Institute *of* **Physics**

History of Physics Group

Newsletter

Spring 2000

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Contents

Editorial

Welcome to the 2000 edition of the History of Physics Group Newsletter. I was going to say "the first issue of the new millennium", but I expect that would open up a large can of worms. If you did celebrate on December 31st last year, then I hope it went well. If you're saving your celebrations for this coming December, then you've got it all to look forward to, and at least the Millennium Wheel might be properly open to the public by then ...

The "Blue Plaques for Physicists" project is slowly developing. We have had a good response from people willing to help by taking a photo or writing a couple of paragraphs about their local physicist, but there are still some gaps, so if you would like to take part, do get in touch (my contact details are overleaf). In the meantime, a plaque of a slightly different kind was unveiled at IOP head-quarters in the summer: a <u>white plaque for a non-physicist</u>! (see page 8).

We have had several very successful meetings in the past year, and much of this issue is devoted to coverage of these. Starting on page 9, you'll find an edited transcript of the extremely interesting and moving talk given by Professor Sir Joseph Rotblat on his <u>early years as a physicist in Poland</u>. Professor Rotblat has kindly spent time correcting the transcript, and has allowed us to print some of the few existing photos from the time.

The meeting on <u>Physics and Religion</u> was held in Edinburgh and in London, and was extremely well attended on both occasions. You can read papers based on six of these talks, taking many different angles on the subject, from page 24. We celebrated 200 years of current electricity with a meeting on <u>Volta and the Invention of the electrochemical battery</u> – a review of this starts on page 63.

See page 67 for <u>future meetings arranged by the group</u>, followed by <u>other meetings at home and abroad</u>. And, as always, do get in touch if you have any comments, ideas or suggestions to do with the newsletter.

Dates for your diary:

- Saturday 26th February (may have passed)
- Monday 12th June (evening)
- One Saturday in October

Lucy Gibson

NB My name has changed as I was married in October last year, to another member of the History Group!

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Chairman's Report

given to the Group at the AGM on October 23rd 1999

1. Meetings

This has been a particularly vigorous year for the group. On the 17th October 1998 we had the most successful of our "concepts" meetings to date, on Electromagnetic fields past and present. We had lectures on *Faraday and Field Theory* by Dr Frank James, *Concepts of Action at a Distance* by Dr Roman Smirnov-Rueda and I spoke on *Modern Concepts of the Electromagnetic field*. It was well attended with a stimulating workshop and discussion afterwards.

We held our annual planning meeting at the Science Museum on 5th December 1998, and got through a considerable amount of work. These meetings, entirely devoted to planning, are indispensable for the effectiveness of the group.

On 8th March 1999, Professor Joseph Rotblat gave an extraordinary evening lecture at IOP headquarters on his physics research experiences in Poland before the War. The meeting was very well attended. Not the least surprising aspect of the occasion was the fact that Professor Rotblat is in his nineties and conducted the whole meeting with an energy which would be the envy of someone thirty years younger.

On 24th April 1999, we had an afternoon meeting at IOP headquarters on Aspects of the interaction between physics and religion. The meeting generated considerable interest, not least perhaps because of the communication from Sir Hermann Bondi contrasting the investigative styles of physics and religion *[see page 25. Ed.]*. Lucy Hudson collected comments from the participants asking why they attended. One amused me particularly: "Annoyance with Richard Dawkins and P C Atkins. Here's a sensible middle way between science and religion and I wanted to find out a little more about the relations between the two".

Stuart Leadstone organised an amplified version of this meeting at Maxwell's birthplace in Edinburgh on 18th September 1999. Physics World heard of it and asked us to write a piece for *Physics Matters* about it, which appeared in the September 1999 issue of Physics World. The Edinburgh meeting was highly successful. We may have begun a trend: Dr. Frank James is running a discussion evening at the Royal Institution on Science and Religion on 9th November [1999] which Peter Atkins, among others, is addressing. The debate runs on.

On the 24th April, we also held a very useful committee meeting over lunch in the Institute of Architects in London. I think it is important that we work so that our meetings continue to be successful.

2. Newsletter and Website

Lucy Hudson brought out her first issue of the *Newslett*er in the spring Spring 1999 (No.12) and for the first time put it on the website. I have received many compliments about the Newsletter and Lucy is much to be congratulated on the quality, contents and presentation. She has set herself a high standard to follow. Mike Thurlow has taken on the task of looking after our website. I think you will all agree that it is now a delight to visit the home page of the group. Mike deserves our gratitude for its professionalism and appealing layout.

3. Elections

Both Neil Brown and I have reached the full term of 5 years in office and we are stepping down to make way for new officers. I approached Jack Meadows for suggestions about a new chairman and he suggested I approach Sir Arnold Wolfendale, which I did. He was delighted with the offer but is overwhelmed at the moment and recommended I invite Professor Ian Butterworth, a high energy physicist at Imperial College. Ian was very pleased to be nominated for the post of Chairman and I think he would be excellent for the group. He seems to be a very pleasant person. He would not be able to take up office until the Spring and I said I would be happy to act as caretaker until then.

I would like to take this opportunity to thank Neil Brown for his services as Honorary Secretary to this group. It has been a great pleasure working with him. I have been struck again and again by his efficiency, his determination, his unfailing good humour and courtesy. I do hope he considers remaining on the committee. I would also like to thank the other committee members for the support they have so generously given over the years. The personal rapport and warmth established between committee members has not been the least enjoyable aspect of our meetings.

John Roche,
Chairman

Honorary Secretary's Report

given to the Group at the AGM, October 23rd 1999

The Honorary Secretary had little to add to the Chairman's report. The group still has about 400 members. Only a minority took any active part by attending meetings, but by paying their subscriptions they indicate a continuing interest. The funding that groups received from the IOP has been increased. We can support all the activities we were undertaking without difficulty, and the budget could be stretched further if we had the other resources to organise more activities. There are still some tensions between the group and headquarters over costs in two particular areas. One is the old problem of one-day meetings. While the principle of charging non-members higher meeting fees is not in dispute, the enforced extra charge of £23 regardless of circumstances can be counter-productive. It meant, for example, that non-members paid two-and-a-half times as much as members to attend the recent meeting in Edinburgh, although the meeting benefited greatly from their presence. Another irritant is the charges for catering for meetings at Portland Place on Saturdays which make the provision of coffee and tea very expensive.

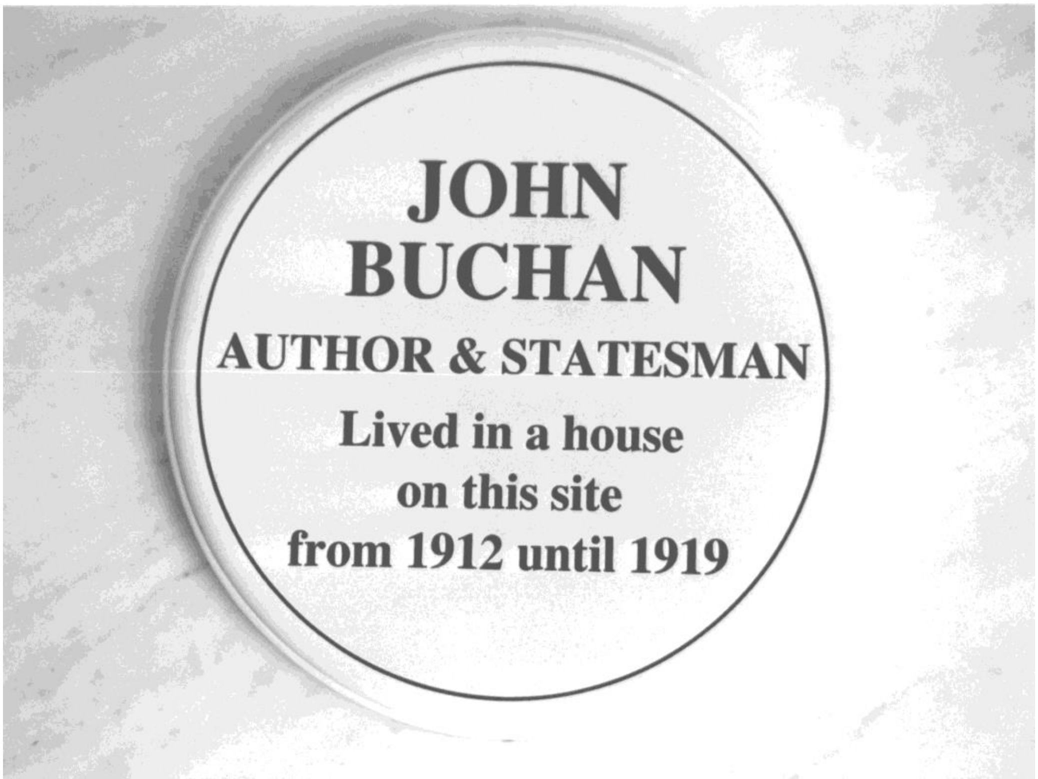
The secretary paid tribute to the Chairman, who was likely to stand down from that role before the next Annual General Meeting. John Roche had been chairman for years, but that is only the latest of his contributions to the group. John, more than any other person, was responsible for the founding of the group, and he put a lot of time and effort into the running of it ever since. We hope to continue to benefit from his insight.

Neil Brown,
Honorary Secretary.

Disclaimer

White plaque for a non-physicist!

On Wednesday 16th June 1999, the IOP unveiled a plaque of a slightly different kind. This one is white, and is situated in the entrance lobby of the IOP's headquarters. It is dedicated to John Buchan, well known as the author of many books, including The 39 Steps. He was a war correspondent and then a civil servant, becoming director of intelligence under Lord Beaverbrook during the First World War, and Governor-General of Canada. During that war, he and his family lived in a house on the site now occupied by the Institute's headquarters in Portland Place, and several of his books, including The 39 Steps, were published in this period. The plaque was unveiled by John Buchan's youngest son, Lord Tweedsmuir, who still has memories of living in that building as a young child. In his address to begin the ceremony, the chief executive of the Institute, Alun Jones, noted that Buchan had actually been very keen on physics, and at a time in his life when he had to start cutting down the number of activities in which he was involved, physics was one of the very few which remained important to him. The plaque was unveiled in association with the John Buchan Society.



