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Publication Date

2011-02-15

Peer reviewed

Submitted to *Physics in Canada*

Phil Wallace and Theoretical Physics at McGill in the 1950's: A personal perspective¹

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¹ This essay is the outgrowth of a talk given in the History of Physics session at the C.A.P. annual meeting in Saskatoon, June 18, 2007.

I. WALLACE'S PATH TO MCGILL

In 1946 Philip (Phil) Russell Wallace joined the *Mathematics* Department of McGill University as an Associate Professor of *Applied Mathematics*, apparently because A. H. S. Gillson, Dean of Arts and Science, wanted theoretical physicists to be in the Mathematics Department. He came with the dream of creating a theoretical physics group at McGill. By the spring of 1949, Phil was authorized to recruit two junior faculty in *Mathematics*. He hired Theodore (Ted) F. Morris from U. Toronto, who joined in September 1949, and me, who came in January 1950. The group had begun.

Phil Wallace was born in Toronto in 1915 and grew up there. He entered the University of Toronto in 1933, earned a B.A. in mathematics in 1937, a M.A. in 1938, and a Ph.D. in applied mathematics in 1940 under Leopold Infeld. His Ph.D. thesis in general relativity was entitled "On the relativistic equations of motion in electromagnetic theory."

In 1940 World War II had engulfed Europe and was having its effect on Canada, but the US was still at peace. L. J. Synge, Head of the Applied Mathematics Department at Toronto, told Wallace that people such as he would be needed in war work, but things were not ready quite yet. Hold yourself ready. Phil took a two-year position as lecturer in mathematics at the University of Cincinnati (1940-42); in the fall of 1942 he became a lecturer in mathematics at M.I.T. It was from there that he was recruited by Synge to join the war effort from 1943 to 1946 at N.R.C.'s Montreal Laboratory, the genesis of the Canadian Atomic Energy Project. Phil has described those heady wartime years in these pages.^[1] Much of the effort of the theoretical physicists was on nuclear reactor theory and the properties of relevant materials, such as graphite, under long and intense neutron bombardment. In late 1945 Phil was sent for four months to Bristol to learn about the properties of graphite from the esteemed N. F. Mott. This exposure led Phil to a life-long interest in graphite and in condensed matter physics in general.

Before World War II Canadian theoretical physicists were few and far between.^[2] The University of Toronto was one noteworthy exception, albeit with non-Canadians and in *Applied Mathematics*:

J. L. Synge (Irish), 1920-1925 and Department Head, 1930-1943;
Leopold Infeld (Polish), 1937-1950.

Another exception was the University of British Columbia:

George Volkoff (Russian-Canadian), B.A. and M.Sc., UBC, Ph.D. University of

California, Berkeley, joined the UBC *Physics* Department, 1940 -

After the war, the group of Montreal Lab theorists dissolved - some had already left for Los Alamos; some went to Chalk River; Volkoff returned to UBC to foster theoretical physics as part of physics in the West; Wallace to do the same in the East.

But the path at McGill was not smooth. As a singular anomaly in a pure math department, Phil was tucked away in the corner of some engineering building, remote from the bulk of the mathematicians. And there was no welcoming mat from Physics. As Wallace remarks, ". . . . I took a post at McGill, not surprisingly in the department of Mathematics. Certain complications of academic politics followed, such as jurisdictional disputes over course assignments. Theoretical physicists were treated more or less as foreigners or rivals by at least a segment of the physics department."² Why was that?

2. Ref. 2, p. 362.

McGill's attitude about theoretical physics was coloured for fifty years by the lingering influence of Ernest Rutherford, who was a faculty member from 1898 to 1907. In his essay about the beginnings of theoretical physics in Canada,^[2] Wallace quotes examples of Rutherford's views about theoretical physics. In short, theoretical physics is applied mathematics and has no place in a department devoted to the study of natural phenomena. Because of his eminence and connection to McGill, numerous physics graduates went to the "Mecca" of Manchester then Cambridge to do a Ph.D. with the great man. Some then returned to the McGill Physics faculty to teach and perpetuate the Rutherfordian view of theory.

