BIOGRAPHICAL MEMOIRS

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JAMES WALTER McLEOD

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BY SIR GRAHAM WILSON, F.R.S. AND K. S. ZINNEHMANN

FAMILY

J. W. McLEOD was born in Dumbarton on 2 January 1887. His father, John, an architect, belonged to a family whose occupations ranged through law, medicine, the civil service, industry and commerce, conducted mainly in the south of Scotland. John McLeod had built up a successful practice, and at the time of his marriage in 1884 had just completed the new Glasgow synagogue—a surprising commission for a Presbyterian. He was then aged forty-five and his bride, Lilias Symington McClymont, who was twenty-one years his junior, was the daughter of what was then described as a gentleman farmer in Borgue, Kirkcudbrightshire.

Less than four years later John died of diabetes, leaving his widow with two sons, Norman and James. Norman was to work for many years on irrigation schemes in India, and later to become a technical adviser to the World Bank. Four months after her husband’s death, Mrs McLeod bore a third son who was named John, after his father. He was to train as a lawyer and to make his career in banking.

The widow was well provided for. After two or three years she moved to Edinburgh where she sent the two elder boys to George Watson’s College. The health of the youngest gave continuous concern, and in 1895 she was advised to take him to Switzerland. The entire family, possessed of no more than the elements of school French, settled in Lausanne. The boys were entered at the Collège Cantonal where they found themselves unable to understand a word. In a surprisingly short time, however, they remedied this defect, and for the rest of his life James Walter spoke French fluently, though with little concession to the accent or intonation of the natives. He was to acquire a similar command of German in the Army of Occupation 25 years later.

When the boys reached Public School age the two eldest were sent as boarders to Mill Hill on the northern outskirts of London, and later to Glasgow University. Their mother returned to Scotland leaving the youngest in Switzerland, where his health gradually improved. In 1914 she moved to London and stayed there till her death in 1952.
At Glasgow University McLeod began to study medicine in 1903 at the age of 16 and graduated M.B., Ch.B. with commendation in 1908. He excelled in rugby, cricket and athletics. After holding two house appointments he served for a time as ship’s surgeon on the India route. In 1909 he was awarded a Coates scholarship, and in 1910 he became a Carnegie scholar. For three years he worked in Professor Robert Muir’s Department of Pathology. This was in the heyday of the Department, which supplied professors to most of the universities in England. Under the direction of Robert Muir (later Sir Robert) and of Carl Browning (later F.R.S.), he studied the properties of streptococcal haemolysin. During this period of initiation he received a training in scientific method and objectives that was to serve him all his life.

In 1912 he left Glasgow to take up an appointment as Assistant Lecturer in Pathology at Charing Cross Hospital Medical School in London. When war broke out in 1914 he was gazetted a Temporary Lieutenant in the Royal Army Medical Corps, and later promoted to Captain in charge of the Eighth Mobile Laboratory. In France he was stationed mainly near Amiens. Four times he was mentioned in dispatches, and finally he was awarded the military O.B.E.

On demobilization he joined the Department of Pathology at Leeds University as Lecturer in Bacteriology. In 1922 he was appointed to the newly instituted Brotherton Chair of Bacteriology. In this capacity he worked alongside Professor Matthew John Stewart, who held the Chair of Pathology, until his retirement in 1952. For the last four years of his tenure he succeeded M. J. Stewart as Dean of the Medical Faculty and Chairman of the Board of Medicine.

At the end of this period he, now an Emeritus Professor, and his wife left Leeds and went to live in the lonely Dye Cottage, near Longformacus in the Lammermuirs. On her death in 1953 he left the cottage, but kept it as a weekend home. Moving to Edinburgh he once more became immersed in scientific inquiry. With the support of the Scottish Hospital Endowments Research Trust he joined the Department of Surgery of the University, working there from 1954 to 1963. When his grant expired he found space in the Central Microbiological Laboratories at the Western General Hospital, where he continued his researches till 1973 with assistance from the Royal Society and the Medical Research Council.

McLeod received many honours. He was chosen to be a corresponding member of the Société de Biologie, Paris, in 1928. In 1933 he was elected to the Fellowship of the Royal Society, London. He was made an Honorary Member of the Scottish Society for Experimental Medicine in 1957, and in the same year a Fellow of the Royal Society of Edinburgh; an Honorary Member of the Pathological Society of Great Britain and Ireland in 1961, and an Honorary Fellow of the Royal College of Pathologists in 1970. From 1949 to 1952 he served as President of the Society of General Microbiology. He received the degree of Sc.D. (hon. causa) Dublin in 1946 and of L.L.D. (hon. causa) Glasgow in 1961.

McLeod’s first wife, whom he married in 1914, was Jean Christine Garvie, M.A. (Glasgow). According to Sir John McNee, who shared the same laboratory
This photograph of the bronze head of J. W. McLeod by Epstein was taken by the Photographic Section of the Leeds University Audio-Visual Service. The bust itself was commissioned in 1952 on the occasion of Professor McLeod's retirement.
as McLeod at Glasgow, she was a splendid girl of great personality and character, and deeply religious. She came from a Scottish family established at Zyrardów in Poland, and her mother, though Slav in appearance and speaking English with a strong Polish accent, was also of Scottish stock. By Jean he had two sons and five daughters. The second boy died in an accident when only four years old. The eldest daughter, Lilias Richard, M.B., Ch.B., became the third wife of the Earl of Cromartie in 1962. One other daughter qualified in medicine at Dundee, and another trained as a nurse. The son, Thomas McLeod, M.A., C.Eng., F.I.E.E., became a technical expert in Plessey Telecommunications Ltd. In 1956 McLeod married again. His wife, Joyce Anita Shannon, M.B., Ch.B., a general practitioner in Edinburgh, was of great help to him while he was investigating a new method of assessing the action of leucocidins. With her he shared a happy life for over 20 years.

McLeod’s last days were clouded by illness. Besides trouble with his hip, which was not altogether relieved by replacement of the joint in 1968, he had an operation for cataract in 1970 and for prostatic enlargement in 1974. By the end of August 1974 he was physically unable to go to the laboratory any longer. His memory failed, and he suffered from delusions, mental confusion and other manifestations of cerebral arteriosclerosis. For the last year of his life he was confined to the geriatric ward of the Royal Victoria Hospital. His death on 11 March 1978 was due to bronchopneumonia.