Professor Joseph Rotblat - my early years as a physicist in Poland

a talk given to the Group on Monday 8th March 1999

When I was born in Poland, in Warsaw in 1908, 10 years after the discovery of Radium, Poland with its one thousand year history didn't exist on the political map. The country was partitioned for more than a hundred years at the time between the German, Austrian and the Russian empires. Warsaw was under the Tzarist regime, and this regime pursued a vigorous policy of Russification. Polish was not allowed, and in schools and universities, the language was Russian. The Poles hated this, and those who could afford it would go to study abroad. The country which Warsaw most favoured was France, because French has always been the language of the Polish intelligentsia.

The most famous, I think, of the Polish émigrés was Marie Curie. Marie Curie was born Manya Sklodowska in Warsaw. Apart from sharing with me the city of birth, it also so happened that I lived in the same street that she lived, but 40 years later. Most significant is the fact that she was the honorary director of the Institute in which I carried out my research work in Warsaw. I met her only once, in person, much later in 1932, not long before she died.

The institute which I refer to was called the Miroslaw Kernbaum Radiological Laboratory of the Polish Scientific Society in Warsaw. Miroslaw Kernbaum was a young scientist - a physicist and chemist - who worked under Marie Curie in Paris. He suffered from fits of depression, and in one such fit, he committed suicide. His parents were wealthy business people, and they wanted to commemorate the short life of their son, and so they decided to provide money to set up a laboratory which would carry on with the work which he has been doing under Marie Curie in Paris. In those days, as I said before, the Government did not support Polish science, and therefore Polish science had to be carried out by private means, financed by private individuals. And there was the Society, the Polish Scientific Society. It was a private organisation which had been supported by donations from wealthy people. And they managed to get a building on Sniadeckich Street.

The street was named after two brothers Sniadecki who were both scientists from the end of the eighteenth century. There, in that four storey building, some institutes were placed in which research was carried out by Polish scientists. There was an institute of Biology, one of Chemistry, one of Neurology - and the money provided by the Kernbaum family was used to put up an institute on the top floor to carry out work on radioactivity.

It was set up in 1913, and the idea initially was that Marie Curie should be enticed to come back to Poland to become the Director of this institute. But although Marie Curie always felt she was a Pole, nevertheless she felt she could not desert the much larger Institute which she had built up at that time in Paris and therefore she declined to take over that directorship. But she designated two of her most promising pupils, Jan Kazimierz Danysz and Ludwik Wertenstein, to come in her place. She agreed to be Honorary Director, but the actual Directors would be these two. Danysz was already well-known as a scientist - he was the one who did most of the work on the continuous spectrum of beta rays - and Wertenstein was working on the recoil of alpha particles.

Even before the Institute came into being properly, the First World War broke out, in 1914. Danish was a French Citizen. He was called back to France, into the army, and he was killed in the first few weeks of the War. And so it was throughout its existence only Wertenstein who was actually the Director of that laboratory. The laboratory came to an end in 1939, when the Second World War broke out, and the Germans came in. During the bombardment of Warsaw, a bomb fell on the building and destroyed the top floor. Our laboratory was destroyed at that time, but the building itself remained, still standing there without a fourth floor. And not long ago, in connection with the celebration of the hundredth anniversary of the discovery of Polonium and Radium, a plaque was put on the wall of the building, unveiled by Leszek Kuznicki, the President of the Polish Academy of Sciences, and myself.

It is now almost exactly sixty years since I left Poland. Looking back after 60 years, one’s memory is bound to play tricks - some things fade, other things stand out. But nevertheless, I do remember very well the laboratory. It was something unique, something different from what you would expect of a scientific laboratory of that period. In its set up, it belonged much more perhaps to the nineteenth century. In the ideas of basic research it was well in advance of its time. One important point about this is that it was very poorly maintained financially. After the end of the Second World War, Poland regained its independence, and an enormous effort went into rebuilding Polish culture – schools, universities and polytechnics. Now you would have expected that when you have a laboratory of this type, with Marie Curie as the Honorary Director, that this would receive much support from the Government. It didn't happen so. In fact, the Government ignored it.

There are various reasons for this, some of them were petty, personal jealousy. One of the main reasons was the anti-Semitism which was rampant in Poland at the time. It was very difficult for Jewish people to get into universities, even more difficult after they had completed their studies to get a Government post - universities were run by the Government. This laboratory didn't suffer from this – it was not in any way anti-Semitic. The result was that in this laboratory, the proportion of Jewish scientists was much higher than in other places. And this irked the Government - they didn't like it, and they did not support it at all. The legacy which was provided by the Kernbaum family was completely devalued as a result of the War, so what was left was hardly sufficient to meet the running expenses.

And the result was that, from the Director to the latest recruit, the staff had to work without any remuneration. Not only this, they often had to pay from their own pockets for equipment and materials. And they were not gentlemen of leisure. They had to work for a living. Some of them worked as teachers at the Free University of Poland, of which I shall talk much more in a moment. Others had teaching posts in secondary schools, and some of them worked in commerce. They had to work for a living, and very often they would carry out their work in the evenings or in weekends. But what the laboratory lacked in resources it made up with enthusiasm.

Photograph 1, reproduced courtesy of Professor Sir Joseph Rotblat

Perhaps some sense of the unreality which I have about the laboratory, is due to the fact that I do not have any documents, any tangible memorabilia, any photographs. As I said before, the laboratory was destroyed soon after the beginning of the Second World War. I had lots of photographs which I took with me when I went to England and later on to America, a lot of my notebooks - all of the history of the 10 or 15 years of my life - and this was stolen by the CIA when I was leaving the United States at the time when I was suspected of being a Soviet spy. And so I was left with no documents at all. But later on, friends sent me a *few* photographs, and I would like to show them to you - the ones which I was sent. They are poor quality, nevertheless, these are the only ones that I have. And the photographs refer to one rather joyous moment - a celebration of the twenty-fifth anniversary of the start of the laboratory, in 1938.

Photograph 2, reproduced courtesy of Professor Sir Joseph Rotblat

In accordance with our austerity, we did not celebrate this jubilee in a banqueting hall, but we had it actually in the laboratory itself. We removed the apparatus, rearranged the tables, covered them with table cloths, put on a few flowers, and this is where we had our dinner. This photograph *[Photograph 1]* shows Professor Ludwik Wertenstein giving the after dinner speech, with his exquisite style and full of humour.

This is the top table - one of the tables we used for experiments. Here is another table, and this is one of the guests - speaking on behalf of the guests *[Photograph 2]*. I am sitting next to him, and I spoke afterwards on behalf of the young workers in the laboratory. There is one more photograph from this dinner - another table with scientific workers.

After the dinner we had the group photograph, and this is this here *[Photograph 3]*. At that time, it is 11 o'clock at night, when this photograph was taken. Here you see in the front Ludwik Wertenstein, the Professor, with the senior guests; all the others in the back are the workers of the laboratory, former and current.

Photograph 3, reproduced courtesy of Professor Sir Joseph Rotblat

I am the only person alive from all those which you see on this photograph. And this is not because it is sixty years now since it was taken. Most of these people died shortly after this photograph was taken. They died in individual executions or in the gas chambers. They died as a result of a project conceived in the diseased brain of Hitler and carried out with scientific precision by his followers. When I look at this picture, I recognise so many of my friends: I see Michael Zyw, one of the most talented physicists. With a name like his, he was bound to be the last in any list of co-authors of a paper, but he was the first with new concepts in physics. I recognise Abram Wronsberg, a person very unassuming, very shy in day-to-day life, but very audacious in his concepts of ideas about science. I recognise Jozef Hershaft, a chemist - one of the first people to come up with concepts in radiation chemistry. I see all these people. I look at this, and I think of them with sorrow and heartbreak. All their lives - promising lives - cut down so young.

But above all I think of Ludwik Wertenstein, my Professor, my counsellor. He was a man of many talents. He was a scientist, a scholar, a linguist, a poet, a teacher, a humanitarian. And he was top in all of these things. As a physicist, he was top both in theoretical and experimental physics, he was as good with Dirac's equations as he was at building a very complex vacuum apparatus with his own hands. He had an enormous sense of humour. He also believed in popularisation of science. He believed that the general public should know what science is about, and therefore he wrote a regular column in newspapers, telling the Polish public what science is about.

I could go on for a long time describing his virtues, but I will only just mention one thing that was very important to me, and that is his humanitarian approach to science. He inculcated in me his concept of the responsibility of scientists for their work. He looked at a scientific discovery as the acme of intellect. He would look at a discovery as other people look at a beautiful picture or a grand sculpture. But he also believed that science has to have a purpose, and the purpose is to serve mankind. I know you might think that after all these years I am exaggerating my picture about him. This is the reason why I want to read out to you one paragraph from the obituary I wrote about him which was published in <u>Nature</u> in 1945.

> "I cannot end this note without a tribute to Professor Wertenstein's character and personality. He possessed such virtues as made him an outstanding man, even without his scientific achievements. He was exceptionally kind, generous, friendly, and utterly unselfish. Everyone who knew him was charmed and attracted by his cordiality, cheerfulness

> and modesty. But we, his students, who worked with him closely, could most fully appreciate the integrity of his character. He was not merely a teacher, but also a friend and counsellor. He cared not only for our intellectual needs, but also for our general welfare, and would not spare any effort to meet any of our difficulties. He will always remain in our memory, a symbol of the ideal man of science: a perfect blend of brilliance and kindness, erudition and good humour, enthusiasm for nature and love of humanity."

As I said to you, he was Director of the Laboratory to the very end. Indeed, his last paper, which was published in Nature, on products of fission, was published at the end of December 1939, a few months *after* Poland was already under German occupation.

His last work of popularisation of science was to translate the last book (in fact it was published after she died) by Marie Curie. It's called Radioactivité (the Polish title is Promieniotwórczosc) and I have just one copy which I value very much because it contains the lectures given by Marie Curie during her lifetime to her students, and also an addendum, which was written by Wertenstein, which brought the subject up to date. It came out in August '39 just before the War. And this book was used in the underground University during the War years when no teaching was going on and this book was just to teach people about radioactivity, and Wertenstein himself was one of these teachers. He, of course, kept on in hiding and he had several lucky escapes, but almost at the very end of the War, his luck escaped him. At that time - 1945 - he was in Budapest, when the Soviet Army came close and bombarded the city. He went out of his hiding on an errand of mercy to try to get some medicines for an ill friend and he was hit by a shrapnel and died on the street.

