.
4. The Second Golden Age stretching from the early 1950s into the 1970s, when again, but this time on a much larger scale (led by the Brewing Industry Research Foundation with help from the universities and follow-up in the breweries), the emphasis was on scientific understanding. In the belief that this approach would lead to improvements which may not be easily quantifiable or even predictable, but would surely be there, brewing chemistry reached its most productive phase.
5. The last decade with its closely targeted objectives and a swing towards technology and development leaving reduced scope for fundamental research or serendipity.

Why do these cycles occur? There can be no easy answer for this question touches many facets of national, industrial, political and scientific policy and attitude. Just as is the case with mainstream science, the history of brewing science is not the history of the rational accumulation of objective knowledge. Shifts of activity and areas of interest are governed far more by socio-economic factors. Thus Victorian confidence in industrial science and the rekindled enthusiasm for science amongst the "new Elizabethans" after the Second World War, must have been factors in promoting the two "golden ages". One could also argue that swings between an emphasis on science and research on the one hand and technology and development on the other are bound to occur as results from the former spur on activity in the latter. Such a general connection has been disputed[79], but a case could be made for this being a mechanism which has operated in the brewing industry. Another factor which may well be expected to influence both the type and the level of research activity is the financial health of an industry. Certainly this would appear to be true with regard to the fortunes of the brewers' chemist. Reference to Fig. 15 will demonstrate the point. Thus the First Golden Age of brewing chemistry grew up when beer sales were booming. Production in Burton where it was all happening increased 10-fold between 1850 and 1890[200]. Guinness launched its campaign of recruiting scientists just at the time it was becoming the biggest brewery in the world[133]. The Barren Period on the other hand coincided to


FIG 15. Beer production in the British Isles 1830–1990 and the pattern of brewing research. Data are plotted as annual averages on a 5-yearly basis. Sources: G. B. Wilson, Alcohol and the Nation (1940) and the Brewers' Society, UK Statistical Handbook (1990). From 1923 onwards data from what is now the Republic of Ireland are not included; production from this source in 1922 was *c.* 2.6 million standard barrels.

a large extent with a difficult period for the industry. With a gentle decrease in volume in Edwardian times giving way to the plumetting falls of the recession between the wars. The Second Golden Age follows a period of good profitability for brewers during the Second World War[253] and includes a period of 20 years sustained increase year on year in volume from 1960 to 1979. The 1980s on the other hand have seen a down-turn in production.

This correlation of economic conditions with research activity is neither unexpected nor uncommon in industry. Nonetheless it is not inevitable. In the chemical industry for example both Du Pont in the USA and ICI in the UK invested heavily in research during the depression years of the 1920s and 30s[84]. Their long term aim was to use science to find them new markets. They employed the best chemists they could find and set up teams to do fundamental research. This was to lead directly to the modern plastics industry with the synthesis of nylon by Du Pont in 1935 and of polythene by ICI in the same year[137]. Perhaps, if the brewing companies of the time had taken a similarly wide view of their business, then they may have been in a position to use discoveries close to their own fermentation interests which were to come within a few years of the synthesis of these polymers. They may have been able to exploit the new field of antibiotics[245]. Such a proposition is, however, in reality unlikely. Comparisons between the chemical industry and the brewing industry are hardly valid. Both industries ultimately depended upon entrepreneurial skills for their success, but in the chemical industry these were derived from technocrats such as Ludwig Mond[2], whilst in the brewing industry the skills were firmly based in commerce. With these roots and with very different markets, it is perhaps inevitable that power structures within the two industries evolved very differently. Both industries have necessarily relied upon institutional investment, but at crucial phases in its history the brewing industry seems to have been particularly influenced by an emphasis on short-term profits[138], which as Kennedy has pointed out[162] has been the philosophy of the city since it began to involve itself in financing British industry in the 1890s.