The bronze bust by Epstein, which was commissioned in 1952 on the occasion of McLeod’s retirement from his Leeds post, now stands in the library of the new medical school. Epstein is said to have been doubtful about accepting the commission, but changed his mind once he had seen McLeod’s fine head.

**Scientific work**

McLeod’s scientific career extended over a period of more than 60 years. Broadly speaking it may be divided into five periods:

1. From 1909 to 1918 he worked in Glasgow, London and France on streptococci and on illnesses occurring in the Army during World War I;
2. The next ten years were spent at Leeds, mainly on problems of bacterial respiration;
3. The third period from 1930 to 1940 was devoted to a study of the various types of the diphtheria bacillus and the clinical characters of the disease to which they gave rise;
4. During and after World War II, up till 1952, when he retired from his professorship at Leeds, his main interest was the rationale of sulphonamide action;
5. And at Edinburgh from 1952 to 1973, with an intermission of two years, he was occupied chiefly with a study of urinary infections in medical and surgical practice.

**Streptococci**

Though most of McLeod’s work on streptococci was carried out before World War I, he kept on coming back to the subject from time to time; and his
contributions to the Medical Research Council's System of Bacteriology on these organisms and on pneumococci were not made till 1929.

As already mentioned, he started with a Coates scholarship in 1909 at Glasgow University in Professor Robert Muir's (later Sir Robert) Department of Pathology and with a Carnegie scholarship in 1910. Under Dr Carl Browning's supervision he studied the properties of the haemolysin produced by pathogenic streptococci. The amount of this he found to be proportional to the extent of growth. The lysin was thermolabile, being destroyed by heat at 50–55 °C in 30 min. With J. W. McNee (later Sir John) he showed that rabbits with little natural antistreptolysin in their blood died of toxaemia after injection with the lysin, displaying both haemoglobinæmia and haemoglobinuria. Less susceptible rabbits survived repeated injections, but suffered from anaemia and hyperplasia of the bone marrow. What was very curious was that, though natural antihæmolysin was present in some degree in the blood of man, the horse, the rabbit and the guinea-pig, even large injections of haemolysin failed to produce antihæmolysin or to increase the natural immunity of the animals. It was therefore not surprising to find that antistreptococcal serum prepared in the horse was useless for the treatment of infected rabbits.

McLeod found that, in addition to the haemolysin, pathogenic streptococci produced a leucocidin. Whether the lytic action on the blood cells and the destructive action on the leucocytes were due to one and the same toxin was not clear.

The virulence of streptococci for man appeared to depend on their activity as toxin producers and on their ability to produce toxin in the blood. Some correspondence was noticed between the capacity of a strain of streptococci to produce haemolysin when grown in fresh human serum and the severity of the lesion from which it was isolated.

When grown on heated blood agar—often referred to as chocolate agar—non-haemolytic streptococci formed colonies surrounded by a yellow-green halo. The reason for this coloration formed a subject of great interest to McLeod. Working with Gordon, he found that these organisms, when grown in media freely exposed to the air and not too rich in catalase, formed hydrogen peroxide, and that the greater the amount of $\text{H}_2\text{O}_2$ formed the more pronounced was the yellow-green colour of the colonies. From further observations it was concluded that the appearance of colonies of streptococci on blood media probably depended on the interplay of a complex group of bacterial activities, notably haemolysin production, acid production, reducing activities, $\text{H}_2\text{O}_2$ production, and possibly peptic and tryptic digestion of the corpuscles.

The appellation of viridans to non-haemolytic streptococci had therefore little significance unless the conditions of growth were defined. The greenish colour appeared to be due to an oxidation product of haematin, which itself was formed by the action of heat on the haemoglobin in the blood during preparation of the chocolate agar medium. It may be added that, even now, the exact cause of the greenish coloration is still under dispute.

In classifying streptococci into haemolytic and non-haemolytic groups, McLeod defined lysis as the ability to secrete a filtrable haemolysin when a
small quantity of a young culture in 20% serum broth was incubated for 1½ h with 0.5 ml of a 5% suspension of washed ox corpuscles. The non-haemolytic group could be divided into the facultatively anaerobic, including the pneumococcus, and the strictly anaerobic sub-groups.

With Wyon and with Gordon he observed that the growth of *Streptococcus pyogenes*, the typical virulent streptococcus, was inhibited by high concentrations of tryptic digests. This action was apparently due to amino acids, those mainly responsible being glycine, cystine, tryptophan and phenylalanine. This organism was almost devoid of the power to reduce cystine and its compounds, as well as such dyes as neutral red, methylene blue and litmus. The inhibitory effect of amino acids on growth was a subject McLeod later studied in another connection.

**The years 1914–20**

During World War I McLeod, who was in charge of the Eighth Mobile Laboratory in France, was occupied almost entirely with clinical pathology. He wisely took advantage of such opportunities as came his way to carry out research investigations on the material available. Besides making observations on the cultivation of the typhoid bacillus in a medium containing brilliant green, as recommended by Carl Browning; devising with R. E. Bevan-Brown an apparatus for the withdrawal of blood aseptically from a vein and for sampling the culture medium during incubation; and assessing with A. G. Ritchie the value of the agglutination reaction in the diagnosis of dysentery, he collaborated with a French military captain, P. Ameuille, in a study of the effect of trench warfare on renal function, and ascribed the frequency in British troops of albuminuria to the excess of protein and the lack of fresh vegetables in their diet, which led to a mild degree of scurvy. With D. L. Tate he found that splenic enlargement and a moderate polymorphonuclear leucocytosis were almost constant features of trench fever.

At the end of the war he was joined by A. G. Ritchie and C. A. Dottridge in an attempt to measure the prevalence of Pfeiffer's bacillus, *Haemophilus influenzae*, before, during and after the great influenza pandemic of 1918–19. Ten years or more before the discovery of the viral origin of influenza, the part played by Pfeiffer's bacillus in the causation of this disease was a matter on which the leading bacteriologists of the day were at variance. I (G. S. W.) well remember, as a very junior bacteriologist, a meeting of the Pathological Society of Great Britain and Ireland at Charing Cross Hospital Medical School at which completely divergent views were expressed and the consequent general perplexity that was felt. The contention of those who supported the role of Pfeiffer's bacillus that their opponents had failed to isolate this organism because of their bad technique was manifestly untrue, since the same medium and methods had often been used by the two sets of workers. The difference in the findings was almost certainly due to the variation in time, place and occupation of the frequency of Pfeiffer's bacillus in the upper respiratory tract of man.
A final investigation, carried out with P. Govenlock, and published in 1921, was on a subject that McLeod had not touched on before, namely the production of bactericidins by micro-organisms. In both its subject matter and its technique, it was almost prophetic in anticipating the work on the sulphonamides and penicillin that occupied the bacteriological world twenty years later. They found that many bacteria produced substances inhibiting their own growth and that of other species. They were heat-labile, at 80–85 °C, and needed for their formation a free supply of oxygen. The pneumococcus was studied most thoroughly and was found to produce substances inhibiting the growth of staphylococci and of pneumococci themselves but not that of streptococci, with the exception of *Streptococcus faecalis*. For demonstrating these substances a modification of Eijkman's disk technique was used. It was a long time before these substances, now known as bacteriocines, were studied by other workers and found to be of value in the identification and differentiation of bacteria.