Since the laboratory was created under Marie Curie's aegis, much of the technology of the laboratory was according to the French tradition, but Wertenstein spent two years at the Cavendish Laboratory under Rutherford, so he also brought in the British tradition. For a long time there was, if you remember, a sort of competition going on between Paris and Cambridge; it had to do with the different ways in which they approached the subject. Even the apparatus which they used was quite different in those days. For example, the measurement of radioactivity in Paris was done with an ionisation chamber in which you put the radioactive substance, and as it discharged it was compensated by a charge in the opposite direction from a piezoelectric crystal. If you pulled down the crystal, this produced a charge of the opposite sign, therefore the electrometer is kept at zero, and that's the idea - keeping it at zero. And then you measure how long it takes to take up a certain weight. The reason why they used this technique was because

Marie Curie’s husband, Pierre Curie, actually discovered this piezoelectric effect together with his brother Jacques.

So this was the technique used in Paris, while in the Cavendish, Rutherford used a much simpler technique. He was interested in alpha particles, mainly, and there was the question of counting. Rutherford used the property of alpha particles to produce a spark of light when it hit a certain target. It was mainly experiments of the scattering of alpha particles by heavy materials which brought the concept of the nucleus of the atom. This is done simply by watching through a microscope the sparks of light emitted and by counting them.

When I was still a student, and I started my experimental studies in this laboratory, my first experiment was to measure the amount of radioactivity, and so I used both of these techniques. The piezoelectric technique needed a bit of skill to make sure that you kept a pointer all the time at zero and it didn’t move about too much. The other technique - the scintillation technique - was much simpler, but it required sitting in a dark room for a long time. First you had to sit for about an hour to get your eyes adapted, and then began to look through a microscope and see these sparks appearing there and to count them. And often, just in the middle of counting, somebody would not notice the sign on the door, and open the door and your adaptation to light had to start all over again!

Now at that time, when I started at work, both of these techniques were already on the way out, because they were replaced by the counting technique: the Geiger counter came into being at the time. But the Geiger counter at that time was even more capricious than any of these techniques because you couldn’t go and buy them over the counter as you do now. One had to make them oneself - the whole thing - the vacuum sealing, filling with the gas and everything else - one had to do it oneself.

I mentioned my studies: these were carried out in an institution which was called the Free University of Poland in Warsaw. Actually, it’s not quite the exact translation of the Polish name, “Wolna Wszechnica Polska w Warszawie”. “Wszechnica” is not a University really - it means “a place of learning”. And the reason why it had to use this name was because it was not recognised as a university. This “Wszechnica” in many ways had the same maverick character as our Laboratory, and for the same reason. Students were admitted there without regard to class or race. Once again for this reason it did not have the support of the government, which did not recognise the Diploma issued by this institution until much later, because the level of teaching reached was so high that they simply couldn't help giving it certain rights.

I am very fond of this institution. Without it, I would never have been able to become a scientist. Due to the consequences of the First World War, I had to start working for a living at quite a young age, so I was not able to take the usual path through the university, to go to the secondary school which was called "Gymnasium" in Poland and receive a document called the "Matura" - a document of maturity which was a piece of paper which enabled you to claim access to university. Of course, schools were full-time, and I had to work. I was an electrician - I started off as an apprentice, and then I set up on my own - installing electrical installations in houses and factories and so on. A hard life - often quite hard labour. I didn't mind this at all. What I *did* mind was that it didn't allow me to get something which I wanted all the time: I wanted to be a scientist.

I was particularly interested in Physics. From my childhood I was excited about science fiction books - Jules Verne, H. G. Wells and many Polish authors. Gradually I advanced to reading more serious books. My idea was that eventually maybe I should be able to get this "Matura" externally - there was a possibility of doing it - but it required a lot of preparation. And even then, even if I had the "Matura", I would not be able to go to a university full-time because, as I said, I had to work for a living. And so it looked hopeless.

But then, one day - it was in January 1929 - somebody told me that an institution existed where the lectures are given in the evenings and there was no need to have a "Matura" for entrance. Look at this - an institution made just for me! So as soon as I had heard about this, I immediately went there to try and get more information. The nice young lady there gave me the information and then she said, "Well, as it happens, tomorrow we're starting the entrance examination for the semester starting in February, and if you like, you can still register for it." I was appalled by this idea - I hadn't prepared at all for this. But then I thought, "Well, what can I lose? Let me try. At least I'll have the experience."

So I said, "OK," and I registered. The following day I came to sit down for this ordeal which very soon turned into a nightmare. I had thought the examination would be in the subject of my studies, namely, physics. It turned out that there were two parts of the examination. Physics was the second part, but the first part, which all candidates had to pass, was of a general knowledge nature. We had to write an essay on either of two topics. One topic was about a review of a book which I had not read at all. The second was to describe, and comment on, the influence of the 1773 Committee for National Education on contemporary education in Poland. Well, I knew a little about the Committee, but nothing about its influence, and so I had nothing to write about. I actually wanted to get up and walk out. But as it happened, I was sitting at the front of the room - the exit was at the other end - and I was too shy, too embarrassed, to pass everybody and walk out. So I thought, “Alright. I’ll sit it out and just hand in a blank paper.” So there I sat, miserable and completely numb, but gradually my thoughts cleared and I began to write - not on the subject, which I didn’t know - but on education in general. I handed in the paper, fully convinced that I had made a fool of myself. Nevertheless, the following day I went and sat through the Physics and Mathematics examinations which I did quite easily. The results were to be given the following week, and for the whole week I blamed myself, “Why have I done this? Why did I sit for an examination about which I didn’t know anything at all?” But still in a masochistic mood, I decided I’d go and hear what the result was. There I sat when the examiner read out the names of the people who passed the exam, and I was flabbergasted when my name was called out!

A few days later, I went to the Dean of the Faculty of Science to discuss the course of my lectures. The Dean of the Faculty of Science at that time was Ludwik Wertenstein, and this was the first time that I met him. He had the papers in front of him - my thesis - and he looked at it and looked at me and said, “You don’t seem to have much idea on the topic of your thesis.” I said, “Oh, no. None at all.” He replied: “Your examiner thought so too. But he liked your original thoughts. You should do well here.” And I did.

I went through the course of studies, and when I finished the course, Wertenstein offered me a post as Assistant at the Free University of Poland, in the Physics Department - a very poorly paid job, very poorly - not enough to live. Nevertheless I was happy to have at long last entered a scientific career.

This was 1932 - the *annus mirabilis* in physics - the year when so many important discoveries were made, like for example the discovery of the neutron by Chadwick. In Poland, too, people thought we must make discoveries. There was a woman, Alicia Dorabialska, a reader at the Warsaw Polytechnic. She announced that she observed the emission of heat from a number of elements - like Scandium, middle weight elements - which she said was due to the spontaneous emission of neutrons from these elements. Now this was something extraordinary, because one wouldn’t have expected the spontaneous emission of neutrons from stable elements. Wertenstein, who was the person who knew more than anybody else in

Poland about this, was staggered by this, but he thought, “Well, if this is the case then we must see whether it is true and corroborate it.” So he gave me the task of measuring the heat emitted from these substances, to make quantitative measurements. So I spent a little time building a calorimeter sufficiently sensitive to be able to detect even less emission than Dorabialska announced. I carried out the experiments, and couldn’t find any emission of heat at all. We announced this result at the next meeting of the Polish Physical Society. Dorabialska got up and said she had carried out a further experiment, she confirmed that there was emission of heat, but much less than her first paper. Indeed, just below the level which I could detect with my apparatus! So Wertenstein asked me to persevere and build a more sensitive apparatus so that I can observe the even lower emission of heat. And this was my first big piece of apparatus I had to build - a differential micro-calorimeter with which I could observe very tiny changes in temperature. I spent a great deal of time in building it, together with our mechanic, and in doing the measurements, but I still couldn’t find anything at all. So this was the result of my first two years of research work. I didn’t even bother to publish it because I thought there was nothing there to publish!

By that time it was 1934, and this was the time when artificial radioactivity was discovered by Irène Curie and Frederic Joliot and people began to work on this. Two of my colleagues, Michael Zyw (who I mentioned before) and Marian Danysz (the son of Jan Danysz I mentioned before, who was killed in the First World War - he became a physicist) had already discovered by that time the radioactivity induced in fluorine by bombardment with alpha particles. But this developed mainly when neutrons became the main source of producing radioactivity. The main centre at the time was in Rome - where Enrico Fermi and his team carried out a systematic study of all the elements of the periodic table to see how many of them become radioactive. Soon afterwards, other means of producing neutron sources were developed - the Cockcroft and Walton accelerator, the van de Graaf, above all the cyclotron, but at that time, when we began this work, it was still the natural source of radium which were the main means of getting the neutrons.

We had 30 mg of radium in a solution, and every few days, we would pump out the radon - the gas - which accumulated in the vessel, and pump it into another vessel, with beryllium powder, and the alpha particles from radon, bombarding the beryllium, became a source of neutrons. So at that time, the person who had most radium was the master of the field. In Rome, Fermi had 1 g of radium, with which he carried out his experiments. I said that we had 30 mg, and with this tiny source, we had to compete with the great

Fermi, but what we lacked in equipment we tried to make up with repetition of experiments, and also with … agility!

It was with this source - tiny source - with which, for example, I discovered the radioactivity of cobalt-60. Nowadays, we know at least 3,300 artificial radioactive nuclides, and the discovery of one of these of course is trivial, but in those days it was quite important. Each newly discovered element merited a publication of its own. I used this apparatus mostly to study the interaction of neutrons with matter using as an indicator of the source - the neutrons - the radioactivity induced in silver. So I exposed a piece of silver to the source of neutrons, under given conditions, and then measured its radioactivity. The half-life was very short - 22 seconds. It was very important to be very quick. As it happens, one couldn't have the source next to the Geiger counter, because the gamma rays from the radium would have swamped it completely. The source of the neutrons was on an annexe to the building higher up and from there one had to go down two flights of stairs, through the corridor, through the housekeeper's flat, along another corridor, and finally to the laboratory. And this one had to do very quickly. And so I speak about agility - I really became a sprinter and a jumper. I learned in the course of time to take a whole flight of stairs in one jump, and run very quickly, and I could do the whole of this procedure in seven seconds! Until one day I was a bit too confident, and I stumbled and fractured my tibia. Only then did somebody find the money to build a chute with which one could send it right through!