At the end of the Second World War, brewing companies thus had neither the culture nor depth of expertise nor the will to achieve the quantum leap necessary to exploit antibiotic production. A superficially similar situation to that of antibiotics in the 1940s arose in the late 1970s and 1980s with the advent of the "new biotechnology". This time the response was better, if still muted. Although new opportunities in biotechnology were greeted with some enthusiasm by the British brewing industry and this led to interesting work, financial backing has been lukewarm. Thus, even those companies which have been to various degrees active in the field[13,232] have undergone retrenchment or abandoned their ventures altogether[9]. This is in contrast to the Japanese brewing industry where the separate research divisions set up in the early 1980s[17]—on a scale reminiscent of the German dye industry of a previous age[179]—continue to be heavily supported[15,16].

If we conclude that the response of the British brewing industry to extending its scientific and technological base has been cautious, it is worthwhile asking what influence scientific and technological advances have had on the core business of brewing. To what extent has research influenced brewing practice?

An answer was first sought by W. J. Sykes in a paper in this journal as long ago as 1895[238] entitled "The indebtedness of the Brewer to M. Pasteur". Sykes concluded that Pasteur's researches had actually had very little effect on brewing practice. This conclusion was reiterated and extended by the economic historian Sigsworth[228] when considering the period 1850–1900, but disputed by Owen[199], at least as far as Burton-on-Trent was concerned, when assessing the impact of the scientists of the Victorian period. Perhaps Wilson, also a business historian, gets nearest to the truth in reconciling these conflicting views when, in a book published in 1990, he refers to the attitude in the brewing industry in the 25 years before 1914 as "an indifference to science in a conservative industry" but notes the readiness of brewers to accept limited technological improvements[252]. This description would suggest that even in what I have called the "golden age" of the Victorians, techno-

logy and not science was the preoccupation of most practising brewers. If Wilson's description is correct then it is not surprising that historians have been unable to find evidence of science driven innovations at this time. But this should not obscure the very real benefits gained by those few companies who employed practitioners of science. These benefits, whilst they went to the core of the business, were subtle and affected the approach to brewing rather than prompting easily demonstrable innovations. The triumph and resilience of Bass whilst under the influence of the O'Sullivan brothers was a prime example of this. The commanding position of Guinness during the "barren period" was another.

As we have demonstrated, the brewing industry in this century has remained essentially conservative when compared with some other industries. Nonetheless, recognition of this conservatism should not obscure our appreciation of the very real impact science has had on brewing since the Second World War. Forty five years ago the industry in this country was a pretty parlous state, suffering from years of under investment and neglect with worn out plant and only a patchy knowledge of the science underlying the business. All this was to change over the coming years. Sometimes the changes that came about were quite dramatic, easily visible, and, as we have seen, financially quantifiable. Examples include, improvements to malting efficiency, increased hop utilisation and the introduction of high gravity brewing. All three were technological successes, but underpinned by fundamental interdisciplinary work in plant physiology, biochemistry, chemistry and microbiology. And here we come to the heart of the matter, for it is (at least in the opinion of this writer) the "hidden" benefits of research which have in fact been the most important in brewing. By these benefits I mean the ability to run the business as smoothly and efficiently as possible, with a large element of control, despite the vagaries of changing raw materials, diversification of products and having to deal with the uncertainties of living organisms. The measure to which this has been achieved is the measure to which we must be grateful for fundamental research. Even when there has been failure, the best work has been carried out with sufficient regard to the fundamentals to give long term benefits. Thus, as John Hudson frequently reminds the Institute AME course, the development of continuous fermentation in the 1950s and 60s may ultimately have failed, but it gave new insights into fermentation which allowed improvements in batch techniques. This is the secret of good research. Even if the ultimate target is never reached, if research is carried out at the right level then the spin-offs in terms of understanding will make it worthwhile.

It follows, that while of course research can lead to real benefits, it does not necessarily do so by what might appear to be the most direct route. Indeed, history would suggest that, in brewing, the most rewarding philosophy is that which regards the benefits of research as coming, not from seeking drastic change, but from having understanding through science permeate the culture of the brewery and hence necessarily bring with it improvements and innovations. This does not mean stagnation, quite the opposite, but it does mean adopting a challenging strategy in which immediate tangible benefits are difficult to quantify. One consequence of this neo-fundamentalist philosophy, is that to be most effective the research needs to be carried out actually in breweries, otherwise the influence of science—Irish or otherwise—will not be become fixed within the fabric of the industry.