**Bacterial respiration**

The subject of bacterial respiration fascinated McLeod and kept him busy during the 1920s. Little attention had been paid to the physiology of bacterial growth, and it was not till the end of the twenties that biochemists such as J. H. Quastel, F.R.S., and Marjory Stephenson, F.R.S., at Cambridge took it up seriously. The originality and authoritativeness of McLeod's work were recognized by his being asked by the Medical Research Council to contribute articles on various aspects of the subject for their 'System of bacteriology in relation to medicine' published in 1929–31; and by E. O. Jordan and I. S. Falk in the United States of America on bacterial oxidations and reductions in 'The newer knowledge of bacteriology and immunology' which was published in 1928. In all his work on this subject he made full use of the staff in Emeritus Professor Cohen's adjoining unit of Organic Chemistry. McLeod's interest in bacterial respiration appears to have been first aroused by noting the green discoloration that appeared around colonies of pneumococci grown in heated blood agar (chocolate agar). In collaboration with Gordon, who was a member of his department, he showed that this phenomenon was caused by the production of hydrogen peroxide, and that it was H₂O₂ which was responsible for the rapid death of the organisms. H₂O₂ could also be demonstrated when pneumococci were grown in a shallow layer of 10% serum broth that had been heated to 65 °C for half an hour to drive off catalase. The substance, thought to be a vitamin, in fresh tissue fluid that promoted the growth of pneumococci was probably catalase, which protected the organisms against the hydrogen peroxide they formed.

Passing on to the study of other organisms they found that lactobacilli also produced H₂O₂, as manifested by the green coloration around colonies on chocolate agar, and by the bluish-black coloration on a blood medium containing benzidine (Penfold's technique). The rapid death of vegetative cells of strictly anaerobic bacteria when exposed to air seemed to be explicable by the formation of H₂O₂. This supposition was strengthened by observing that a
green ring appeared at the upper limit of growth in a deep tube of chocolate agar; that the growth of anaerobes was promoted by catalase; and, in a paper published after his retirement from the Leeds chair, that if the organisms in a liquid culture were centrifuged down, the medium and metabolites in the supernatant fluid removed, and the deposited cells suspended in peroxide-free distilled water and oxygenated, a positive reaction for $H_2O_2$ could nearly always be shown.

From further study it appeared probable that all bacteria in the presence of oxygen formed $H_2O_2$; and on this basis and on that of the formation of catalase they divided bacteria into four groups:

1. those that were very sensitive to $H_2O_2$ and devoid of catalase, such as the potential producers of peroxide—the anaerobes;
2. those that were moderately sensitive to $H_2O_2$ and devoid of catalase, such as the peroxide producers—pneumococci, lactobacilli and some streptococci;
3. those that were moderately sensitive to $H_2O_2$ and devoid of catalase, but that did not produce $H_2O_2$, such as Shiga's bacillus and the haemoglobinophilic group of organisms; and
4. those that were sensitive in varying degree to $H_2O_2$ but produced catalase—a group that included most aerobes and facultative anaerobes.

The introduction by Clark and Lubbs in the United States of dyes that acted as indicators of the oxidation-reduction potential enabled McLeod to study the reducing action of bacteria, and the relation between this action and the formation of peroxide. Again working with Gordon, he found that all bacteria possessing an active reducing mechanism, i.e. by generating active or atomic hydrogen, and devoid of catalase, produced $H_2O_2$.

In 1928 McLeod and Gordon studied the presence or absence of a thermostable oxidase-producing system in various bacteria. For demonstrating this they used a 1–1.5% solution of dimethyl-para-phenylene-diamine hydrochloride. When this was poured over a pure culture, oxidase-producing organisms took on a maroon colour within 5 min, deepening to black within half an hour. This reaction distinguished clearly between gonococci, which were positive, and staphylococci and streptococci, which were negative; and also between the oxidase-positive cholera vibrio and the negative colon bacillus. It provided a most valuable means of diagnosis in patients suspected of suffering from gonorrhoea. For this purpose, Ellingworth, McLeod and Gordon found that the tetramethyl compound was superior to the dimethyl. It was oxidized to a substance giving a blue-violet colour that did not turn black but faded away under the influence of reducing enzymes. Its lower toxicity was of special value in enabling colonies of gonococci to be picked off a plate and subcultured before they were killed by the dye.

In his article on bacterial respiration in the Medical Research Council's *System of Bacteriology* in 1930 McLeod brought together many of the observations that he and Gordon had made during the previous eight years, including reducing enzymes, the oxidizing activities of dehydrogenating ferments, and
the influence of the gaseous environment in bacterial growth and metabolism. Expanding their previous classification (p. 427) they divided bacteria into two main classes:

Class 1
(a) Anaerobic bacteria deficient in catalase, strong reducers, relatively insensitive to potassium thiocyanate (which arrests oxidation processes dependent on the utilization of free oxygen, and paralyses cytochrome by fixing it in the reduced state) and devoid of oxidizing power for substituted phenols;
(b) microaerophilic bacteria, such as the lactobacilli, that are active reducers, and form only traces of \( \text{H}_2\text{O}_2 \);
(c) organisms, such as *Streptococcus faecalis*, that are tolerant of oxygen, have a moderate reducing action, and do not form peroxide.

Class 2
Bacteria provided with catalase, sensitive to KCN, and incapable of accumulating in cultures detectable traces of peroxide:
(a) bacteria, such as facultative aerobes and anaerobes, that reduce both dyes and nitrates, and lower the redox potential considerably;
(b) bacteria that grow more abundantly aerobically and are rapid oxidase-producers;
(b1) bacteria very sensitive to \( \text{H}_2\text{O}_2 \), forming only a small amount of catalase, and reducing nitrates, e.g. vibrios;
(b2) bacteria producing catalase freely, e.g. meningococcus and *Pseudomonas aeruginosa*.