Perhaps our most important discovery at that time was the discovery of the inelastic scattering of neutrons. Until then, we had assumed that neutrons just hit the nucleus like a ball, and only had elastic scattering and nothing else. And then Niels Bohr came out with his idea of the compound nucleus: that is to say that the neutron does not just bounce off but actually it joins together with the nucleus to form a compound nucleus and then is re-emitted, and - depending on the energy levels within the nucleus - it will come out at different energies … a very large burst of energy. And this was what we discovered, actually, in our laboratory. In a study of this inelastic scattering, the heavier the element, the easier to observe this, and therefore we decided we should use gold. We were too poor to acquire gold ourselves, but Wertenstein managed to persuade the Director of the National Mint to lend us some gold, and not only lend us, but actually they moulded it in the right shape that we needed. And so we had 4 kg of this gold, which we used in observations of inelastic scattering. We did not have a safe in the laboratory, so every evening I had to take the gold back to the Mint, and the following morning bring it out again, until we got tired of it, so I decided I would change to another material, namely, uranium. In those days, uranium as a metal did not exist - I remember the first time I received uranium in a metal form was during the War, when I was at Liverpool - I used uranium oxide to carry out my experiments on the scattering of neutrons.

And then came the discovery of fission by Robert Frisch and Lise Meitner at the beginning of 1939. Their paper in Nature appeared in February 1939, but Neils Bohr told the press about it in January, so I heard about it in January from the newspapers. Now this was of course a very important discovery, and as often happens with such discoveries, it made people think. I was an experimentalist and for me it was an enormous surprise, but it was also a surprise to the theoretical physicists, and Robert Frisch told us later that when he told Bohr about this, Bohr smote his forehead and said, "Oh, what idiots we've all been. Oh, but this is wonderful - it is just as it must be." But of course *after* the discovery, it's easy to say: this is how it must be!

As I said, it made me think when I read this. What I had been wondering since I'd been working with neutrons for a long time, was about the ratio of the protons to neutrons, or neutrons to protons, within stable nuclei. In a chart of stable nuclei, with the number of neutrons against the number of protons, for light elements the ratio does appear to be almost 50/50 - half and half neutrons and protons. But then the line begins to go upwards, in other words, more neutrons than protons, and the reason is that for stable nuclei to overcome the repulsive force - the coulomb force between the protons - you have to get a larger nuclear force to bind them together, so the number of neutrons goes up. So it occurred to me that if we take a nucleus in the heavy element region, and break it up into two nuclei in the middle region, then these two require fewer neutrons, therefore there would be a surplus of neutrons. So I said I would have to look at this and see whether this really occurs. As I said, I had the apparatus almost ready. Since everything was ready for another experiment, it didn't take more than a few days to carry out this experiment and find that indeed there were more neutrons coming out - free neutrons.

What happened then is that I wrote up this observation. I didn't know any English at the time, so I used to write my papers in Polish, and Wertenstein would then translate them into English. Of course, most of my papers were published in Nature. At the time, Wertenstein was away, abroad, so I had to wait a couple of weeks until he came back. When he came back, I showed him my paper, he looked at it and made some comments, but he found it alright. He said, "Very good paper". He took it home to translate it into English so he could send it off to Nature. I remember that day, that evening, very well. Saturday evening, I was at home. The telephone rang, Wertenstein on the phone, he has just received a copy of Comptes Rendu, the journal of the French Academy of Sciences, where Frédéric Joliot-Curie and his wife Irène had reported the emission of neutrons at fission. I was of course very depressed about this and decided not to publish my findings but eventually Wertenstein convinced me that I should - somewhat later.

Why I felt I should not publish at the time, was that during these few weeks, I had been thinking very much about the consequences of that observation because I could see at the time that if more neutrons come out than you put in, then this opens the way for a chain reaction, which could multiply very rapidly in a short time, and release a large amount of energy. And of course this would be as we know now a source of electricity in nuclear reactors. But it also occurred to me that if this chain reaction could multiply rapidly - and of course from simple calculations you can see that you only need less than a microsecond to release a huge amount of energy - which means if this really happens, you get a mighty explosion. In other words the idea of the atom bomb occurred to me at the time, and I didn't like it at all. I didn't think that scientists should be involved in doing military work.

Well as it happened at that time, something else occupied my mind. Wertenstein had managed to get me a fellowship to go abroad for a year to do research in another country. Until then I had never been out of Poland except when, in the Tatra mountains, I had managed to get over the Czech side, but otherwise I had never been outside Poland. And there was great difficulty in those days, all sorts of bureaucratic difficulties there - with passports and visas and everything else. So this occupied my mind quite a lot and I tried to forget about the things that bothered me. I must tell you that actually I had *two* invitations to spend a year - one was from Chadwick at Liverpool, and the other was from Joliot-Curie in Paris. Now because of cultural bonds, and in other ways, I should really have gone to Paris, quite apart from the fact that if you compare Liverpool with Paris, any sensible person would make the other choice. I chose Liverpool, and the reason was quite simple, because I still had at that time the idea that I wanted to go back to Poland after the year's research, and build up physics in Poland. I knew at the time that you need a cyclotron in order to do proper physics using new techniques. Anyway at that time, Chadwick was building a cyclotron in Liverpool and I thought the best time to learn about a machine is when it is being built - to take part in its building. So this is the real reason why I went to Liverpool. It turns out to have been a wise decision - if I had gone to Paris, I wouldn't be here to talk to you today.

So I went to England, and during that summer - as I said, my English was practically non-existent - I couldn't talk to anybody there, not really talk to somebody on a very sensitive issue. I became particularly worried when in June 1939 I read a paper in Naturwissenschaften by a German physicist, Siegfried Pflügge, in which he discussed the military applications of fission. I thought that *if* the bomb can be made, German scientists will make it and Hitler then would use it to win the War. Because, living in Poland, we *knew* that the War was imminent. It was not a question *whether*, but *when* it was going to happen. And I thought if Hitler is going to have the bomb, then I'm afraid democracy will be doomed - Nazism would take over the world. So this was for me a dilemma - a terrible dilemma in fact.

In August '39, I went back to Warsaw for personal reasons, but I used the occasion to visit my Professor - and by that time he was my friend - Wertenstein, and I told him about my rough calculations about the feasibility of the bomb, and my dilemma - my moral dilemma - about working on such a project. By that time, I had developed a rationale for working on the bomb. The rationale was - it was faulty thinking, but this is what I thought at the time – that, if the bomb can be made, the only way to prevent Hitler from using it against us during the War would be if we also had the bomb and threatened him with it. In other words, the concept of nuclear deterrence I had developed by the summertime of 1939. So I put my questions to Wertenstein - I asked his advice. He thought for a long time, and then he said, "Please forgive me, I'm not going to advise you." He said, "This is something on which I have got my own views. I myself could *not* do that, but you've got your own personality, and you've got your own approach. You must decide for yourself. It is too big for somebody else to advise you."

This was the last time I saw him. Two days after I went back to Liverpool the war broke out, and within a few weeks Poland was defeated and the whole military might of Hitler's Germany stood revealed. I thought that if in addition to this Hitler also had the atom bomb, I was afraid that the future as I saw it of democracy would be finished. And this was not acceptable to me. And this is the reason why two months later, as soon as I had settled down in England, I went to Chadwick and suggested to him that we should begin research on the feasibility of the atom bomb. And the rest is history - recorded history - so I think I'd better stop now. Thank-you very much.

Aspects of the relationship between Physics and Religion

The Physics and Religion meeting sparked a great deal of interest. Indeed, so much so that it was held twice – in Edinburgh and in London. Here are some of the comments we received afterwards:

> “Reconciling science and religion is a problem faced by a lot of scientists. As a physicist and a Christian, the overlap and questions raised interests me, as does how other people in history and today view this topic.”

> “Interested in programme (history of physics) and specifically in Newton and Faraday”

> “I am a muddled Christian and a muddled physicist.”

> “A Quaker hence interest in programme. Born in Grantham with relatives at Woolsthorpe – Newton. Having lunch tomorrow with a Barnard – hence Faraday.”

> “I have no firm religious or anti-religious feelings but cannot accept such beliefs as facts. As a physicist however I instinctively ask, “Why?” and I want to obtain other people’s ideas so that I can make up my own mind about the origins of the Universe.”

> “Many people are interested in these topics which ultimately affect us all.”

> “Interest in the area sparked by doing a history and philosophy of science course in university. Also, because as a committed atheist, I spend considerable time arguing these sort of points with religious friends!”

The Group also received the following communication from Sir Hermann Bondi, which was read out at the meeting:

Different kinds of knowledge

Virtually every religion appears to be based on a "revelation". The truths enshrined in it are, in the eyes of the believer, absolute and unchanging. They take precedence over any other form of knowledge. Yet these truths are of only limited communicability.

What is "gospel truth" or "the word of God" to the adherents of one faith enjoys no such status in another one. In fact there may well be some contradictions between the basic tenets of different religions, each one of which is adhered to by only a fraction of mankind.

Scientific knowledge is very different in that it is, at least in theory, of unlimited communicability. In practice, of course, the number of, say, physicists is actually quite limited, yet it is accepted that there is only one physics which is totally independent of the location, religious belief, political ideology, etc., of the physicist. Moreover, we never view our knowledge of physics as absolute and unchanging. (In fact, many of us work to change this knowledge, hopefully to make it better!) But science is by its nature provisional, waiting to be altered by the latest experiment.

The nature of these very different forms of understanding must be kept in mind when links between science and religion are examined.

Sir Hermann Bondi 1/4/99

Some Questions Concerning the Relation of Physics to Religion

Dr. Hugh Montgomery

1. Introduction

Today's programme includes scholarly accounts of three classical physicists, Newton, Faraday and Maxwell, all of whom were deeply religious men in their own different ways. I would like to make a few general comments on some contemporary physicists, who have derived their physics but not their religious attitudes from their great predecessors. I shall be asking questions rather than providing answers, and no doubt I shall learn more from the discussion than you will from my talk.