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81. Bud & Roberts, op. cit. (79), p. 156.
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94. Comrie, A. A. D., *Brewers' Journal Centenary Number*, 1965, 166–171.
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102. Cosbie, A. J. C., Tosic, J. & Walker, T. K., *Journal of the Institute of Brewing*, 1942, **48**, 82–86.
103. Cosbie, A. J. C., Tosic, J. & Walker, T. K., *Journal of the Institute of Brewing*, 1942, **48**, 156–158.
104. Cunliffe, S. V., *Journal of the Royal Statistical Society*, A, 1976, **139**, Part 1, 1–19, 3.
105. Cunliffe, op. cit. (104), 2.
106. Daintith, J., Mitchell, S. & Tottill, E., *Chambers Biographical Encyclopaedia of Scientists*, 504–505. Tyndall is another Irishman who like Boyle has been mistakenly described as English. Included in those making this error is the author of this paper who is grateful to Mr Tom Halpin for first alerting him to the true origins of the Carlow born scientist.
107. Darington, H., *Brewers Guardian Centenary Issue*, 1971, 37.
108. Daubeny, C., *A Supplement to the Introduction to the Atomic Theory*, London: John Murray, 1840, p. 20, quoted by Bud, op. cit. (74), p. 123.
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113. Donnelly, J., *British Journal for the History of Science*, 1991, 3–20, p. 16.
114. Editorial notes, *Journal of the Incorporated Brewers' Guild*, 1949, **35**, 169. Heilbron was not in fact the first director of research to be appointed. John Masson Gulland (1898–1947) who had been Professor of Chemistry at University College Nottingham, held the post for less than 4 weeks before he was killed in a railway accident on 26th October 1947.
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116. Editorial notes, op. cit. (115), p. 408.
117. Editorial notes, op. cit. (115), p. 404.
118. Eyre, J. Vargas., *Henry Edward Armstrong*. London: Butterworths, 1958.
119. Ferguson, W., *Dublin Journal of Medical and Chirurgical Science*, 1833, **2**, 11–14. It is possible that it was Ferguson's knowledge of specific gravity measurement which brought him to Reids. His