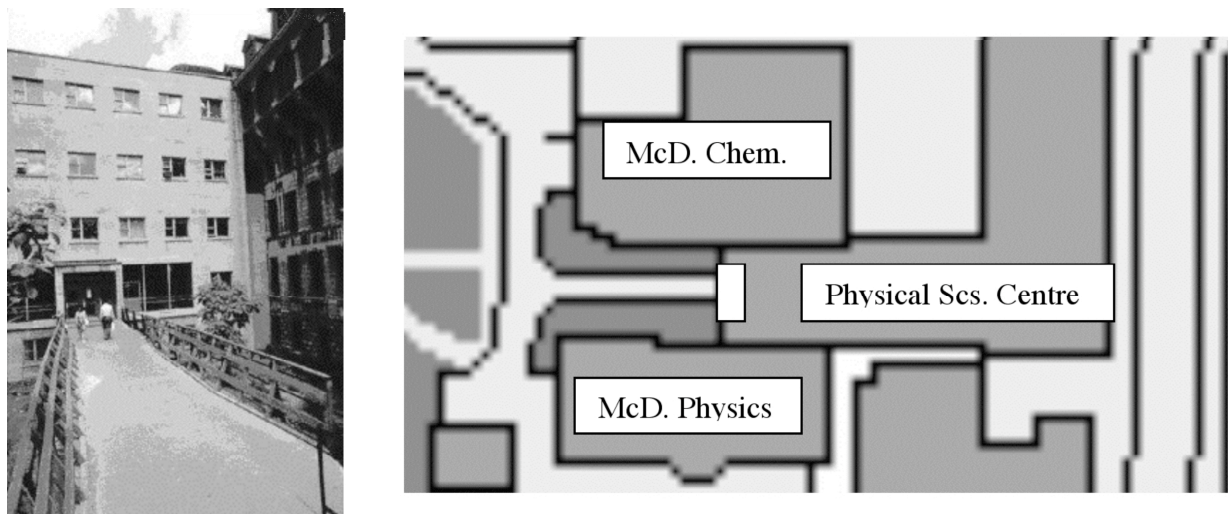


Fig. 1. View of the bridge into the Physical Sciences Centre and a segment of a map showing the location. The row of windows at the top in the photo are those of the Wallace group offices, indicated by the blank small rectangle on the map. The street at the right in the map is University Avenue.

II. BEGINNINGS AND PEOPLE

In 1949, with the imminent arrival of two junior colleagues, Phil was moved to more spacious quarters, the attic of the Arctic Institute of North America! At that point the Arctic Institute was housed on the first two floors of a large Victorian house on University Street at Milton, opposite the east side of the campus. The third-floor attic was our home for two years, until the Physical Sciences Centre (now the F. D. Adams Building) was completed in 1951. The Physical Sciences Centre was a four-floor building fronting on University Avenue, with its inner side linking the 50+-year old Macdonald Chemistry and Physics Buildings. On a large part of the top floor there were facilities - ventilation equipment and so on - but on the inner side there was space for a row of offices. See Fig. 1. Phil was able to arrange that his group of faculty and graduate students occupy this space, once access was created through the fan room and also, on one end, by stairs up from the Macdonald Physics Building (now the Macdonald Stewart Library). Progress was being made; we were inching closer to Physics! But for many more years we would be neither fish nor fowl.