To be a successful physicist nowadays it is certainly not necessary to believe in the existence of God, and one does not even need to believe in the existence of the physical world which is the object of our study. (I am a not very successful physicist who believes both in God and in the physical world, and perhaps this provides some unwelcome support for my argument.) It is strange that physics has been able to make such fantastic progress in the twentieth century, without developing a generally accepted philosophy to underpin it. The only universal principles one can detect in contemporary physics are a strict adherence to the empirical evidence, and the use of abstract mathematics as a language in which to develop theories. Wigner[1] has described mathematics as "a wonderful gift which we neither understand nor deserve", and it seems to have replaced philosophy as the fundamental discipline behind the subject. This may not be entirely healthy, as mathematics helps us to think, but it also helps us not to think. Mathematics builds extremely elegant deductions on a platform of axioms which are never defined or explained - as Lord Cherwell once complained, mathematical physics is just a lot of squiggles on paper. Can one imagine any other field in which a subject such as quantum mechanics could be developed with enormous success over a period of eighty years, without achieving a consensus on the physical meaning of the symbols it employs? Physicists cannot even agree on whether such a consensus is necessary or desirable.

On the other hand, the most hard-nosed physicist will agree that there is something very beautiful about a fruitful theory in mathematical physics. This encourages some of us to go further, and to feel that there is an aura surrounding physics which points to a far deeper significance than the minimalist can accept. It is in pursuit of that aura that I would like to consider recent theories of cosmology.

2. Theories of the "big bang"

I am very much a layman in this field, but I found Stephen Weinberg's The First Three Minutes a fascinating book, and the story it describes is one of the most exciting myths of the twentieth century[2]. (The word "myth" is not of course being used in a pejorative sense). As a theory it combines general relativity, the physics of elementary particles and thermodynamics to produce a convincing history of the Universe, and one which agrees with the available evidence, particularly as regards the galactic red-shifts and the 3 K background radiation. As a myth it has curious parallels and differences compared with Judeo-Christian teaching. (I appreciate that the big bang must not be *equated* with the Creation in a theological sense; it is the analogies between them which concern me at the moment.) In the initial singularity, space and time and energy are created in a fireball at an enormously high temperature, and this fireball expands and cools and eventually becomes a Universe of galaxies, stars, planets and living things. This agrees in general terms with Christian ideas on creation out of nothing, but cosmological theory differs from Christianity in that it offers two alternative eschatologies. If the initial density of matter in the universe is greater than a critical value, the Universe will at some stage begin to contract again under the force of gravity, and it will be destroyed in a catastrophic "big crunch". On the other hand if the matter density is too low, the Universe will not be destroyed; it will continue to expand and to cool for ever. The nuclear fires inside the stars will go out, and eventually all forms of life will succumb to the freezing darkness:

> "This is the way the world ends,
> Not with a bang but a whimper."

What is entirely missing from this myth is any concept of a Fall and subsequent Redemption. Weinberg fully accepts this depressing state of affairs, and he says sadly that the study of science "lifts human life a little above the level of farce, and gives it some of the grace of tragedy". On the other hand Freeman Dyson reacts strongly against such pessimism. He pins his hopes on a Universe which expands for ever, and searches frantically for ways of beating the cold[3]. Neither of them looks to religious belief as a way out of his dilemma.

3. The Anthropic Principle

Let us return to the more cheerful aspect of the story, the early history of the Universe. The theory is sufficiently well developed that one can discuss counterfactual situations - if the initial balance of forces had been slightly different, so and so would have happened. And one soon finds that small changes in the initial conditions would have had disastrous results from the point of view of human life. If the initial matter density had very slightly exceeded the critical value, the Universe would have recontracted and destroyed itself long before any structures could form inside it. If the initial density had been slightly less than the critical value, the matter in the Universe would have flown apart and dispersed before it was able to form galaxies and stars and planetary systems. To obtain a Universe with the longevity of the one we live in - whatever its final fate - the initial matter density has to be incredibly close to the critical value. There are many other examples of "fine tuning" in the system. The strong nuclear forces and the electrical forces balance each other in such a way that the deuteron is stable while the diproton is unstable; both of these conditions are essential for the steady burning of hydrogen in stars like the sun. The production of carbon atoms in a star occurs by the unlikely process of three helium nuclei colliding simultaneously; this would be hopelessly inefficient if the carbon nucleus did not have a strategically placed resonance. Some of this carbon will eventually be needed as a vital ingredient in living tissue, and it would all quickly drain away into oxygen, but for the fact that the oxygen nucleus does not have a corresponding resonance[4]. Such "cosmic coincidences" have led some cosmologists to suggest what is known as the *Strong Anthropic Principle:*

> "The Universe *must* have those properties which allow life to develop within it at some stage in its history"[5]

It is fair to say that the status and significance of this Principle are extremely controversial. Physicists tend to be unhappy with it because it does not lead clearly to testable hypotheses, and it smacks too much of teleology. John Wheeler[6] has tried to rescue it from this fate by relating it to the Copenhagen Interpretation of Quantum Mechanics, but this Interpretation is itself controversial. Quantum Mechanics developed mainly as a "bench" subject, and it was designed to explain experiments in atomic physics. According to the Copenhagen Interpretation no physical system has a reality which is independent of the measurements being performed on it by an observer. Wheeler argues in effect that the events in the early Universe are like a set of post-dated cheques, which cannot be cashed for reality until the appropriate measurements are performed by human beings in the twentieth century AD. When the Copenhagen Interpretation is applied to cosmology, some of us have the feeling that something is rotten in the state of Denmark.

Theologians are also uneasy about the Anthropic Principle, and they are wary of the suggestion that it provides evidence for Divine Providence. The situation smells too much of the God of the Gaps; it could be that future theories will show that many of the apparent coincidences are not really coincidental at all, and recent developments indicate that this is already the case[7].

From a human point of view an interesting aspect of the Anthropic Principle is its pre-Copernican quality; it restores mankind to a central place in the Cosmos, metaphorically if not literally. The Principle has encouraged some physicists not to express gratitude to God, but rather to enhance the stature of human beings, whose destiny is the complete control of the Universe. For example Barrow and Tipler argue that at present we are the only intelligent beings in existence, and that at some time in the future human beings will launch self-replicating robots into space. These will carry instructions to explore the Galaxy and to colonise other Solar systems, setting up civilised communities like our own. The assumed absence of natives in these Solar systems absolves the scheme from any possible charge of imperialism[8].

The philosopher Mary Midgley has great skill in placing physicists over her knee and giving them a well-deserved spanking, and she has had a field day analysing speculations of this kind[9].

4. *Creatio continua*

So far I have been discussing the thoughts of physicists who are willing to speculate outside the strict confines of their subject, but who are clearly not bound by any kind of Christian orthodoxy. I would now like to turn to the arguments of physicists who are also committed orthodox Christians, and the only writer in this class whom I have looked at in any detail is John Polkinghorne. As an Anglican priest he is naturally appalled by the suggestion that physics weakens the case for Christianity, and he argues strenuously against it. He describes himself as a "bottom-up" thinker who starts from contingent facts rather than from metaphysical principles, and he guards fiercely the origins of Christianity in its historical roots in the gospel accounts[10]. I certainly agree that Christianity is by its nature a historical church, but Polkinghorne uses the gospel accounts as if they were experimental evidence, which clearly they are not. He is determined to build a direct unifying bridge between scientific and theological thinking, and I believe that he is distorting them both in the process. Physical concepts are constantly forced into doing theological work for which they were never intended, as we shall see shortly.

Polkinghorne is anxious to dispel the Deist notion that God created the Universe and then stepped back and allowed it to evolve under its own steam. He believes fervently in *Creatio continua*, the ceaseless creative activity of God in the physical world. This was also a deeply held belief of Newton, who described Space as the Divine Sensorium, in which gravitational attraction was a constant application of the Will of God. He believed that the Solar system was inherently unstable, and that eventually it “shall want a Reformation” - in which God temporarily changes his activity in order to restore stability. A hundred years later Laplace calculated that the Solar system would always right itself over a period of time, and he was able to make his famous remark about the Deity: “I had no need of this hypothesis.” God’s role was reduced to that of *Le Dieu faineant*, the “do-nothing God”, and this is the notion which Polkinghorne is determined to refute.

Physics has moved a long way away from Laplace’s deterministic clockwork universe, but physicists are extremely uneasy about a God who intervenes in the physical world, as if He were a meddlesome supervisor who fiddles with his research student’s equipment while the latter is away on holiday. Maxwell does discuss such an individual in the form of Maxwell’s Demon, and we all know what mischief he would get up to if he were actually allowed to exist.

Polkinghorne fully admits this problem, but he insists on looking for the “causal joints” at which God intervenes in the physical world. He says ominously:

“The demand for an integrated account of both theological and scientific insight impels this task.”[11]

One suggestion he considers is that God intervenes at the moment of a quantum mechanical measurement process, in a situation where the outcome is not predetermined. Einstein insisted that “God does not play dice”, and Bohr said in effect “God *does* play dice”. Polkinghorne asks “Are the dice loaded?” He knows perfectly well that they are not, and that quantum mechanics provides an exact calculation of the various probabilities. Although Polkinghorne rejects quantum mechanics as the location of the "causal joint", he still searches for it inside physics, and suggests that chaos theory might a good place to look. But I cannot understand how evidence for God's intervention could be found in any existing physical *theory*, which is based on an implicit assumption that such things do not occur.

Although Polkinghorne does not discuss the point, it is reasonable to argue that the acceptance of *Creatio continua* would take all the wind out of the sails of the Anthropic Principle. No cosmic coincidences are needed if God is giving a touch to the tiller at each stage in the evolution of the Universe. Much more seriously, *Creatio continua* would destroy the whole of physical cosmology. If God's intervention in the physical world is significant, it is free and unpredictable, and cannot be constrained by a physical theory. *Creatio continua* is *Creatio incognita.*

I have a great respect for Polkinghorne as a physicist, but I find myself deeply out of sympathy with his ideas on the relation of physics to religion. It seems to me that he is too anxious to please both the physicist and the theologian, and that paradoxically he is developing a form of Christianity which ultimately few physicists can accept. I believe that God did have a guiding purpose for the Universe during the long period before human beings appeared, but I very much doubt if such a purpose can ever be expressed in the language of physics. Perhaps we should admit honestly that there are real differences between the outlook of the physicist and that of the theologian, but that they also have wide areas of common concern; this could lead to a much more fruitful interaction between them.