Shiga’s bacillus did not fit into any of these categories; though it was sensitive to KCN, it lacked catalase and formed no \( \text{H}_2\text{O}_2 \).

Though relating more to metabolism than to respiration, it may be mentioned here that McLeod, working first with Wyon and later with Gordon, found that the growth of some micro-organisms was inhibited by amino acids. He studied the effect of 14 different amino acids on the growth of bacteria in peptone broth. No effect was noted on staphylococci or *Escherichia coli*. The growth of some of the more delicate organisms, however, was inhibited by cystine, glycine, phenylalanine and especially tryptophan, but favoured by taurine, aspartic acid and alanine. The toxic effect appeared to be due to products of deamination, such as indole, which was found to be more toxic than carbolic acid. Addition of serum to the medium had a protective effect against such toxic products.

With Wheatley and Phelon, McLeod studied in particular the difficulties met with in cultivation of the gonococcus. This organism required carbon, amino acids, and a suitable colloid to protect it against the toxic effect of some of the amino acids present in meat extract, thus enabling it to assimilate them. For this purpose blood heated to 60–100 °C was superior to other colloids. The failure of the gonococcus to grow on ordinary nutrient agar was ascribed to an unduly low ratio of protective colloid to amino nitrogen.

The rapid death of gonococci and meningococci in aerobic cultures was traced, at any rate in part, to the high pH, 8.6–9.0, caused by ammonia and
alkaline carbonates that resulted from oxidation of sodium salts of fatty acids in the medium. One further investigation made during the twenties in collaboration with Sugare was into the bacteriological diagnosis of whooping cough. *Bordetella pertussis* could be isolated from the sputum during the first week of the disease, but less often later. The differential features of the organism from *Haemophilus influenzae* were described, among which the strong catalase effect was stressed. The Medical Research Council's trial on the prevention of whooping cough by vaccination in which he participated before 1951 caused him to take up the subject again. In collaboration with Betty Dawson, Enid Farnworth and D. E. Nicholson, he failed to improve on the original Bordet–Gengou medium for the cultivation of *Bordetella pertussis*. He attributed its excellence to the potato extract it contained, which provided optimal concentrations of the amino acids and peptides required for growth. Many peptones he examined were found to inhibit development of the organism.

**Diphtheria**

The work that McLeod is best known by and that brought him international fame was that on diphtheria—its bacteriology, epidemiology and diagnosis. It occupied him and his numerous collaborators most of the ten years 1930–40, but after this period he came back to the subject from time to time. During the latter part of the nineteenth century and the first 40 years of the present century diphtheria was a widespread serious disease of childhood causing in 1901 in England and Wales a death rate of about 300 per million inhabitants. It was likewise common in north-west Europe, and during the first 20 or 30 years of the century in the United States and Canada. Its final virtual eradication as the result of active immunization in the forties and fifties was one of the triumphs of preventive medicine, but does not come into our story here.

**Types of diphtheria bacilli**

McLeod's first paper on this subject was published in 1931 under the authorship of Anderson, Happold, McLeod and Thomson. Incidentally it may be noted that, when working with collaborators, he usually arranged their names in alphabetical order. In this paper he described two main forms, and later on an intermediate form, of diphtheria bacilli, and a new medium on which to distinguish between them and to improve diagnosis. The medium used was the same heated blood agar (chocolate agar) as that on which his studies on bacterial respiration had been conducted, with the exception that the base consisted of meat extract heated not above 75 °C, as recommended by Hedley Wright, instead of the usual 100 °C. To it was added 0.04% potassium tellurite, which turned colonies grey to black by the reducing activity of the growing organisms. The two main types were designated *gravis* and *mitis* according to the severity of the disease with which they tended to be associated. The type having characters in between these two, and that was met with far less often, was designated *intermedius*. Without going into more detail than is here justified it
may be said that, broadly speaking, the bacilli of \textit{gravis} type were usually short, straight, uniformly stained rods having few or no granules; forming low convex pearly grey or greyish-black colonies that assumed in 3–5 days a daisy-head appearance; fermenting starch and glycogen; and being almost invariably virulent for the guinea-pig. Bacilli of the \textit{mitis} type, representing the classical diphtheria bacillus of Löffler, were usually long curved pleomorphic rods with prominent metachromatic granules; forming colonies that varied greatly in size, of a mushroom-grey colour, assuming on further incubation a poached-egg appearance; failing to ferment starch or glycogen; tending to be of lower virulence for the guinea-pig than \textit{gravis} strains, and, when isolated from diphtheria carriers, often non-virulent. \textit{Intermedius} strains, on the whole, resembled \textit{gravis} more closely than \textit{mitis} strains. For distinction he also attached great importance to the three different growth forms in broth—a feature often neglected.

Many observations were made on the relation of the three types of bacilli and the severity of the cases of diphtheria from which they were cultivated. In a paper written in association with Leete and Morrison, McLeod described how in Hull, where the morbidity and mortality of the disease were high, the \textit{gravis} type was responsible for 35 out of 40 toxic deaths and the \textit{intermedius} type for the remaining five. In \textit{gravis} cases the toxaemia ran so rapid a course that serum treatment was often unavailing. \textit{Mitis} cases in Hull were few, and were mild and non-toxic.

Observations, with Anderson, Cooper and Happold, in a series of 500 cases at Leeds confirmed these findings. \textit{Gravis} and \textit{intermedius} strains accounted for nearly all cases of paralysis.

Later observations on over 6000 cases in England and Wales and in Germany occurring during the four years 1931–35, made with a number of collaborators, were reported at a meeting of the Royal Society of Medicine in 1936; the whole subject was reviewed and some of the previous findings were amplified. The \textit{gravis} cases had the highest case-fatality rate and the greatest incidence of paralysis. \textit{Intermedius} cases had nearly as high a case-fatality rate, and an equally high tendency to produce haemorrhagic lesions. \textit{Mitis} strains were more likely than \textit{gravis} or \textit{intermedius} to cause obstructive lesions in the respiratory tract, spreading down to the larynx and lungs; otherwise they were rarely responsible for death. Typical \textit{gravis} strains were so constantly pathogenic to guinea-pigs that virulence tests for confirmatory purpose were deemed superfluous.