As members of the Mathematics Department, we had "applied" duties such as teaching elementary differential equations to undergraduate engineering students. The largest part of our teaching was, however, to undergraduate and graduate students from the Physics Department, as well as our own graduate students. The undergraduate physics courses were the more theoretical ones - classical mechanics, mathematical methods of physics (a famous course taught by Wallace) - with atomic physics, electricity and magnetism, a lab-oriented course, and kinetic

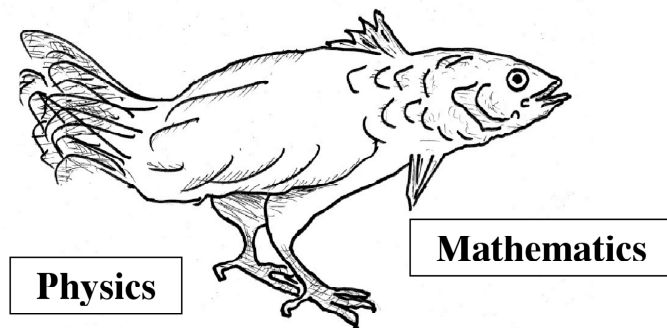


Fig. 2. Neither fish nor fowl: theoretical physics at McGill in the 1950's

theory and thermodynamics firmly in the hands of Physics. The latter was a speciality of Norman Shaw, long-time head of department, whose research and publications centered around the partial differential relations among thermodynamic variables.

As intimated by Wallace in the above quotation, there was some friction, but eventually the obvious graduate courses (quantum mechanics, electromagnetic theory, nuclear theory, etc.) became cross-listed in the catalogue.

Initial Roster

The roster of theoretical physicists in the McGill Mathematics Department by fall 1955 had grown to four:

- Wallace, Philip R., 1946 - 1982
retired as Professor of Physics
B.A. '37, M.A. '38, Ph.D. '40, Appl. Math. (all U. Toronto)
- Morris, Theodore F., 1949 - 1987
retired as Professor of Physics
B.A., '44; M.A., '45; Ph.D., Math., '48 (all U. Toronto)
- Jackson, J. David, January 1950 - 1957
on leave, '56 - '57
B.Sc., '46 (UWO); Ph.D., Physics, '49 (MIT)
- Sharp, Robert T., 1955 - 1988
retired as Professor of Physics
B.A., ? ; M.S., '50 (McGill); Ph.D., '53 (McGill)

Bob Sharp had been Phil's graduate student. After his Ph.D. he spent two years at the University of Alberta and then returned to McGill. Figure 3 shows this initial group of four.

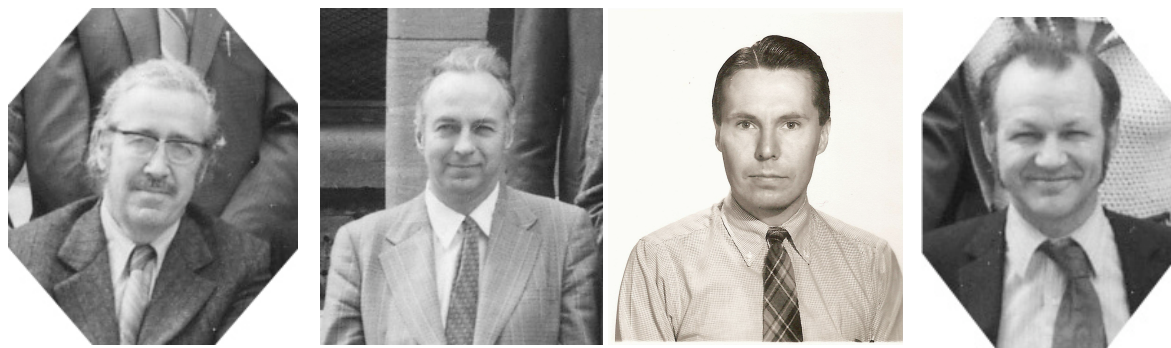


Fig. 3. (L to R) Phil Wallace, Ted Morris, Dave Jackson, Bob Sharp.

Next Complement

Starting in 1957, when I left for University of Illinois, the composition changed. Over the next four years, four new faces joined the theory group in the Mathematics Department:

- Lomon, Earle L., 1957 - 1960
B.Sc. '51 (McGill); Ph.D. '54, Physics (MIT)
- Kahana, Sidney H., 1957 - 1967
B.Sc., '54, M.Sc. '55 (Manitoba); Ph.D. '57, Physics (Edinburgh)
- Grisaru, Marcus T., 1960 - 1962 (visiting Asst. Prof.)
B.A.Sc. '55 (Toronto); M.A. '57, Ph.D. '59, Physics (Princeton)
- Margolis, Bernard, 1961 - since 1963, Professor of Physics; died 1995
B.Sc. '47, M.Sc. '49 (McGill); Ph.D. '52, Physics (MIT)

Figure 4 shows the second wave of four.