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The Calendar and Religion

Dr. Edward Graham Richards

The secular uses of the calendar are legion and obvious but its ecclesiastical uses are no less important; with it the priests can determine the days to hold rituals and make sacrifices; every Religion has its Calendar and every Calendar has its Religion

Nearly all calendars are based on the cycle of days and nights. Apollo, the sun god, brought light and warmth and demanded worship. The simplest of all calendars numbers the days from some fixed day. Astronomers still use Julian day numbers. Julian Day Number 0 was Tuesday, January 1st 4713 BC. The new millennium will start on day 2,451,545; such large numbers require us to subdivide the count of days. Calendars thus group the days into months based on the moon and years based on the sun. Early calendars were regulated by direct observation of these bodies; more recent ones operate by fixed rules.

Like her brother, Apollo, Artemis has been worshipped from early times and the lunation was of significance long before formal calendars appeared. Several bone or stone artefacts, some from upper Palaeolithic times, show a sequence of marks arranged in groups of 59. Marshack believes that they represent a tally of days marking the period of two lunations; some people were still doing this in recent times.

Whether or not there were Palaeolithic lunar tallies, many early calendars were based on lunar months. Later calendars evolved to take account of the seasons and the sun. Thus we have lunar calendars based only on the moon, lunisolar calendars which have struck a compromise with the sun, and finally solar calendars which have abandoned the moon.

The Islamic calendar is a purely lunar calendar. It has 12 months of alternately 29 and 30 days in a common year but in an embolismic year the last month has one day more. There are 11 embolismic years in a cycle of 30, counted from the year of the Prophet’s flight to Mecca - 632 AD. In this cycle there are 10,631 days, so that the average of days in a month is 29.53056, close to the mean synodic period of about 29.53059 days. It will remain in synchrony with the moon for about 2500 Islamic years before it is a day out. The year contains 354 (or 355) days and its start thus cycles through the seasons, being about 11 days earlier each astronomical year. In practice, the start of each month is often determined by observing the new moon.

A lunar calendar is inadequate for agricultural communities who must arrange their farming according to the seasons. Thus solar calendars that keep in step with the astronomical year were developed. These require an estimate of the length of the mean tropical year (365.24219 days). This is harder to measure than the length of the lunation and the history of solar calendars is marked by refinements in its measurement.

Perhaps the first purely solar calendar was the civil calendar of Egypt. Agriculture in Egypt was dominated by the annual flooding of the Nile. At some time in the remote past it was noticed that this was portended by the Heliacal rising of Sirius. As they counted the days between annual floods, or Heliacal risings, they concluded that these occurred every 365 days. By about 3000 BC they had developed a calendar year with 12 months of 30 days each with an extra short month of 5 epagomenal days. This was just short of the mean solar year and meant that the start of the year slowly cycled through the seasons. A later version with a leap day, the Alexandrian calendar, was introduced by Augustus.

It is easy to calculate the number of days between any two Egyptian dates since the number of days in a year is constant; for this reason it was used by astronomers into the 16th century. It, or variants of it, were also adopted by several others under various names. These include the Yazdegard calendar of the Parsees, the Fasli or Soor San calendar used in Asia Minor; the Coptic and churches use the Alexandrian calendar to this day. A variant was adopted by the French Revolutionaries.

Nevertheless, Egypt also originally had a lunar calendar for religious purposes. This underwent several changes and eventually the religious and the civil calendars were used side by side with a mechanism for synchronising their years.

The Maya and the Aztecs of central America both counted the days using two different schemes. The first, the so called Calendar Round, employed several cycles including one of 365 days. Any day within the calendar round, a period of about 52 years, could be defined by specifying its position in each of the cycles.

To register longer periods they had a method of counting the days from an epoch in the remote past (probably 8th September 3114 BC), the long count in which the large numbers of days required were divided into a series of time units. This elaborate system was used to determine propitious days for grisly religious sacrifices and for wars and establishing the credentials of rulers.

An ancient method of reconciling the demands of lunar religion and agriculture was the various forms of lunisolar calendar. These are based on the observation that 235 lunations almost exactly matches the period of 19 years. The idea is to divide these 19 years into 12 common years of 12 lunations apiece and 7 embolismic years of 13 months each.

Such calendars are sometimes attributed to Meton of Athens, but it was actually invented in Babylon by the 6th century BC and independently in China. There are several variants and they are known throughout the entire world. It underlies the Jewish and Chinese calendars, the Hindu lunar calendar and the calculation of Easter in the Christian Churches.

The Jewish calendar was adopted by the Jews from the Babylonians during their captivity. In early times, the start of each year and month was determined by observation of the new moon at Jerusalem but, after the diaspora, this lead to problems until it was reformed by Hillel II in the 4th century; he introduced the rule-based calendar used today.

The mean lunation is assumed to be a constant of 29.530594 days and is initiated by a *molad*, the nominal instant of conjunction of the moon. Given the epoch of the calendar, it is possible to calculate, by adding multiples of the period of the lunation, the instant of the molad of each month, the first of the year in particular. However, the start of the year may be postponed by up to two days according to another set of rules. These ensure that there are not two consecutive days on which cooking and other activities are forbidden.

The epoch of the calendar was estimated from the moment of creation as described in Genesis. The year of the creation year was calculated by adding up the ages of the Patriarchs and biblical events and relating them to historical dates such as the destruction of the Temple at Jerusalem. The upshot is that the creation was calculated to have taken place on Monday 7th October 3761 BC. This sort of calculation has been attempted many times, one of the most famous being Bishop Ussher's date of 4004 BC.

The Roman calendar was, originally, lunar. The Nones, Ides and Kalends were once associated with the phases of the moon. By the time of the Republic, attempts to keep the months in step with the moon had been abandoned but there were haphazard attempts to keep the calendar in step with the seasons. In 46 BC Julius Caesar reformed the Roman calendar. He gave us the Julian calendar with a year of 365 days with an extra leap day inserted regularly every 4 years. It became the official calendar of the Christian Church.

The Julian calendar has a mean year of 365.25 days, about 11 minutes too long, and it thus gained a day relative to the sun about every 128 years. In 1582 pope Gregory XIII reformed the calendar by dropping the leap day in centurial years (divisible by 100) not divisible by 400. This gave a mean calendar year of 365.2425 days which we use to this day.

The Romans numbered their years in various ways: by the names of the Consuls, from the foundation of Rome (assumed to be in 753 BC) or from the inauguration of the Emperor Diocletian in 284 AD. The convenience of the Gregorian scheme, means that anyone can tell if a year is a leap year but this depends on a proper numbering of the years. The present scheme was invented by Dionysius Exiguus in the 6th century, but did not become popular till much later. He placed (wrongly) the birth of Christ in 1 BC (zero had not yet arrived from India).

One of the most recent religions is Bahai, derived from Islam in the 19th century. In this religion, 19 is an important number. The founder had 18 disciples (which with himself makes 19), and the Badi year is divided into 19 months of 19 days each. These are followed by 4 or 5 epagomenal days.

It is perhaps inevitable that revolutionary movements which wished to abolish Christianity should institute a new calendar. Just this happened on at least two occasions.

The first of these was the culmination of several proposed reforms of the Christian, Gregorian Calendar put forward by thinkers from the Enlightenment and was instituted by the French Revolution at the end of the 18th century. It lasted till 1806 when it was abolished by Napoleon.

This Revolutionary calendar was similar to the Alexandrian calendar, with 12 months each of 30 days with 5 or 6 epagomenal days at the end, the *sanculotides* or *Jour Complémentaires*. It also replaced the 7 day week with an unpopular 10 day period. Stringent penalties were imposed to ensure that the new week rather than the old was honoured in a proper revolutionary manner.

After the Russian revolution, a number of proposals to reform the Calendar were discussed, for the Julian calendar was still in force. The most radical of these, which lasted from 1929 to 1931, involved a week of 5 days. Each worker was assigned one of these five days for his rest day (the days were distinguished by five colours). The factories would be manned continuously instead of being idle for 1 day in 7. But people complained that they could never spend time with relations assigned a different colour; furthermore the machinery suffered because nobody took responsibility for it.

Many societies have had “weeks” of different periods: 5, 7, 8, 10 days. The Romans based their religious observances on an 8 day “week” - their *nundinae* - but later adopted the seven day planetary week. In this, each day was assigned to one of the seven planets or wandering stars (which included the sun and moon). The Babylonians may have recognised a variable “week” based on the 4 phases of the moon, and the Jews probably adopted it from them.

The first definitive evidence for this planetary week dates from AD 79 from a graffiti uncovered in Pompeii. About the time of its option, Christianity and Mithraism were both contending for the hearts and minds of the Roman Empire. Christianity won, but it has been proposed that the adoption of the Day of the Sun as the day devoted to Christian worship, might have been the result of a compromise with Sun-worshipping Mithraists. The Moslems, Jews and Christians today each honour a different day of the week as their holy day: Friday, Saturday and Sunday.

The very early Christians apparently did not commemorate the Crucifixion and Resurrection of Christ annually. Only later did the practice arise. For a century or more there was considerable contention as to exactly when the celebrations should take place. Eventually the Council of Nicaea was called by the Emperor Constantine in 325 AD to settle various points of Christian belief and practice including the proper date of Easter. It was decided that the Church at Alexandria would be responsible for a Paschal letter to inform the other churches of the correct date according to a rule: Easter Sunday should be the first Sunday which came after the 14th day of the Paschal lunation which began with the first new moon after the vernal equinox.

Even then several centuries elapsed before an adequate method of applying it was evolved. Eventually Dionysius Exiguus produced, in about 532, the method employed until 1582. He prepared tables which were based on the Metonic cycle. Nevertheless, even by the 13th century, defects were becoming manifest. These were consequences of the use of the Julian year, and the length of the assumed mean lunation. Both of these were too long. This meant that the date of Easter was falling later and later in the Julian year, so that the Nicaean rule appeared to being broken, a matter of great concern, and after many false starts, the Church decided to reform the calendar.

The reform of Pope Gregory XIII was based on a proposal put forward by Aloyisius Lilius. It was codified by Christopher Clavius and promulgated by a Papal Bull dated 1582. Clavius wrote the definitive account of the reform. Before that a compendium of the reform had been circulated to all the Princes of Christendom.

The reform was subtle and, as some would say, difficult to follow. Nevertheless in 1582 it was formally adopted by the Roman Church and in the Catholic countries ten days, October 5th - 14th in 1582, were omitted from the calendar and a new method of calculating the date of Easter put into effect. Gregory’s reform was rejected by the Eastern churches, which never accepted it, and also by the Protestants who refused to take instructions from the Pope. This resulted in both religious and secular difficulties and eventually, one by one, the Protestant churches came to adopt Gregory’s reform.