In a paper in 1939 with Orr and Hester Woodcock, McLeod gave an account of the morbid anatomy of diphtheria. In \textit{gravis} infections there was much less superficial membrane formation than in \textit{mitis} infections, and less tendency for it to extend into the intrathoracic air passages; the membrane itself, too, was of a looser texture. The tissues of the inflamed parts were penetrated more deeply, and the lymph nodes and surrounding tissue were more often involved. The tonsils in particular were affected, and in some cases were completely replaced by fibrinopurulent and haemorrhagic exudate. Death in \textit{gravis} and \textit{intermedius} infections resulted usually from the action of the diphtheria toxin.
on the heart and kidneys, and *mitis* infections from respiratory obstruction as the result of membrane formation.

Seven years later McLeod again reviewed the subject. He noted that there was a small proportion of strains of diphtheria bacilli that did not correspond exactly to any of the three types. They were commonest in cases of mild or moderate severity, and were found more often in convalescents and carriers than in severe cases. They had never been observed to become epidemic. *Intermedius* strains caused, as a rule, a slightly lower death rate than *gravis* strains, and disappeared more rapidly in convalescence. This, he thought, might be the reason why they were less likely than *gravis* strains to cause epidemics.

The classification of diphtheria bacilli into three types was misunderstood in the United States. Frobisher, Adams and Kuhns, for example, used the term *minimus* to describe strains from an outbreak at Baltimore in 1944 of greater severity than had previously been experienced. They formed very fine colonies and fermented glucose slowly. When examined by Johnstone and McLeod they were found, for all practical purposes, to be identical with *intermedius* strains. Obviously, Frobisher and his colleagues interpreted the designation *intermedius* as applying to colony size and not to clinical severity. What was far more important was Frobisher's description of virulent strains that fermented saccharose. Saccharose-fermenting strains had always been regarded as belonging to the diphtheroid group of bacilli bearing no relation to the causation of disease. The correctness of Frobisher's observation was confirmed by Johnstone and McLeod, and many years later by Christovão in Brazil on a much larger sample of strains, who found that 28% of 199 virulent strains isolated at São Paulo were saccharolytic.

On the other hand, the fermentation of starch had been defined originally as a property of *gravis* strains associated with virulence. Examining more than 200 starch-fermenting strains from the United Kingdom, West and Central Europe, and the Mediterranean area, McLeod and Robinson found that 5–6% of these proved non-virulent to the guinea-pig, and that 4% of all the typical *gravis* strains were likewise non-virulent. The association, therefore, between starch fermentation and virulence for the guinea-pig was not absolute.

Surveying the epidemiology of diphtheria in north-west Europe and in North America in the period 1920–46, McLeod noted that a high ratio of urban to rural population favoured a continuously high level of diphtheria incidence. Differences in the prevalence of the disease during and after the World War I occurred in different countries and in different towns in the same country. His analysis of the findings established the importance of *gravis* strains in the causation of epidemic diphtheria, and of the ability of *intermedius* strains to cause severe disease. It seemed probable that fluctuations in the occurrence of outbreaks of diphtheria were dependent on the particular type of bacillus that gained access to the population.

Besides the bacteriology and epidemiology of diphtheria, McLeod and his colleagues paid a great deal of attention to the diagnosis of the disease. At a
meeting of the Association of Clinical Pathologists in 1935 they recorded that
diphtheria bacilli had been isolated from 11% of throat swabs cultured on
tellurite medium as against only 3% on Loeffler’s medium. In a later com­mu­ni­cation
the results on various media that had been recommended for diagnostic
purposes were compared. On the whole, Neill’s medium appeared to be the best.
They recommended that suspicious colonies on any medium should be picked
on to plain heated blood agar for a study of colony formation and of the
morphology of the bacilli when stained with alkaline methylene blue. All
atypical strains should be tested for virulence. For this purpose they preferred
the injection of a quarter to an eighth of the growth on an 18-h Loeffler’s slope
into the axilla of a guinea-pig to the simultaneous injection of several strains into
the skin. A control animal injected with antiserum was unnecessary, provided
that the test animal died with a local lesion, pleural effusion and oedema
combined with patchy congestion and collapse of the lungs, congestion with or
without haemorrhage of the adrenal bodies, and diphtheria bacilli demonstrable
in the local lesion.

The article on diphtheria in the 1964 edition of *Encyclopaedia Brittanica*
covered the whole subject.

During and after World War II McLeod made observations on a miscellany
of subjects. With Gordon he described a simple and rapid method of distin­guishing
*Clostridium oedematisens (Cl. novyi)* from other bacteria associated with gas
gangrene. Colonies of this organism when left for half an hour exposed to the air
became surrounded by green haloes, and when grown on chocolate agar contain­ing
benzidine were, again after exposure to the air, coloured black. Both
phenomena were due to the formation of hydrogen peroxide. Other clostridia
studied showed neither of these phenomena, with the exception of *Clostridium
botulinum*, which was slightly positive.

In a report in 1946 with Downie and Robinson on two cases of tetanus, he
brought evidence to suggest that dust in the operating theatre was responsible
for the infection. In both cases *Clostridium tetani* was cultivated from the dust
of the operating theatre floor.

With Czekalowski and Rodican he studied the growth and respiration of
*Leptospira icterohaemorrhagiae* in semi-solid media. In deep media, growth
occurred in a band a few millimetres below the surface, as Dinger had described.
This disk formation was inhibited by a 1/3000 concentration of potassium
thiocyanate. The organisms required gaseous oxygen, but were microaerophilic;
they lacked catalase, had only slight reducing activity and failed to produce
recognizable traces of H₂O₂. Witte’s peptone was found to be the best for
promoting growth, and tryptic digest broth was equally good. The value of
laked blood appeared to depend on its catalase content, since the leptospira
did not produce this enzyme. The optimal pH for growth was around 7.6.