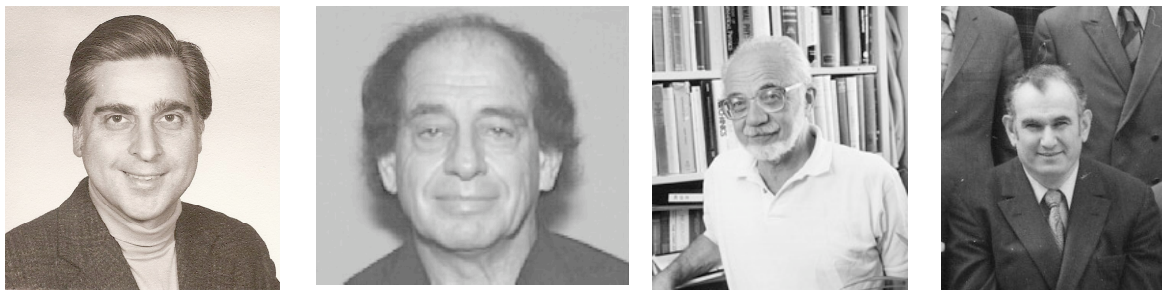


Fig. 4. (L - R) Earle Lomon, Sidney Kahana, Marc Grisaru, Bernard Margolis

Through these years Phil Wallace was the defacto leader of the group, which had no official standing in either Mathematics or Physics. He largely shielded us from bureaucratic concerns and provided scientific leadership through organization of seminars and other activities.

In 1960, Lomon returned to M.I.T., where he is still active in nuclear physics in retirement. In 1967 Kahana joined Brookhaven National Laboratory, where he remained, working at the interface of nuclear and particle physics, and recently retired. Grisaru went to Brandeis in 1962, where his research ranged over quantum field theory, including super symmetry and string theory, and then returned to McGill in 2000, as an adjunct professor. Margolis remained at McGill, as did three of the original four. Ted Morris, long retired, lives near Toronto; Bob Sharp died in 2001,^[3] Bernie Margolis died in 1995.

III. TEACHING AND COURSE LOADS

I have already mentioned our teaching of graduate quantum mechanics, electrodynamics, and nuclear theory to both physics and our own students, as well as our dose of mathematical courses for engineers. Ted Morris recalls teaching calculus to engineers, elementary quantum mechanics to chemists, statistical mechanics, and graduate and undergraduate mathematical methods in physics.

The teaching loads were heavy by present day standards, typically five semester-courses each year. To illustrate, here is one person's teaching load for three academic years:

Quantum Mechanics I (Math 62=Phys 62)
Diff. Eqns. for Eng'rs (Math 1260)

Fall 1951

Quantum Mechanics I
Electromagnetic Theory I (Math 68)
Seminar in Appl. Math.(jointly)

Fall 1952

Electromagnetic Theory I (Math 668)
Theoretical Nuclear Physics I (Math 672)
Seminar in Appl. Math. (jointly)

Quantum Mechanics II (Math 62=Phys 62)
Advanced Dynamics (Math 48b)
Diff. Eqns. for Eng'rs (Math 1260)

Spring 1952

Quantum Mechanics II
Electromagnetic Theory II (Math 68)
Advanced Dynamics (Math 48b)
Seminar in Appl. Math. (jointly)

Spring 1953

Electromagnetic Theory II (Math 668)
Theoretical Nuclear Physics II (Math 672)
Advanced Dynamics (Math 48b)
Seminar in Appl. Math. (jointly)

A vignette about the proprieties of classroom teaching at McGill in the 1950's

A vignette about the proprieties of classroom teaching at McGill in the 1950's

Fifty years ago a male lecturer was expected to wear a shirt and tie and a suit, or slacks and a sports coat. Many at McGill wore in addition a black academic gown. My practice from the beginning was to enter the classroom in jacket, shirt, and tie. I would then remove my jacket before the lecture began and place it on the lecture table, so that I would have better freedom of movement at the blackboard (and to give a message to the class that we were here to work).