Queen Elizabeth I passed her copy of the Compendium to her court astrologer, Dr. Dee. He advised adoption of the reform and a committee headed by Lord Burghley prepared an act which passed two readings in the House of Lords. Despite this, the Bishops, who saw the Pope as the Antichrist, turned it down. Later in 1699 there was a further proposal for reform which again came to naught. At last in 1751 Lord Chesterfield’s act: “for regulating the commencement of the year and for correcting the calendar now in use” was passed. Previously, in England, the year had begun on March 25th. The new act moved the start back to January 1st (when the Romans started their year) and 11 days, September 3rd - 13th 1752 were dropped from the calendar. The reform was accepted almost without problems though in the 19th century, spurious stories of riots were invented: “Give us back our 11 days!” the mob is said to have shouted. It was even reported that the Glastonbury Thorn flowered on the new official Christmas Day.

Newton and the interactions between Science and Religion

Dr. Robert Iliffe

With almost no exceptions, mathematicians and natural philosophers in early modern Europe claimed allegiance to some form of Christianity. Roman Catholicism, traditionally seen as more hostile than Protestantism to the pursuit of science, can boast Nicolas Copernicus, Galileo Galilei, René Descartes, Blaise Pascal and Marin Mersenne amongst others as members of their faith. On the other hand, Wiliam Harvey, Robert Boyle, Christiaan Huygens and Isaac Newton all claimed allegiance to various forms of Protestant confession. These were devout men, who took their religion seriously, and who saw no fundamental incompatibility between their religious faith and their pursuit of science. If one considers the contemporary commonplace view that God had created two books - the Book of Nature and Scripture - then this view is readily incomprehensible, even in an age where such views are held by a minority of scientists.

In the case of Isaac Newton, there is ample evidence of close connections between his religious views and his natural philosophy (science), and indeed he often asserted as such. In a number of places he described the relationship between God and His Creation as one in which a world created by inscrutable *fiat* was periodically rejuvenated by its Creator, acting either directly, or more often indirectly, by means of secondary processes such as comets. In the “General Scholium” added to the Second Edition of the Principia Mathematica of 1713, he argued that natural philosophy itself was part of natural theology and spoke powerfully about the nature of God and God’s relationship with His Creation.

In detail, however, the picture becomes more complex. On a number of occasions, he explicitly denounced the use of “litigious” styles of arguing in natural philosophy; these included scholastic disputation and the invocation of “witnesses” as a means of vouchsafing experimental facts. Yet these were precisely the techniques used by Newton himself in attempting to discover the truth relating to what he took to be the corruption of true anti-trinitarian Christianity in the fourth and fifth centuries after Christ. In a number of places and in extended treatises, he put the great founder of modern trinitarian orthodoxy, Athanasius, on trial. Any orthodox Christianity, whether Protestant or Catholic, took the work of Athanasius to be fundamental in founding trinitarian orthodoxy; while on the other hand, orthodox Christians denounced the character and doctrine of Arius, the great devisor of anti-trinitarianism, as the gravest heresy. Newton himself composed hundreds of thousands of words attacking both the obscurity of the notion of the trinity and the morals of Athanasius. Perhaps worse still, as far as he was concerned, Athanasius was the founder of what Newton knew as “monkery”, and an architect of what he took to be the evil of the Catholic Church. Trying Athanasius like a skilful barrister, the mathematician who loathed the use of this technique in science found Athanasius guilty in what he clearly believed was the more important discipline of theology.

Of equal significance to Newton was his understanding of prophecy. He always argued - like a good empiricist - that the future could only be known by God, but that proper understanding of the obscure *Revelation of St. John the Divine* could show how events described therein had been fulfilled in history. For this one needed a deep grounding in history, and Newton arguably knew the relevant patristic literature as well as any of his contemporaries. The images of *Revelation*, especially the sealed book shown to John, and the sounding of the trumpets and pouring of vials of wrath were crucial to Newton as to other Protestant exegetes, since they depicted the historical succession of the downfall of the Beast. Although he abhorred the trappings of Catholicism, he again turned to the growing dominance of trinitarianism in the late fourth and early fifth centuries as the central turning point in the growth of Antichristianism. Indeed, while nearly all contemporary Protestants referred to the Reformation as one of the two or three most important stages in the triumph of the true religion, Newton argued that it had changed little of any moment. Instead, the key point in the fate of Christianity had come with the official embrace of trinitarianism by the Emperor Theodosius, a move that was followed by what Newton took to be the divinely inspired reprisals against idolatrous and immoral Catholics perpetrated by the Goths, Vandals and Huns in the fifth century.

Certain features of this sort of interpretation can be compared with his work in natural philosophy. Firstly, Newton claimed that all of this was based on hard evidence and truth, and second, his treatises of the late 1670s and early 1680s were clearly founded on a mathematical format. Scriptural terms were “defined” and connections or “synchronisms” that linked identical periods of time described by different images were called “propositions”. This structure did not last, however. Otherwise, this approach is redolent of an entirely different tradition to that practised in scientific circles by the end of the seventeenth century, and indeed the study of revelation itself was becoming deeply unfashionable by the time Newton embraced it with such enthusiasm.

In another project, however, there was a fundamental unity to Newton's religion and natural philosophy. Drawing on the tradition of the *prisca sapientia*, which held that God had originally given the true science and religion to the Ancients, Newton argued that a proper reading of ancient texts such as Ovid, Hesiod, Lucretius and Pythagoras showed them to be heliocentrists. Avebury, Stonehenge, and various old stones dotted around Ireland, Denmark, India and China pointed to a widely distributed ancient religion that - because its worship was based on a circular architecture arranged around a central, vestal fire - Newton thought was the most "rational" of all. His Principia was thus merely a "rediscovery" of this ancient truth, and Newton implicitly likened himself to one of the knowledgeable priests who had been the original guardians of both religious and natural knowledge before its corruption by Aristotle and others. Thus, a proper understanding of Newton's religion reveals different levels of similarity and difference in the ways in which he conceived their relationship.

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The Religious Outlook of James Clerk Maxwell

Professor F. Kingsley Elder

Our principal source for determining the religious outlook of James Clerk Maxwell is the definitive biography written by the Rev. Professor Lewis Campbell (his intimate friend and companion since boyhood) and Professor William Garnett (his demonstrator at the Cavendish Laboratory at Cambridge).[1] Professor Campbell gives general biographical material as well as being principally responsible for the religious data. An Episcopal minister, Campbell was also Professor of Greek at St. Andrews University.

Maxwell's religious commitment. Throughout his relatively brief lifetime James Clerk Maxwell had the opportunity to enjoy Christian fellowship with members of several different communions, particularly with Presbyterians in the Church of Scotland, and Episcopalians in the Anglican Church and the Scottish Episcopal Church. As an adolescent he was thoroughly introduced by catechetical instruction, and preaching, to both Presbyterianism and Prelacy.[2] His parents, devout Christians, brought him up to revere the Holy Bible as the Word of God. One might wonder what would be his denominational preference and affiliation as an adult. Circumstances often placed him where his usual religious activity was with the Episcopalians, but I think there is adequate evidence that his convictions and preference lay with the Presbyterian system, although this fact is not clearly presented by his biographers.

Ordination as a ruling elder. While recognising Maxwell's Scottish Presbyterian heritage as well as Maxwell's thorough acquaintance with the theological literature, Campbell fails to grasp the religious significance, for Maxwell, of his taking the vows for ordination as a Ruling Elder in the Church of Scotland. These vows commit him literally to the Calvinistic doctrine of the Westminster Standards of the Church of Scotland, and also to its Presbyterian form of Church Government and Polity.[3] This, in fact, is a principal consideration in identifying his religious outlook.

Previous religious experience as a young adult. As a student at Edinburgh University, he would have continued at the Church of Scotland, but when he transferred his studies to Cambridge University he would be required to participate in the services of the Anglican church. I think he could go from one of these religious environments to the other in good conscience, however, despite personal preference, because of his gracious personality, and his ecumenical spirit, consonant with the teaching of the Westminster standards regarding Christian liberty, regarding the unity of the church of Jesus Christ, and regarding the communion of the saints (all believers, that is).[4]

Example set by his mentors. Another factor that helps explain how Maxwell could have strong personal commitment to the Presbyterian system and to the Church of Scotland and yet accept the Episcopalian ministry and fellowship on occasion, is the impact of his Presbyterian and Episcopalian pastors during his adolescent years, who both were men of strong convictions, coupled with a commitment to the unity of Christ's Church. For example, Dean Ramsay, a strict Episcopalian, would not even consider an attractive church call to an otherwise congenial congregation who were not as fully episcopal as he believed they should be. Yet he was at the same time an admirer and champion of the Rev. Thomas Chalmers, leader of the Free Church of Scotland. Also, Dr. Thomas Crawford, who wrote a strong defence of Presbyterian versus Episcopalian church government,[5] as being much closer to that of the apostolic church, nevertheless had a strong sense of the unity of the Church as the body of Christ.

Direct Bible study. The Westminster Confession of Faith and Catechisms are intended to present a systematic summary of the Bible's principal teaching. However, in addition to this indirect Biblical teaching, Maxwell's religious outlook was directly influenced by the Bible itself. At one place, for example, he speaks of "Christianity—the religion of the Bible."[6] James had an extraordinary memory, and as a child he was encouraged to commit large portions of Scripture to memory, particularly from the Psalms. Lewis Campbell comments: "His knowledge of Scripture, from his earliest boyhood, was extraordinarily extensive and minute; and he could give chapter and verse for almost any quotation from the Psalms .... These things were not known merely by rote. They occupied his imagination, and sank deeper than anybody knew."[7] In a special way, then, his familiarity with the Bible, which he learned as a child to revere and trust as God's Holy Word, contributed directly to his religious outlook.

Other evidences of Presbyterian commitment. What other evidences do we see that James Clerk Maxwell's religious outlook was indeed Presbyterian and not uncertain?

(1) There is the fact that as Professor of Experimental Physics at Cambridge he made a special point each year of leaving as soon as possible after the end of the Easter term so as not to miss officiating as a Ruling Elder at the midsummer Communion Service at the Kirk in Scotland.[8]

(2) There is the fact that he was a signator of a petition to the London Presbytery of the Presbyterian Church in England requesting them to establish a Presbyterian Church in Cambridge. (Sadly, he died before St. Columba's Presbyterian Church was established in Cambridge.)[9]

(3) Unlike his father, James married a Presbyterian, the daughter of the Rev. Dr. Daniel Dewar, a scholar and a prominent and articulate minister of the Church of Scotland.