interest in brewing may also have been stimulated by contact with Michael Donovan, Professor of Chemistry to the Company of Apothecaries in Ireland. In 1830 Donovan wrote a volume on brewing, distilling, wine making, baking, etc. in the *Cabinet Cyclopaedia* series conducted by the Reverend Dionysius Lardner (Donovan, M., *Domestic Economy*, vol. 1. London: Longmead, Rees, Orme, Brown and Green, 1830). I am grateful to Mr P. A. Martin for drawing my attention to this work.
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125. Furze, J. N., *Memoirs of the Chemical Society*, 1843–45, II, 21–25.
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129. Gourvish & Wilson, op. cit. (127), p. 152.
130. Green, B. (Ed.), *The Wisden Book of Obituaries*. London: Queen Anne Press, 1986, p. 149. This may make Case the only brewer/brewer's chemist to have an obituary in Wisden.
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132. Hacking, I., *Dictionary of Scientific Biography*, p. 476–477.
133. Halpin, T. B., *Brewer*, 1988, **74**, 162–167, p. 164.
134. Harcourt, A. V., *Journal of the Chemical Society*, 1868, **20**, 460–492.
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136. Hardie & Pratt, *A History of the Modern British Chemical Industry*, London: Pergamon Press, 1966.
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138. Hawkins, K. H. & Pass, C. L., *The Brewing Industry. A Study in Industrial Organisation and Public Policy*. London: Heinemann, 1979, p. 32. See also Hawkins, K. H., *A History of Bass Charrington*. Oxford: Oxford University Press, 1978, Chapter 2, p. 36–65.
139. Hector, D., *The Department's story: A History of the Department of Agriculture*. Dublin: Institute of Public Administration, 1971, quoted in Box op. cit. (55), p. 49.
140. Henri, V., *Comptes Rendus*, 1901, **133**, 891–894.
141. Henri, V., *Zeitschrift fur Physikalische Chemie*, 1901–2, 194–216.
142. Henri, V., *Comptes Rendus*, 1902, **135**, 916–919.
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152. Hudson, J. R., *Development of Brewing Analysis*, London: Institute of Brewing, 1960, p. 19.
153. Institute of Brewing Annual Report 1981, *Journal of the Institute of Brewing*, 1982, **88**, 195.
154. Institute of Brewing Annual Report 1984, *Journal of the Institute of Brewing*, 1985, **92**, 291. See also Anon, *Brewing & Distilling International*, 1990, **21** (12), 4. A recent newspaper report (Morning Advertiser, 12th April 1991) quoted statements to the affect that the ICBD is to do work of direct commercial application and linked this to the changed funding arrangements for BRF in the 1990s.
155. Institute of Brewing Annual Report 1986, *Journal of the Institute of Brewing*, 1987, **93**, 255.
156. Institute of Brewing Annual Report 1987, *Journal of the Institute of Brewing*, 1988, **94**, 196.
157. Irons, G., *Brewing & Distilling International*, 1988, **19** (7), 22–26, 31.
158. Iveagh, Lord, quoted in *Brewers Guild Journal*, 1955, **41**, 403. In addition to the brewery microscope, the 2nd Lord Iveagh (1874–1967) is recorded as having cajoled his father into giving him a microscope at the age of 7 for use in the playroom—see Mullally, F., *The Silver Salver. The Story of the Guinness Family*. St Albans: Grenada Publishing Limited, 1981, p. 50. His interest in microbiology continued into manhood and led to endowments to the Lister Institute and the financing of the Wright-Fleming Institute of Microbiology (Mullally, op. cit., p. 54). The Earl's real interests were, however, in agriculture and the contributions he made to experimental farming were to lead to the award of a gold medal by the Royal Agricultural Society in 1957 and his election as a Fellow of the Royal Society eight years later at the age of 91. (Mullally, op. cit., p. 60).
