même d'avoir un Ministre de la Science et de la Technologie semble assurer que les questions concernant la science et la technologie resteront à l'arrière-plan.

Ainsi, lorsque le Ministre de la Science et de la Technologie est au bas de l'échelle d'un gouvernement, il est facile de s'imaginer quelle place prennent les questions scientifiques dans les réunions du Cabinet.

Une autre illustration de cette faiblesse fut donnée lorsque le Ministre conservateur admit n'avoir pas pu convaincre ses collègues du Cabinet de l'importance de l'allocation de fonds aux programmes scientifiques essentiels. Il reconnut que le problème tenait à « . . .la facilité avec laquelle le Cabinet alloue des fonds pour un problème que l'on veut résoudre le lendemain matin ». Mais les dividendes de la science, ajoutait-il, ne seront touchés qu'en 1989 ou 1990.

La science et la technologie souffrent non seulement à cause de l'organisation gouvernementale mais aussi parce que vous-mêmes ne faites pas assez pour faire valoir vos intérêts. Le gouvernement ne peut pas tout faire. Vous avez un rôle primordial à jouer.

Je suis député depuis plus de 6 ans et je n'ai que rarement été approché par des scientifiques. Parmi la longue liste de groupes d'intérêt qui approchent les parlementaires, — l'Association des manufacturiers canadiens, le CCC, le BCNI, le Conseil national du travail, les groupes autochtones, ethniques, féminins et j'en passe, mais c'est très rarement, à des occasions spéciales, que des chercheurs universitaires m'ont écrit. Toutefois, oui, j'ai reçu l'année dernière, à titre de Critique pour la Science et la Technologie, à cause des coupures au Conseil national de recherches et à Environnement Canada, de 15 à 20 lettres ou copies de lettres adressées au Ministre de la Science et de la Technologie, au Chef de l'Opposition et au Premier ministre. C'était inhabituel. Quant à la période, plus longue, pendant laquelle je n'étais pas spécialement rattaché au dossier de la science, ces lettres furent beaucoup moins fréquentes.

Il est donc clair que le Ministre de la Science et de la Technologie n'arrive pas à obtenir l'attention de ceux qui prennent les décisions cruciales qui nous concernent. A mon avis, ceci veut dire que les scientifiques et chercheurs devront le faire eux-mêmes. Si vous, réunis dans cette salle, ne vous impliquez pas davantage, il est peu probable que les questions touchant à la science auront la priorité qu'elles méritent à la table du Cabinet. Pour ce faire, il est absolument nécessaire que chaque député comprenne l'importance de la science et de la technologie. Il est aussi nécessaire que vous communiquiez à vos députés, dans vos propres localités et leur fassiez prendre conscience de l'étroite relation entre science et emplois. Ce n'est donc pas seulement à la fermeture de l'usine d'à côté que les députés doivent s'arrêter, mais au lien entre la recherche et le développment et cette même fermeture d'usine.

Unification of Fundamental Forces*

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Overwhelming experimental evidence has accumulated over the last decade for the unification of electromagnetic and weak subatomic particle interactions. This success has motivated the international high energy physics community to seek further evidence for the inclusion of strong interactions in a broader unification of elementary particle forces. Indeed, such unification has been successful in predicting the relative strength of strong, electromagnetic and weak interaction coupling constants.

Most recently the attention of many theorists turned to the pursuit of an even bolder goal: the unification of gravity with the other three fundamental forces. This latest pursuit has recently made impressive and exciting gains in several areas, to such an extent that some leading theorists believe that we may have already found the correct theoretical framework for the desired unification.

The gravitational force is one of the phenomena of nature that holds scientists and laymen alike in deepest fascination. It is certainly the one natural force that exerts the strongest influence on our collective destiny. Yet, despite the fact that our first understanding of it three hundred years ago launched the beginning of modern physics and that our present understanding has allowed man to probe deep into the cosmos far from earth, gravity may well be the least understood of the four fundamental forces.

There is a consensus that before a true understanding of the theory of gravity is achieved, we must learn how it can be quantized; at the moment there are only classical formulations of the theory. It is known that neither Einstein's gravity nor any of its empirically acceptable extensions can be quantized using standard techniques. Any attempt to quantize gravity is invariably beset by uncontrollable infinities which render the outcome of any calculation meaningless.

Infinities also occur in any calculation involving the Yang-Mills gauge theories that underly the electromagnetic, weak and strong forces. But such infinities can be absorbed in rescalings of field theoretical quantities by a well defined "renormalization" procedure. Consequently such theories are capable of generating finite results that can be compared with experimental data to any desired degree of accuracy.