*Investigations into the mode of action of sulphonamides*

One of the obligations of the academic staff in McLeod’s department was an
evening visit to the premises, taken in rotation, between the hours of 8 and
10 p.m. for the reading of tellurite plates inoculated on the previous day; this he found necessary for the early detection of colonies of *C. diphtheriae intermedius* which appear only after 36 h incubation. On these occasions it was quite usual to see the lights switched on in McLeod’s room where he sat reading and abstracting English and foreign language medical journals till late at night. One of the subjects of his reading during the 1930s was the antibacterial action of Prontosil and, particularly, after the papers of the Tréfouëls, Fourneau, Nitti and Bovet (1937–38), of sulphanilamide which the French workers had identified as the active part of Prontosil. The mode of action of sulphanilamide occupied McLeod and various collaborators for nine years. On the basis of his earlier work on bacterial respiration he assumed that the *in vivo* action of the sulphonamide compounds was dependent on bacterial oxidation, and that some oxidation derivatives of sulphanilamide, yet to be identified, ought to have much greater bactericidal activity *in vitro* than could be shown for sulphanilamide itself. This line of investigation had been suggested first in the French literature by Mayer, and Mayer and Oechslin in 1938–39, and had been picked up by some American investigators, to be finally chosen by McLeod for intensive research in late 1939 and developed in three papers published in 1939, 1940 and 1942. His efforts in this direction probably resulted in the greatest disappointment in his whole career. In 1944, in two papers, McLeod formally acknowledged the correctness of (a) D. D. Woods’s observations on the complete inhibition by *p*-amino-benzoic acid of the antibacterial action of sulphonamides; (b) Paul Fildes’s theory, based on D. D. Woods’s findings, of *p*-aminobenzene-sulphonamide blocking an unidentified enzyme system that accepts the intermediate breakdown product *p*-aminobenzoic acid as an essential metabolite. He showed in these papers that access of oxygen increased the antibacterial effect of sulphonamides. He regarded the oxidation products of sulphonamides as an essential step in their effective action on bacteria without having been able to explain the relation of his observations to the blocking effect of *p*-amino-benzoic acid on the action of sulphonamides.

During the later stages of these experiments, haemoglobin in the form of laked horse blood had been added to some solid media to serve as a colour indicator for oxidation or reduction. He could not help observing that laked horse blood potentiated sulphonamide action on staphylococci, which did not occur when nutrient agar alone or with addition of laked blood from other species was used. Having followed a wrong line of approach to the mode of action of sulphonamides McLeod now concentrated his efforts on an attempt at explaining the ‘potentiating’ effect of horse blood on the *in vitro* antibacterial action of sulphonamides, only to be forestalled by Harper and Cawston. In 1945 these authors postulated the presence of unidentified substances in nutrient agar or broth that were inhibitory to the antibacterial action of sulphonamides; and noted the neutralization of this inhibitory effect by laked horse blood. Though not denying the possible truth of the Harper and Cawston hypothesis, he showed in two semisynthetic media known not to contain sulphonamide antagonists that the addition of 2% laked horse blood resulted in greater inhibition of *E. coli* and
shigellae by sulphonamides than could be obtained without it. Additionally, a
Harper-Cawston broth (laked horse blood filtrate concentrated fivefold in
\textit{vacuo} at a temperature below 50 °C) increased the inhibition-diffusion zone of
sulphonamides. From these observations McLeod concluded that potentiation
of sulphonamide action must play a considerable part in the change brought
about by the addition of equine haemoglobin. The closely argued discussion of
this report is typical of McLeod's tenacity.

In the context of sulphonamide action a useful paper ought to be mentioned
which he published with J. Gordon in 1941 and which he regarded as one of his
contributions to the war effort. It had become accepted at that time that the
prophylaxis of gas gangrene depended on surgical wound toilet together with
the liberal use of sterilized sulphonamide powder in the wound. The prophyl-
lactic use of polyvalent or monovalent antitoxin was deprecated officially. In a
series of experiments with mice and guinea-pigs McLeod showed that the success
of the prophylactic use of sulphonamide injections was limited by the size of
the subcutaneous infecting dose of three clostridial species, whereas prophylactic
injections of specific antitoxin near the site of infection resulted in survival of
from 50 to 100% of the animals. Contrary to the official recommendation to use
antitoxin only therapeutically, neither antitoxin nor sulphonamides saved any
animal lives when given in established cases of gas gangrene. McLeod and
Gordon suggested reversal of the official recommendation, i.e. to use clostridial
antitoxin prophylactically and not therapeutically. This report could be criticized
for the comparatively small number of animals used, but it must be remembered
that wartime imposed severe restrictions on resources and assistance. The
advent of penicillin prevented more thorough testing of the conclusions,
although the use of clostridial antitoxin near contaminated wound sites should
retain its value in conjunction with penicillin and may deserve retesting.

\section*{THE EDINBURGH PERIOD

\textit{Urinary tract infections}}

McLeod’s appointment to the Department of Surgery at Edinburgh
University was made with a view to entrusting him with the investigation of (a)
urinary tract infections arising after urological operations, and (b) of paraplegic
patients with an indwelling catheter who were liable to develop similar infections.
The problem was not an easy one to solve because of so many variable factors,
and the need for the full-time attention of an experienced investigator free from
administrative and teaching duties. In a series of seven papers, the result of
work carried out between the ages of 67 and 80, McLeod succeeded in defining
some of the important sources and pathways of urinary tract infections in these
groups of patients and suggesting some methods of preventing or delaying their
occurrence. Additionally he devised improved methods for assessing the presence
or absence of urinary tract infections in newborns and children.

The most dangerous postoperative infection of the urinary tract is that caused
by \textit{Pseudomonas aeruginosa}, which is not a commensal of the external male
genitalia. To establish the sources of infection it was necessary to identify
individual strains of the species. For this purpose Gould and McLeod (1960) had to devise a method of their own. Their procedures were too technical to be described here. Suffice it to say that two complicated methods had to be used simultaneously for the identification of individual strains isolated.

McLeod then proceeded to apply this method in two urological and one paraplegic hospital ward. Objects of examination were implements and apparatus on wards used in conjunction with patients' urine, dust samples from the floors of wards and the laboratory, the hospital water supplies, catheter lubricants, used blankets, and waste water in ward washbasins and laboratory sinks.

The occasional strain of *Ps. aeruginosa* found in the urine of patients on wards other than urological ones but not at all in that of patients from general practice was different from the three types in urological hospital wards and was usually transient. When the same strain was found more than once, it was in a patient who, as a rule, was confined to bed and had to use urine bottles and bed pans—articles that on urological wards habitually harboured this organism. An almost immediate result at the beginning of the investigation was the finding of *Ps. aeruginosa* in open-necked Winchester bottles collecting the urinary flow from indwelling catheters inserted during prostatectomies. This was a source of infection so obvious to McLeod that, after having isolated the ward strain in only three cases, he could not bring himself, for ethical reasons, to continue this particular aspect of the investigation until he had examined a statistically significant number of cases and controls. He insisted on replacement of open-necked Winchester bottles by a closed, sterilized system installed with aseptic technique. Finally, he came to the conclusion that *Ps. aeruginosa* in urinary infection was not introduced by catheterization, since the micro-organism was not part of the flora of the external male genitalia, did not persist in the dry state, and was, therefore, found only in dust exposed to recent heavy contamination. Its presence resulted from a hospital infection transmitted via urine bottles and bed pans. Sterilizing these, as was general practice, was not enough, as the hands of ward personnel might be infected by handling these implements after they had been used by patients. Urine bottles and bed pans, after proper sterilization, should contain sufficient 2% solution of carbolic acid or 0.2% solution of hibitane to prevent such transmission.