One day, the lecture room door remained open for stragglers as I was removing my jacket. A certain Physics professor happened to pass by . . . No, he did not burst in to admonish me. That would have been quite improper. But he did return at the end of class after the students had left. As I was donning my jacket, he pointed out kindly but firmly that "we" did not lecture in shirt sleeves, and that a gown was preferable! I am sure his intentions were of the best- setting a new faculty member on the right path. The impertinent young man did not change his ways.

My Ph.D. and M.Sc. students

In my seven and one half years at McGill, one on leave, I supervised two Ph.D. students and three M.Sc. students. Their names and thesis topics and photographs are given in chronological order:

Schiff, Harry, Ph.D., 1953

Theoretical calculations of electron capture cross sections.



Vosko, Seymour H., M.Sc., 1953

Theoretical interpretation of radiation emitted in neutron capture reactions.



Betts, Donald Drysdale, Ph.D., 1955

A theoretical investigation of resonance electron capture cross sections.

Reeves, Hubert, M.Sc., 1956

The formation of positronium in hydrogen and helium gases

Chapdelaine, J. L. Marc, M.Sc., 1956

Scattering of positrons by hydrogen atoms and formation of Positronium.

[no photo available]

Harry Schiff, still active in his retirement in British Columbia, went to the University of Alberta for his whole academic career. His research is largely in field theory and model building; his service included being departmental chair and director of U. Alberta's Theoretical Physics Institute. Seymour (Sy) Vosko went on to Carnegie Tech to do a Ph.D., taught at McMaster

University, and after a period in industry, resumed his academic career at the University of Toronto in 1970. His research was in condensed matter physics. He died in 1994 at the age of 65. Donald Betts went first to the University of Alberta, then after 24 years, went east in 1980 to his beloved Nova Scotia, to Dalhousie University, where he was Dean of Arts and Science for ten years. His research was in statistical mechanics and spin systems. He was elected President of the Canadian Association of Physicists while at Alberta, and in the 1990s became Editor of the Canadian Journal of Physics. He retired in 1994 and lives in Halifax, now in poor health. Hubert Reeves went to Cornell to do a Ph.D. in astrophysics, taught in Montreal for a time, and then went to France where since 1965 he is a Directeur de Recherches au Centre National de la Recherche Scientifique, Paris. He is prominent in Europe as a popularizer of science on television and through his books. I have lost track of Marc Chapdelaine.

IV. PERSONAL RESEARCH ACTIVITIES

My own experiences in research at McGill illustrate how, although the theorists were held at arm's length from Physics (except for the teaching of their students), informal relationships could occur because of common interests in research. My Ph.D. (MIT, 1949) was in theoretical nuclear physics. The first course I taught (Spring 1950) was Mathematics 672, Theoretical Nuclear Physics. The students were a mix of mathematics and physics graduate students.

Initially, I worked on atomic collision processes, as you can tell from the thesis topics of my students, but nuclear physics was still central to my interests. Inevitably I looked to the nuclear experimentation in the Physics Department. The major activity was at the Radiation Laboratory (Fig. 5), up on the hillside beyond Engineering, where Professor John Stuart Foster had constructed a 100 MeV cyclotron, patterned after the one built at Harvard by Norman Ramsey. At Foster's invitation, I began an association with his Rad Lab, with a small office (Fig.6) where I could do my own research and be available for discussions with the experimenters (some might say, as a part-time "house theorist"). The connection with the experimenters was mutually beneficial, leading to some solo and joint 10-minute papers at American Physical Society meetings, as well as regular publications of theory relevant to some of the experiments.