159. Iveagh, op. cit. (158), p. 404.
160. Jones, G. C., *Journal of the Institute of Brewing*, 1937, **43**, 361–363.
161. Jones, M. & Pierce, J. S., *Journal of the Institute of Brewing*, 1964, **70**, 307–315.
162. Kennedy, W., *Industrial Structure, Capital Markets and the Origins of British Economic Decline*. Cambridge: Cambridge University Press, 1990. In the particular case of the brewing industry it is a moot point as to what extent the existence of the tied-trade has on the one hand encouraged short-termism, and on the other acted as a disincentive to technical diversification. The cost of acquiring and maintaining the tied estate certainly accounted for the majority of capital employed in most brewing companies from the 1880s. It is also well documented (Hawkins & Pass, op. cit. (138)), that the poor return on capital which this investment came to represent was one of the major factors in attracting outside predators to the industry in the 1960s, precipitating a spate of amalgamations. The existence of tied estate, on the one hand acting as a cushion and on the other as a drain, may well have curtailed both the enthusiasm and the will to support other activities. Without a tied estate it can be argued that the brewing industry in the UK may have become less firmly a part of the leisure industry and more an integral part of manufacturing industry. It will be interesting to see whether the loosening of the tie in the 1990s has any effect on production companies with regard to manufacturing diversification.
163. Lancaster, H., *Journal of the Institute of Brewing*, 1942, **48**, 31–33.
164. Liebig, J., *Annalen der Pharmacie*, 1838, **26**, 113–189.
165. MacLeod, A. M., *Proceedings of the Royal Society of Edinburgh*, 1983, 37–64. The chemist appointed to William Younger's in 1889 was John Simpson Ford (1866–1944). Ford, who made extensive contributions to brewing chemistry, would undoubtedly have found a larger place in this history had not Irishmen been chosen to exemplify its theme. Reference should be made to Professor MacLeod's erudite paper for a balancing account of Scottish contributions.
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167. Martin, P. A., *Journal of the Institute of Brewing*, 1987, **93**, 43–52.
168. Mathias, P., *The Brewing Industry in England 1700–1830*. Cambridge: Cambridge University Press, 1959, p. 64.
169. Mathius, op. cit. (168), p. 551–552.
170. Matthews, C. G., *Journal of the Institute of Brewing*, 1923, **29**, 598–611, p. 599.
171. Matthews, J., *Burton Weekly News*, 10 March, 1865.
172. McMullen, A., *Barley Cultivation in Ireland*. Dublin: Arthur Guinness Son & Co., Ltd., 1908.
173. McMullen, L., *Biometrika*, 1939, **30**, 205–210.
174. Miller, J. H., *Journal of the Institute of Brewing*, 1909, **15**, 729–730.
175. Miller, J. H., *Journal of the Chemical Society*, 1910, **92**, 684–685.
176. Miller, J. H., *Journal of the Institute of Brewing*, 1925, **31**, 229–233.
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179. Moy, T. D., *Ambix*, 1989, **36**, 109–120.
180. Muspratt, S., *Chemistry, Theoretical, Practical & Analytical as Applied and Relating to the Arts and Manufactures*. Glasgow: William MacKenzie, 1854–1860, p. 236–285.
181. Muspratt, op. cit. (180), p. 281.
182. Neville, S. O., *Seventy Rolling Years*. London: Faber and Faber, 1958, p. 39. The future Sir Sydney Nevile (1873–1969) sometime Managing Director of Whitbreads, President of the Institute of Brewing and Chairman of the Brewers' Society, was an early customer of the practice. He records how as a busy young brewer