The scope of this investigation was widened subsequently to include microorganisms other than *Ps. aeruginosa* that were frequently isolated from urinary tract infections. The programme was confined to operations on the bladder and particularly to prostatectomy (1959). First in frequency were coliform infections. Urinary tract infections with *Proteus* species were either present at the onset or occurred rather late in the postoperative period. They were usually afebrile, were associated with chronic urinary dysfunction and with stone formation, which resulted from the alkalinity of the urine and from failure to empty the bladder completely. Infections with *Staphylococcus aureus* and faecal streptococci occurred but rarely. *Ps. aeruginosa* was the only organism responsible for early death, proving fatal in three of the 72 cases studied. The infections it caused were more severe and persistent than those caused by other organisms.
Four years later McLeod found a partial solution to the problem of urinary tract infections with coliform micro-organisms and Proteus species. By the introduction of a highly complicated technique he succeeded in keeping three long-term patients free from urinary tract infection for more than 10 weeks in contrast to the average period of 12.5 days.

The last in this group are two reports in the British Medical Journal of 1967 published a week before McLeod's eighty-first birthday. Three other authors' names precede his but the design and style of the reports bear McLeod's hallmark. Both papers are concerned with urinary tract infections but this time in newborns and children up to the age of 14. Technical difficulties in the collection of suitable specimens of urine in young subjects presented themselves but, after the examination of normal children and of children suffering from urogenital infection, it proved possible to establish a standard of $10^6$ cells/mm$^3$ combined with a bacterial count of $10^6$/ml in males and $10^5$/ml in females, below which infection was improbable.

**Heat-stable staphylococcal toxin, and a method for measuring leucocidal activity**

Presumably as the result of isolating large numbers of strains of staphylococci in his genito-urinary work, McLeod took up the study of thermostable toxin that many of the coagulase-positive strains of these produce. Death of rabbits injected intravenously with thermostable staphylococcal toxins occurred after 24 h. Only concentrated $\delta$-toxins produced death consistently; heat-labile $\alpha$-toxins caused death more usually within 5–30 min. Several strains of coagulase-negative staphylococci produced highly heat-resistant haemolysins that were active on human and rabbit red blood cells. These toxins were neither lethal nor antigenic, but were neutralized *in vitro* by normal serum. This curious neutralization distinguished these toxins from Elek and Levy's $\varepsilon$-haemolysin. During the course of this work he noted the presence of considerable quantities of leucocidin in heat-labile ($\alpha$) toxins, and of smaller quantities in heat-stable ($\delta$) toxins. With his second wife, Joyce, he found that the heat-stable leucocidins acted on leucocytes by producing cell disintegration, whereas heat-labile leucocidins stopped oscillation of the intracellular granules and altered the staining properties of leucocytes. Though Achard and Ramond in 1912 had formed the opinion that granular oscillation was independent of life, McLeod brought evidence to show that this was not so. The microscopic technique used was then applied to his study of the leucocidins that were thought to be present in diphtheria and tetanus toxins. In fact it was found that, in the absence of preservatives, purified specimens of these toxins contained no leucocidins. Leucocidins, therefore, could not be neutralized by commercial diphtheria antitoxin produced with such purified toxin. Yet, in the discussion McLeod expressed the belief that, in severe *gravis* diphtheria, leucocidins did play a part, because of the scarcity of leucocytes in the diphtheritic exudate. Apparently he must have overlooked the fact that in severe *gravis* diphtheria death intervenes too rapidly in cases coming to autopsy for an appreciable number of leucocytes to accumulate.
In this connection, it may be noted that McLeod had always hoped that some special pathogenic property of *C. diphtheria gravis* strains might be found, and was much disappointed when O’Meara’s claim for ‘substance B’ in extracts of strains could not be substantiated by other workers, amongst whom was a member of his own staff. It must be remembered that more than 15 years had elapsed since he had seen the last case of clinical diphtheria. Research on this subject by him and his team had long ceased for lack of material and topical interest. Perhaps one should take care not to go back to a problem that at one time was of the greatest interest to many people unless similar circumstances arose again. There is a lot to be said for Theobald Smith’s attitude that one should leave some work to be followed up and completed by others. After all, most advances are made by using work of predecessors as stepping stones. Moreover, posterity will always be the final judge of the value of any original work. And J. W. McLeod was an originator.

Summing up, it may be said that McLeod was a staunch laboratory worker. Though not a particularly able technician, he introduced numerous improvements into bench routine. As Professor Happold writes, there is no ‘doubt that his contribution to the development of diagnostic bacteriology was immense’. The reason for this was a combination of thoroughness, patience and determination to do the best, coupled with a wide knowledge of the literature of his subject.

**Personality**

I (G. S. W.) first met McLeod in 1912 when, as a prospective student, I was being shown round the Medical School of Charing Cross Hospital by the Dean. McLeod was working at a bench in the pathological laboratory. He was eight years older than I was, and I viewed him with some awe. His massive frame, his rugged features, and the serious, almost visionary, look in his half-closed eyes created in me an indelible impression. To my mind he appeared the prototype of a research scientist. Little did I think at the time that 60 years or so later I should be writing his obituary.

The next time I saw him was after the war when I listened eagerly to the opposing views of the bacteriological pundits of the day on the cause of epidemic influenza. Based on his own observations, McLeod cautiously favoured the aetiological role of Pfeiffer’s bacillus. Not till more than ten years later did Smith, Andrewes and Laidlaw show that the disease was primarily due to a filtrable virus. Though this finding has been generally accepted, it must be remembered that all diseases are multifactorial in origin, and that the part played by Pfeiffer’s bacillus in paving the way for the entry of the virus, or of complicating the disease it produces is still not fully understood. It would, therefore, be unfair to regard McLeod’s views as wrong; they expressed rather only one aspect of the truth as known at the time.

I never had the privilege of working with McLeod, but I met him fairly regularly at the meetings of the Pathological Society, and learnt to admire the enthusiasm with which he approached problems of research. The last time I
saw him must have been three or four years before the end. He was walking slowly and painfully with a stick, so differently from the rapid confident stride of his earlier days.