Fig. 5. Foster Radiation Laboratory, named after E. O. Lawrence's Radiation Laboratory in

Berkeley. Built in 1948; demolished in 1996. The cyclotron was housed in the building in the rear of the lab/office structure.

Regrettably, there was no extracted proton beam. Experiments were largely creation of new radioactive isotopes by bombardment of internal targets, although an external neutron beam from protons on a internal beryllium target permitted some neutron scattering and reaction dynamics to be studied.



Fig. 6. *Left*: Physics Professor William Martin (left) and the author at a seminar at the Radiation Laboratory in the mid-1950s. *Right*: My small Rad Lab office, as viewed from the doorway.



Fig. 7. McGill Physics faculty and staff (plus one) on the steps of the Radiation Laboratory on

the occasion of J. S. Foster's retirement as department head, 1955.³

3. *Front row*: Mr. D'Angelis, E. R. Pounder, A. McPherson, J. S. Foster, G. Woonton, H. Watson, F. R. Terroux, R. Whitehead. *Second row*: S. Wagner, J. D. Jackson, G. T. Ewan, J. S. Marshall, M. Telford, W. Hitschfeld, K. Gunn.

John Stuart Foster, although gruff and opinionated, was the one Physics faculty member who showed no reluctance to welcome a theoretical physicist to his laboratory.⁴ See Fig. 7. His

4. Gar Woonton, Director of the Electronics Laboratory next door, was perhaps another. He came to McGill by a different route as well.

attitude stems perhaps from his different route to McGill. He did his Ph.D. at Yale in the mid-1920's, studying the Stark effect in hydrogen and helium. By 1927 he was publishing extensive experimental results on helium in the Proceedings of the Royal Society^[4] and, while visiting Bohr's Institute in Copenhagen that year, publishing Born-Heisenberg-Jordan matrix-mechanics calculations on helium to compare with his data.^[5] Foster did not have the aversion to theoretical physicists of those in the Rutherford tradition.

V. CODA AND PAEAN: THE MOVE TO PHYSICS & PHILIP RUSSELL WALLACE

In 1946 Phil Wallace was appointed associate professor of applied mathematics in the *Mathematics* Department at McGill, apparently at the whim of a Dean. From 1946 to 1961 Wallace's group in Math flourished and grew from one to six under Phil's leadership. By 1961 the group coalesced around the desire to join Physics and Physics was willing. With the help of a different dean, in 1961-1962 the anomaly was corrected; the theorists became equal members of the now enlarged Physics Department.

Today theorists of all stripes comprise about 35% of the 40-some regular active McGill Physics faculty, all housed in the Rutherford Physics Building, constructed in 1977 up the hillside, slightly east of the site of the Foster Radiation Laboratory. Theory postdocs (and visitors) and theory graduate students are in closely the same proportion - 14/41 and 61/166, respectively. Among the theory faculty, I count six in high-energy physics, six in condensed matter physics, two in nuclear physics, and perhaps others in other undifferentiated fields.^[6] Clearly, theoretical physics at McGill is well established in its rightful place, on a par with other research universities in North America.

While before them there were isolated examples of theorists in Canadian physics departments, Phil Wallace in the east and George Volkoff in the west planted the seeds that led to theoretical physicists playing a significant role in every sub-field of Canadian physics. Wallace's role in efforts other than at McGill - his personal research, his involvement in the C.A.P., his visits to Toulouse, his administrative positions after retirement - would take us too far afield. For these aspects the reader may consult "In Memoriam" by Bélas Joós in *Physics in Canada*^[7] and the obituary in *Physics Today*.^[8]

But I cannot omit mention of his pioneering 1947 work^[9] on the band theory of graphite, including the basic theory of graphene, subject of the 2010 Nobel Prize in Physics. Wallace showed, among other things, that at low energies the $E(k)$ dispersion relation is linear: there is no gap; the electrons and holes have zero effective mass, an important property of the single-layer of graphite.

I restrict myself now to providing comments from others on Phil's influence as a teacher. But first I list, in chronological order of awarding of degree, his 33 M.Sc. and Ph.D. students in his 35 years of teaching at McGill.