at around the turn of the century "I still found time to spend a few hours weekly at John Heron's laboratory in the City, learning all I could about the new methods of scientific control . . . I used to arrive at Heron's laboratory about twice a week in the early afternoon. I would work with two or three other enthusiasts until nine, when we retired to a chop house for an evening meal". The author is grateful to Mr P. A. Martin for bringing this passage to his attention.

183. Newbold, C. J., *Journal of the Institute of Brewing*, 1942, **48**, 7–8.
184. O'Raghallaigh, D., *Three Centuries of Irish Chemists*. Cork: Cork University Press, 1941.
185. O'Sullivan, C., *Journal of the Chemical Society*, 1872, **25**, 579–592.
186. O'Sullivan, C., *Journal of the Chemical Society*, 1876, **29**, 478–483.
187. O'Sullivan, C., *Journal of the Chemical Society*, 1876, **30**, 125–145.
188. O'Sullivan, C., *Journal of the Chemical Society, Transactions*, 1879, **35**, 770–785.
189. O'Sullivan, C., *Journal of the Chemical Society, Transactions*, 1882, **41**, 24–33.
190. O'Sullivan, C., *Journal of the Chemical Society, Transactions*, 1886, **49**, 70–75.
191. O'Sullivan, C. & Tompson, F. W., *Journal of the Chemical Society, Transactions*, 1890, **57**, 834–931.
192. O'Sullivan, H. D., *The Life and Work of Cornelius O'Sullivan FRS*. Guernsey: Privately printed, 1934.
193. O'Sullivan, J., *Journal of the Chemical Society, Transactions*, 1892, **61**, 926–943.
194. O'Sullivan, J., *Journal of the Institute of Brewing*, 1921, **27**,, p. 93–101.
195. O'Sullivan, J., *Journal of the Society of Chemical Industry*, 1897, **16**, 112.
196. O'Sullivan, J., *Transactions of the Laboratory Club*, 890, **3**, 102–119.
197. Owen, C. C., *The Development of Industry in Burton upon Trent*. Chichester: Phillimore, 1978, 89.
198. Owen, op. cit. (197), p. 83. Owen cites 1876 as the year of Bass's supremacy. Hawkins in his history of Bass Charrington (see reference 138, p. 11) states that in 1876 the Guinness brewery in Dublin was in fact bigger than Bass's. However reference to the data presented by Halpin in his history of the Irish brewing industry (Halpin, op. cit. (133)) reference 133, p. 164) would suggest that Owen's contention is the correct one and that Guinness did not overtake Bass in terms of volume until some time in the 1880s.
199. Owen, op. cit. (197), p. 94.
200. Owen, op. cit. (197), Appendix 30, p. 229.
201. Owen, op. cit. (197), Appendix 34, p. 234.
202. Partington, J. R., *A History of Chemistry*. London: Macmillan, 1962, Volume 3.
203. Pass, M. & Anderson, R. G., unpublished results. A survey of the publications by UK and Irish Breweries covering all major journal and conference sources of original research work, for the years 1985–1990 is suggestive of the wider significance of this criterion. The survey shows that 68% of the output came from only three companies Bass (26%), Guinness (22%) and Allied (20%) with the rest someway behind. The same ranking order is obtained whether or not patients are included in the sample. As was pointed out in discussing Cornelius O'Sullivan's influence on Bass in Victorian times, it would be unwise to lay too much stress on the part played by scientific and technical expertise in the success of a brewing company. This proviso is even more valid today with such complex company structures and it would be foolish to ignore the dominant influence of financial investments, marketing, acquisitions, etc. But, the underlying attitude exemplified by a strong publication record should also not be ignored. Is it just a co-incidence that the major brewing company which has had the most market growth and the largest volume sales in the last decade should be the one which continues to publish the most original work?
204. Pearson, E. S., Plackett, R. L. & Barnard, G. A., *Student, A Statistical Biography of William Sealy Gosset*. Oxford: Clarendon Press, 1990, p. 19.
205. Pierce, J. S., *Journal of the Institute of Brewing*, 1987, **93**, 378–381.
206. Pierce, J. S. (Ed.), The Institute of Brewing Centenary, 1986, p. 19.
207. Pierce, op. cit. (206), p. 53. L. R. Bishop, F. E. Day and R. S. W. Thorne came together in Birmingham in April 1934. They were later to be joined by others including Cyril Rainbow. With regard to funding, Seligman gives an insight into how far the brewing industry was lagging behind (Seligman, R., *Journal of the Institute of Brewing*, 1948, **54**, 130–140). From a list of industries which maintained research associations, he compared annual turnover and expenditure on these research associations using data collected just before the outbreak of the war. He notes "The figures gave percentages varying from 0.083% in the case of the linen trade down to 0.009% for the printing industry . . . at that time the brewing industry was spending 0.003% of its turnover on collaborative research".