Although quantized Yang-Mills theories are renormaliable, a theory completely free of infinities would be even more desirable. In recent years it has been found that in theories where (integer-spin) bosons and (half-integer-spin) fermions are united by "supersymmetries", the degree of infiniteness is reduced. Some supersymmetric theories are in fact completely finite; i.e. those infinities which do occur cancel among themselves without being absorbed in rescalings (as discussed above). Interestingly, when supersymmetric transformations are made to depend on spacetime, or are localized, the ensuing theory — supergravity — automatically contains gravity. Unfortunately, no known supersymmetry is sufficient to render the corresponding supergravity theory finite.

Another related development in the last few years is the realization that a convenient way to generate supersymmetric theories in four-dimensional spacetime is to start with an ordinary theory in a spacetime with extra (i.e., more than three) spatial dimensions and then reduce the theory to a four-dimensional one. In a way the extra space dimensions

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in the original theory become the internal space upon which supersymmetries (and other internal symmetries) transform.

This realizitation lead to a revival of the sixty-year old Kaluza-Klein [1] idea that the real spacetime may indeed have more than three spatial directions, an idea that was originally proposed for the purpose of uniting Einstein's gravity with Maxwell's electromagnetism. In Kaluza-Klein theories the extra-dimensional spaces are taken to be physical, but in order to accommodate the physics of the apparent four-dimensional world, the extra dimensions must be compact (closed onto themselves) and have an extremely small size — of the order of the Planck length, or approximately 10^{-32} cm. This means that the existence of the extra dimensions would be manifest only on an energy scale approaching the Planck mass at approximately 10^{19} GeV. This unimaginably large energy scale, beyond the reach of any conceivable accelerator, may nevertheless be probed through ingeneous future experiments: for example, present day proton decay experiments are actively probing interactions mediated by particles of mass 10^{15} GeV.

Finiteness is not the only issue in the search for a unified theory. The most important other criteria for an acceptable unified theory are: cancellation of anomalies (an anomaly is the violation of a classical conservation law by quantum effects), reduction to a low energy ($\sim 10^{15}$ GeV) gauge theory with asymmetrical left- and right-handed fermions (chiral fermions), and reduction to four-dimensional gravity in which spacetime is essentially flat in the absence of matter (vanishing cosmological constant). In the last year or so, through the brilliant efforts of Green, Schwarz, Witten, Gross, and others [1,2] , a class of theories that appear to satisfy all the criteria except the one concerning the cosmological constant has emerged.

The fundamental geometric entity of these theories is not the point particle. Instead these theories are based on one-dimensional extended objects, or strings, whose length is of the order of the Planck length. So far, two phenomenologically acceptable superstring theories (as they are called) have been found: the theory of Green and Schwarz, [2] in which open strings live in a ten dimensional spacetime, has the simplest (N=1) supersymmetry, and an SO(32) (the rotation group in thirty-two dimensions) internal gauge symmetry. An alternative theory due to David Gross and collaborators [3] at Princeton University (called the "Heterotic" string theory) consists of only closed strings whose fermionic degrees of freedom live in a 10-dimensional spacetime, while the bosonic degrees of freedom propagate in 26 dimensions. The supersymmetry is again N=1 but the gauge symmetry is the exceptional group $E_8 \times E_8$.

It was precisely with the above exciting developments in mind that twenty-four Canadian physicists met at the University of Western Ontario for a CAP Summer Theoretical Institute/Quantum Field Theory Workshop, from July 19 to August 9, 1985. The purpose of the meeting was to promote discussion and collaboration among the participants, whose expertise covered those aspects of quantum field theory that are essential to a better understanding of superstring theories: anomalies, Kaluza-Klein theory, regularization and renormalization, and of course superstring theory itself. The workshop, directed by G. McKeon, was divided into four sections focusing on the above specific topics and organized respectively by R. R. Mann (Anomalies), G. Kunstatter (Kaluza-Klein), G. Leibbrandt (Regularization) and K. S. Viswanathan (Superstrings). Financial support was provided by NSERC, IPP and the University of Western Ontario. The proceedings of the workshop will be published in a special section of the Canadian Journal of Physics. Considerable progress was made during the workshop in all the above areas and many collaborations were commenced. The meeting was so successful, in fact, that another meeting is already being planned for the Summer of 1986 at Simon Fraser University.

It is not clear at this stage whether superstring theories will indeed provide the golden fleece sought by modern quantum field theorists, namely a finite and consistent unified quantum theory including gravity. In any case, the workshop at the University of Western Ontario did provide a forum for a strong community of Canadian physicists to attack such ambitious topics as the unification of all the fundamental interactions.

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