Those who were closer to him than I was were united in regarding him with respect and affection. His outlook on life was dictated by his Presbyterian upbringing and belief. He had a strict code of morals to which he not only conformed himself, but to some extent imposed with kindness on others. His presbyterianism was not that of his eighteenth-century forebears, with the narrow, harsh, inquisitorial bearing depicted, for example, by G. M. Trevelyan. Though he was a disciplinarian, he was humane, understanding, tolerant of the failings of others so long as he thought they were doing their best, putting the welfare of the individual first, just and fair in all his dealings, and the soul of honour and integrity. He was a non-smoker and a life-long abstainer from alcohol. However, he tempered his principles occasionally by consideration for others, and in his later years he learnt to enjoy a cigar. T. S. McLeod writes: ‘On one occasion he had found himself in a Danish Park with the wife of a scientist [Madsen] whom he was visiting. To his consternation she produced a picnic basket, poured out a glass of beer and handed it to him. “What was I to do”, he wrote [in one of his weekly letters to his family]? “We had no common language so how could I indicate that I had signed the pledge never to let alcohol pass my lips? After careful thought I decided that courtesy demanded that I should drink the beer, and I was surprised that the taste was not unpleasant, nor did I feel any sensation of intoxication. But did I act rightly?” He appeared genuinely relieved to find that there was general support [of his family] for his handling of the dilemma.’

His child-like innocence in matters of alcoholic drink showed also in the fact that he could never understand why his wife’s trifles did not compare in flavour with those of Mrs M. J. Stewart. When a dinner guest in the Stewarts’ house he invariably asked for a second helping of trifle ‘particularly from the juice at the bottom of the dish’. His enjoyment was so obvious and the amount of alcohol taken in this way so innocuous that none of those present on these occasions dared ever to tell him of Mrs Stewart’s trifle secret.

The McLeod household, though in a big family house, was conducted on very modest lines. Education of the six children took priority over everything else, and economy was strict, as it had to be when he gave away a proportion of his income to the church and to various charities. In 1948 his salary was almost doubled by the receipt of an ‘A’ distinction award. Of this he did not approve, as he considered that his achievements were due not solely to himself but to a team effort and to the conditions provided at the Medical School. He therefore handed over the annual award to the University, making sure, however, that the University took over the responsibility for settling the extra income tax demand. He practised and enjoyed the Spartan life; and at the Cambridge meetings of the Pathological Society in January would whistle cheerfully as he crossed the snow-covered quadrangle of the College to the common wash houses, clad in no more than pyjamas and a dressing gown. Because of his disapproval
of public transport on Sundays he insisted on his family walking to church. T. S. McLeod writes on this aspect of his father: 'He was meticulous in distinguishing essential tasks such as urgent requests from the hospital wards [or the laboratory confirmation of clinical diphtheria] from research and academic work which could be scheduled for week-days... On one occasion he found himself in the laboratory one Sunday morning an hour before the Church service was due to start. With him were the two older of his children, as he seized every opportunity of his children's company. After taking his readings he found there was just time to look at the monkeys. Accustomed as he was to working with mice and guinea-pigs, he was always reluctant to use cats or dogs, and when it was absolutely essential to use monkeys he was visibly upset. He did his best to make it up to them by patting and playing with them. This time he handed one to one of his children who carelessly allowed it to escape, and the next hour was spent in an exciting chase [helped by the animal attendant]. It probably never occurred to him that faced with the choice between an old-time Presbyterian sermon or a monkey chase his children would ensure that the quarry was not caught too soon.'

To quote from Sir James Howie, 'Walter, as he was best known to his friends, was a great microbiologist and a great character. As with great characters, remarkable legends as well as verifiable facts accumulated around him.' Both facts and legends were of equal importance in showing how his friends saw him. 'He was in every way a big man, handsome in appearance and generous in spirit', needing Epstein to do justice to so fine and so firm a face. 'Physically, mentally, and morally he was a fit man who enjoyed his strength and used it wisely.' When challenged he could assume a threatening bulldog expression, but equally when telling a humorous story he had an attractive glint in his eyes.

In his youth he was an athlete. In the opinion of Sir John McNee, he might have become one of the great rugby forwards for Scotland. His weight of 14 or 15 stone and his massive frame of solid muscle combined to make him a formidable opponent. Sir Gordon Cox, F.R.S., well remembers a game of football played when McLeod was over 60 years of age. Coming up against him, he said, was like coming up against a stone wall.

Throughout his life he was a great walker, covering long distances at a fast pace. He was also a fast driver of his motor car, causing often no little apprehension in his passengers.

As an elder of the Presbyterian Church he was concerned with parochial activities, and during the whole of his time at Leeds, and later at Edinburgh, he worked with the Boys' Brigade, going to camp with them in the holidays. He gave help to refugees, and was free from colour prejudice.

As an examiner of undergraduates he was fair and generous. According to the late Professor Tulloch, he would ask in the *viva voce* examination quite difficult questions in broad Scottish diction that the English students found difficult to understand. Even hearing was rendered difficult by his habit of closing his eyes and addressing his voice to the ceiling. Fortunately, however, their anxiety
was lessened when they realized that he was not only asking difficult questions but was also answering them. On one of these occasions the external examiner said to him that there was nothing to stop a candidate who answered the questions completely satisfactorily from scoring 100 per cent. McLeod decided to test this statement. Writing out a set of model answers to questions in the following examination he had them copied in longhand by his secretary to prevent his handwriting from being recognized and sent them with the other papers to this external examiner. When they came back the comment against his pseudonym was: 'This student is the best of a poor bunch but not really up to honours standard.' T. S. McLeod who contributed this story writes, 'Although the honours that he received gave him genuine pleasure he never forgot this salutary lesson on the fallibility of human judgement.'

His work, which often carried him long hours into the night, was directed particularly towards the welfare of the community. Whether at work or play he was vigorous, persistent and untiring. In his staff he created deep and permanent loyalty; his singleness of mind made him a whole man; and his character was an inspiration to all who knew him.

I (G. S. W.) am greatly indebted to Sir John McNee, Sir James Howie, Sir Gordon Cox, F.R.S., Professor K. E. Cooper, Professor F. C. Happold, and Mr Thomas McLeod and Mrs McLeod for the help they have given me; and in particular to Professor K. S. Zinnemann who has collaborated with me in the preparation of this Memoir.

The photograph reproduced was taken at Leeds, probably about 1950.

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