208. Piesse, G. S., *Proceedings of the Chemical Society of London*, 1841–42, 42–43.
209. Porter, G., Dimbleby Lecture, BBC TV, *Laboratory News*, 18th April 1988, p. 22. Sir George (now Lord) Porter, then President of the Royal Society, took this opportunity (amongst others) to present his views on the importance of serendipity in science and the dangers of neglecting fundamental research.
210. Portno, A. D., *Journal of the Institute of Brewing*, 1983, **89**, 146–148.
211. Preece, I. A., *Brewers' Guild Journal*, 1964, **50** (591), 11–17. From a lecture given at Aldermanbury, England on 28th September 1963 and reproduced in *Wallerstein Laboratory Communications*, 1964, **27**, p. 1–5.
212. Pyke, M., *Institute of Biology Journal*, 1963, **10**, 102–108.
213. Rainbow, C., *The Brewers Journal*, 1964, **92**, 637.
214. Reilly, D., *Wallerstein Laboratories Communications*, 1951, **14** (45), 101–110.
215. Richardson, J., *Statistical Estimates with the Saccharometer*, 1784.
216. Richmond, L. & Turton, A. (Eds), *The Brewing Industry. A Guide to Historical Records*. Manchester: Manchester University Press, 1990, p. 322.
217. Rose, A. H. & Harrison, J. S. (Eds), *The Yeasts*, Vol. 2, 2nd Edition. London: Academic Press, 1987, p. 5–40.
218. Royal Commission on Scientific Instruction, I, 1872, c. 536 Minutes of Evidence, 5834, p. 369.
219. Royal Commission on Technical Instruction III, 1884, c. 3981, answers to Q 1523/4, p. 145.
220. Shimwell, J. L., *Journal of the Institute of Brewing*, 1936, **42**, 119–126.
221. Shimwell, J. L., *Journal of the Institute of Brewing*, 1940, **46**, 207–210.
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223. Shimwell, J. L., *Wallerstein Laboratories Communications*, 1941, **4**, (11), 41–48.
224. Shimwell, J. L. & Carr, J. G., *Journal of the Institute of Brewing*, 1958, **64**, 477–484.
225. Shimwell, J. L. & Kirkpatrick, W. F., *Journal of the Institute of Brewing*, 1939, **45**, 137–145.
226. Sigsworth, E. M., *Economic History Review*, 1964–1965, **17**, 536–550.
227. Sigsworth, op. cit. (226), p. 538.
228. Sigsworth, op. cit. (226), p. 550.
229. Slator, A., *Journal of the Institute of Brewing*, 1938, **25**, 323–326.
230. Smiley, N. B., *Journal of the Institute of Brewing*, 1947, **53**, 7–8.
231. St Johnston, J. H., *Journal of the Institute of Brewing*, 1956, **62**, 212–213.
232. Stansell, J., *Financial Weekly*, 2 October 1986, p. 4.
233. Stern, A. L., *Journal of the Federated Institutes of Brewing*, 1895, **1**, 448–450.
234. Stuart, D., *County Borough, the History of Burton upon Trent 1901–1974*. 2 volumes. Burton upon Trent: The Charter Trustees, 1975, volume 1, p. 74.
235. Student, *Biometrika*, 1907, **5**, 20–24.
236. Student, *Biometrika*, 1908, **6**, 1–25.
237. Student, *Biometrika*, 1938, **29**, 363–379.
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239. Szabadvary, F., *History of Analytical Chemistry*. London: Pergamon Press, English Edition 1966, p. 125–139.
240. Thompson, L. C., *Journal of the Institute of Brewing*, 1943, **49**, 1–4, 3.
241. Thorburn Burns, D., *Analytical Proceedings*, 1977, **14**, 171–177. This paper contains a discussion of the origin of the quotation often used to describe Boyle "the Son of the Earl of Cork and the Father of Modern Chemistry", in which it is traced to the chemist James Price in a publication of 1782.
242. Thorne, L. T., *Journal of the Institute of Brewing*, 1913, **19**, 330–331.
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MS B/THB, Greater London Record Office, quoted in Bud, op. cit. (74), p. 138.
244. Tyndall, J. in *Essays on the Floating-Matter of the Air in Relation to Putrefaction and Infection*. London, 1881. *Fermentation, and its Bearings on Surgery and Medicine*. A discourse delivered before the Glasgow Science Lecturers Association, 19th October, 1876.
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246. Ward, E. R., *Journal of the Royal Institute of Chemistry*, 1958, **82**, 383–389, 458–463.
247. Warington, R. (Jnr), in *Jubilee of the Chemical Society of London: Record of the Proceedings together with an Account of the History and Development of the Society 1841–91*. London: Chemical Society, 1981, p. 117.
248. Warington, R., *Memoirs of the Chemical Society*, 1843–45, **II**, 326–329.
249. Watson, A. F., *Journal of the Institute of Brewing*, 1909, **15**, 294.
250. Wilson, R., in Richmond, L. & Turton, A. (Eds), *The Brewing Industry A Guide to Historial Records*. Manchester: Manchester University Press, 1990, p. 4.
251. Wilson, op. cit. (250), p. 5.
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253. Wilson, op. cit. (250), p. 17.