Wallace's M.Sc. and Ph.D. students

Golbfarb Lionel	M.Sc. 1948	Geher Leslie	M.Sc. 1962
Logan Ralph A.	M.Sc. 1948	McKay Carlyle D.	Ph.D. 1962
Rouly Paul M.	M.Sc. 1948	Chan Kam H.	M.Sc. 1963
Margolis Bernard	M.Sc. 1949	Matz Detlef	Ph.D. 1963
Watson Hugh A	M.Sc. 1949	Richardson John R.	M.Sc. 1963
Schiff Harry	M.Sc. 1950	Morris Stanley P.	Ph.D. 1964
Jardine William G.	M.Sc. 1950	Brews John R.	Ph.D. 1965
Gottfried Kurt	M.Sc. 1953	Jog Shridhar D.	Ph.D. 1965
Sharp Robert T.	Ph.D. 1953	Stavn Melvin J.	M.Sc. 1965
Williams Rosco C.	M.Sc. 1953	Caillé Alain	M.Sc. 1969
Eliopoulos Hermes A,	M.Sc. 1954	Reiss Micheal L.	M.Sc. 1969
Puhach Paul A.	Ph.D. 1956	Sanders John	Ph.D. 1970
Haering Rudolph R.	Ph.D. 1957	Caillé Alain	Ph.D. 1971
Murphy Joseph	M.Sc. 1958	Veronneau Pierre	M.Sc. 1971
Masson David R.	M.Sc. 1959	Birecki Henryk	M.Sc. 1972
Khare Harischandra	Ph.D. 1960	Joós Béla	Ph.D. 1978
Storey Samuel R.	Ph.D. 1960		

Phil's philosophy and influence has been multiplied through these students, many of whom have gone on to distinguished careers.

Phil Wallace's Teaching and Advising

A superb lecturer and demanding instructor, Phil was inspirational, especially in his undergraduate course in mathematical physics. Here are three students, one subsequently a M.Sc. student under Phil, who remember that course and speak of his role in other aspects of their education; the fourth, a younger faculty colleague, speaks of Phil's mentoring in research:

Kurt Gottfried, B.Eng., '51, M.Sc., '53 (McGill); Ph.D., '55 (MIT):

“Phil’s Math Phys course was a turning point in my life. Had he not been there I would never have become a physicist. To me it was the most important course I ever had at McGill, MIT, or Harvard, including superb courses by Jackson, Weisskopf and Schwinger.

“Phil’s personal style was totally different from the other faculty at McGill I had encountered before he came into my life: warm, engaging, enthusiastic, unpretentious, intellectually tough and demanding. It was clear he was interested in what was going on at the cutting edge across the field, and not just in his own specialty, and that he saw physics as a great adventure.”

John Harnad, B.Sc., ‘67 (McGill); D. Phil. ‘72 (Oxford):

“I was an honours physics student at McGill 1963-67, and had quite a lot of interaction then with Phil Wallace. He taught me quantum physics, I wrote my first paper with him (on helicons) while still an undergraduate, and he arranged for me to have a Shell scholarship to go to Oxford for my D.Phil. He was a wonderful person, and a great inspirer of enthusiasm and love for the subject in young physicists.

.....the only course in which we felt we were doing ‘real, live physics’ was Phil Wallace’s. Everything was described with vividness and enthusiasm. Nothing was taken for granted - and nothing was ‘too advanced.’ ”

Harry Lam, B.Sc. ’58 (McGill); Ph.D. ’63 (MIT); Chair, McGill, ’76-80

“When I came over from Hong Kong in 1955 I went to the U of Ottawa to study electrical engineering . . . After a year I decided engineering was not for me . . . so I decided to transfer to McGill to go into Math and Physics. . . . McGill admitted me but I had trouble getting into Hon M&P. . . . Physics would not take me. Math would take me in Hon Math, Appl. Option third year, but to get into Hon M&P, Physics had to agree. The Math Chair sent me to Phil Wallace. . . . Phil was very sympathetic and told me I should not go into Hon Math. He went out of his way to talk to people in the Physics Department and somehow persuaded them to agree to take me into (third year) Hon M&P. [Physics] grudgingly agreed.

“Without Phil I would either have been a mathematician now, or back at U of Ottawa. I owe my whole career to Phil for what he did right there. That is so characteristic of Phil; he was not conventional and would not accept the common wisdom if he thought he was right in doing something different.”

Sidney H. Kahana, B.Sc. '54, M.Sc. '55 (Manitoba); Ph.D. '57 Physics (Edinburgh); faculty colleague of Wallace, '57- '67:

Phil Wallace was responsible for my first job, at McGill, as a visiting Assistant Professor while Dave Jackson was away at Princeton University for a year. Dave never came back and I stayed for a decade.

Phil was a pioneer in theoretical physics at McGill as an active researcher and enlightened teacher. He put me on to the then existing problems with positron annihilation in metals, which I

approached with non-relativistic field theory, and a one-legged Bethe-Goldstone equation. He attracted very good undergraduates to our programs in Honours Maths and Physics, as well as of course, with considerable effort, building up an equally good graduate student population.

He had a unique skill at encouraging young people, listening and instilling confidence with positive reinforcement. A remarkable trait with many good results. Many of his old students passed by (or stayed for a while) and became acquaintances - Arthur Kerman, Kurt Gottfried and others - or colleagues - Earle Lomon, Bernie Margolis.

Conclusion

Although the theoretical physics group at McGill in the 1950s had no official standing and no statutory leader, Phil Wallace was that leader and builder of the group. An inspiration to students and junior colleagues alike, he protected and nurtured us in the sometimes difficult circumstances of citizens without a country.

He gave me my first academic job and propelled me on my way. I chose to go a different path, but those that stayed were part of a flowering of theoretical physics as an equal sub-field within the McGill Physics Department.

“Things Change” (David Mamet film)
“All’s Well That Ends Well”
 (Shakespeare)



Philip R. Wallace
 1915-2006

ACKNOWLEDGEMENTS

Thanks to Charles Gale, Chair, McGill Physics Department, and especially to Jean Barrette, for their patient assistance. Thanks also to Kurt Gottfried, John Harnad, Béla Joós, Sidney Kahana, Harry Lam, Ted Morris, and Harry Schiff for valuable input. This work was supported by the Director, Office of Science, High Energy Physics, U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

REFERENCES

1. P. R. Wallace, "Atomic Energy in Canada: Personal Recollections of the Wartime Years," *Physics in Canada*, Mar/Apr 2000, p. 123-131.

2. P. R. Wallace, "The beginnings of theoretical physics in Canada, *Physics in Canada*, Nov 1993, p. 358-364.
3. *Symmetry in Physics, In memory of Robert T. Sharp*, P. Winternitz, J. Harnad, C. S. Lam, and J. Patera, eds., CRM Proceedings and Lecture Notes, Vol. 34, 2004 (American Mathematical Society). Two tributes to Sharp, by P. R. Wallace and J. Harnad.
4. J. S. Foster, "Stark Patterns Observed in Helium," *Proc. Roy. Soc. (London)* **A114**, 1927, 47-66.
5. J. S. Foster, "Application of Quantum Mechanics to the Stark Effect in Helium," *Proc. Roy. Soc. (London)* **A117**, 1927, 137-163.
6. McGill Physics: People in Physics, at <http://www.physics.mcgill.ca/people/faculty-f.html>
7. B. Joós, "In Memoriam, Philip Richard (sic) Wallace, 1915-2006," *Physics in Canada*, July/August 2006, p.134.
8. Kurt Gottfried, John David Jackson, and Harry C. S. Lam, "Philip Russell Wallace," *Physics Today* **59** (9) 78 (September 2006).
9. P. R. Wallace, "Band Theory of Graphite," *Phys. Rev.* **71**, 1947, 622-634.

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