Personal religion. Household devotions. After his father's death, following his example, James took seriously his duties to conduct family worship as head of the household, the new Laird of the family estate of Glenlair, although he[10] had initial concern lest any variation in how the devotions were done might be misconstrued as criticism of his father's procedures. He evidently developed an effective approach. Prof. Campbell comments, referring to the period of initial retirement from London[11], "One who visited at Glenlair between 1865 and 1869 was particularly struck with the manner in which the daily prayers were conducted by the master of the household. The prayer, which seemed extempore, was most impressive and full of meaning."

Perhaps he benefited from the fact that both his previous Presbyterian pastor at Edinburgh, Dr. Crawford, and his father-in-law, Dr. Daniel Dewar, were involved in writing books to help families conduct family devotions.[12]

It is clear in Campbell's biography that visitation of and ministry to families in his neighbourhood, with his wife, was also an opportunity in which James took delight.[13] This could very well have been a part of his responsibilities as an elder in the Kirk. Campbell has also preserved a couple of copies of prayers such as he might have used. They show a strong influence of the Psalms, although they are not taken from the psalms verbatim.[14]

As late as September 1879, when his final illness had begun to take its toll, James was able to continue household devotions at Glenlair. The biographer says, "In the evening, however, the master of the house conducted family worship as usual for the assembled household."[15]

Family devotions were evidently an important part of the day, in sickness and in health, although sometimes the sickness might limit James to private devotions with his wife. In the two serious illnesses at Glenlair that Maxwell suffered, one near the beginning, the other near the end of their time in London, his wife took devoted care of him. Professor Campbell recounts how during the second sickness, in 1865, Mrs. Maxwell was again his nurse, and he insisted on listening to her quiet reading of their usual portion of Scripture every evening even though "it was the utmost mental effort which he could bear."[16]

Even in physical pain, James welcomed the time of spiritual refreshment. Again and again, Campbell's biography points to the spiritual quality of their marriage - from the mutual care and concern for one another, to the content of their Bible study in their letters.

Maxwell's outlook on sermons. Several comments of Lewis Campbell on Maxwell's attitude toward sermons are significant. We see much of James's religious side through his eyes. When they were boys together visiting Glenlair,[17] Lewis was impressed at the serious way in which James intently studied sermons, and also attests with favour to his critical retention of the important points. Campbell later says of the mature Maxwell, "He had no use for indefiniteness or indifferentism in sermons[18] or of a style of preaching which "dings ye wi' mere morality", as he put it." Although he claimed to "have no nose for heresy [perhaps because of his graciousness]", he did not believe in "progress by ignoring differences, or by merging the sharp outlines of traditional systems in the haze of a "common Christianity"." His concern for the unity of the church did not justify the compromising of truth.

Another aspect of Maxwell's outlook on sermons is indicated in a letter to his friend the Rev. C. B. Tayler telling of the Maxwells's experience in London while he was a professor at King's College, London.[19] The main thrust of the letter is to indicate that what they looked for was Bible exposition and application, and that they usually found it in a Baptist preacher nearby, although they had no intention of becoming Baptists. In a letter to his wife, Maxwell elsewhere reports favourably on a sermon of Lewis Campbell's[20], again indicating his belief in the need for clear, Biblical sermons.

Science and scripture. Maxwell recognised that the same omnipotent God has revealed Himself in His Word (the Bible) and in His works (the Created universe), and that these two revelations are intrinsically compatible. This is not a theorem to be proven; it is an axiom to be assumed at the outset. There is no conflict between true science and true theology. Each may be studied independently, to learn more of the glory of God, and to marvel.

In the Psalms Maxwell learned to seek God's glory in His Word and in His works of creation. The Psalms reiterated the "cultural mandate", of Genesis, which he cites, with approval, in his inaugural lecture at Aberdeen. "... the study of the world in which we live is our obvious duty as a condition of our fulfilling the original command "to subdue the earth and have dominion over the creatures"." There is no intrinsic conflict between Religion and Science. The all-powerful and all-knowing God of Creation is the God of the Bible, and the Author of Salvation.

What are the consequences of this attitude on Maxwell's part? In his response to Bishop Ellicott's query about reconciling certain specific statements in the Bible with accepted scientific laws he makes the thoughtful comment that this is inappropriate to do because both accepted scientific laws and accepted interpretations of Scripture are subject to change, and one is risking perpetuating an obsolete concept by the attachment of a transient scientific opinion to a transient theological opinion.[21]

In answering a similar question raised by Maxwell's repeatedly being invited to join the Victoria Institute, he essentially says that reconciling scientific ideas with religious ideas is a very personal matter. Everyone ought to work out such a reconciliation for himself, but no one should work it out for someone else. For this reason he has reservations about some of the objects of the Victoria Institute.[22]

Maxwell writes in a similar vein to his fiancée with regard to interpretation of the Bible as an individual.[23] In sum, it is the duty of the individual to study God's revelation in His Word and Works, and thereby to seek pleasure and God's glory. For Maxwell, "Man's chief end is to glorify God, and to enjoy Him forever."[24]

Maxwell's psalm. Over the front entrance of the original Cavendish Laboratory, which James Clerk Maxwell himself meticulously designed, is inscribed a sentence in Latin, with no identification. It is a quotation from the Old Testament, the Latin Vulgate Bible, Psalm 111, verse 2. The verse, in English, is "Great are the works of the LORD; They are studied by all who delight in them."

Whether this Bible verse was placed there by Maxwell's instruction or merely by his permission, it expresses neatly and succinctly the work of the

Christian who is a physicist! For James Clerk Maxwell, studying nature was surely an opportunity to glorify God by discovering His wonders, and taking part in that eternal enjoyment by studying them. And when the new Cavendish was built, many years later, the tradition was perpetuated, this time in English!

When I consider this verse in the context of the entire psalm, I am struck by the fact that the psalm in its entirety is itself a summary of "Maxwell's outlook on religion". As an evangelical Christian, he believes in God the Creator and Sustainer of all things, a God of righteousness, truth, and justice, Who cares for His covenant people, and has redeemed them from their sins for all eternity. Thus I close this paper with this psalm.

PSALM 111 (New King James Version)

1. PRAISE the LORD!
I will give thanks to the LORD with all my heart,
In the company of the upright and in the assembly.

2. Great are the works of the LORD;
They are studied by all who delight in them.

3. Splendid and majestic is His work;
And His righteousness endures forever.

4. He has made His wonders to be remembered;
The LORD is gracious and compassionate.

5. He has given food to those who fear Him;
He will remember His covenant forever.

6. He has made known to His people the power of His works,
In giving them the heritage of the nations.

7. The works of His hands are truth and justice;
All His precepts are sure.

8. They are upheld forever and ever;
They are performed in truth and uprightness.

9. He has sent redemption to His people;
He has ordained His covenant forever.
Holy and awesome is His name.

10. The fear of the LORD is the beginning of wisdom;
A good understanding have all those who do His commandments.
His praise endures forever.[25]

1. Lewis Campbell and William Garnett. The Life of James Clerk Maxwell (MacMillan and Co, London. 1882). This is the most quoted single source in this paper. For simplicity we will refer to it as CG, followed by the page reference.
2 CG, pp 55-6.
3 See Kirk Session minutes for vows. Maxwell's nomination, approval, and ordination and installation given in Corsock Kirk Session minutes, 1863.
4 See the Westminster Confession of Faith: Chapter XX:2; Chapter XXV:1,2; Chapter XXVI:1,2..
5 Thomas J. Crawford, D.D. Presbytery or Prelacy which is the more conformable to the pattern of the apostolic churches?. (Blackwood and Sons, 2nd ed, 1867, Edinburgh and London).
6 CG, p 179.
7 CG, p 32,
8 CG, p 371.
9 St. Columba's Church, Cambridge (1879-1979) A Centenary Survey by Dr. A. Buick Knox, Professor of Ecclesiastical History, Westminster College, Cambridge.
10 CG, p 254.
11 CG, p 323.
12 Dr. Crawford was convenor of a committee of the General Assembly of the Church of Scotland, with responsibility for producing a publication to encourage family worship. Dr, Dewar, whilst Pastor of the Tron Church in Glasgow, published at least two editions of his own book on The Nature and Obligations of Personal and Family Religion.
13 CG, pp 322-3.
14 CG, p 323.
15 CG, p 407.
16 CG, p 320.
17 CG, p 83.
18 CG, p 322.
19 CG, pp 344-5.
20 CG, pp 311-12.
21 See CG, pp 392-6.
22 See CG, pp 404-405. The general thrust of the objects of the Victoria Institute is indicated by the First Object: To investigate fully and impartially the most important questions of Philosophy and Science, but more especially those that bear upon the great truths revealed in Holy Scripture; with the view of reconciling any apparent discrepancies between Christianity and Science.
23 CG, p 309. (2nd May 1858)
24 Westminster Shorter Catechism, Answer to first question.
25 Scripture taken from the New King James Version. Copyright 1982 by Thomas Nelson Inc. Used by permission. All rights reserved.

The Significance and Importance of John Philoponos as a Forerunner of James Clerk Maxwell

Very Rev Professor Thomas F. Torrance

My concern as a theologian is not with religion and science, which can so easily evade the fundamental issues at stake, but with the deep level *conceptual interface* between theological and scientific understanding of the rationality embedded in the created order of things. Here we have to take into consideration something of which few scientists and fewer theologians seem really to be aware: the epistemological revolution brought about through general relativity theory, in the inseparability of ontological and empirical factors found in nature and in our authentic understanding of it at every level. Along with that goes the realisation that there is no logical bridge between ideas and reality. Failure to discern and grasp this is often evident in the epistemological naïveté that characterises even some of our most distinguished scientists, not to speak of theologians, especially those of a rationalist or fundamentalist kind.

The inherence of theoretical and ontological factors in one another applies particularly to the basic concept of order with which we have to do in all natural and theological science under an imperative and obligation of a categorical kind that is thrust upon us from an ultimate ground of order. This means that we are forced to think out natural, and indeed moral laws, in terms of their intrinsic ontological grounds, and think out physical laws in terms of their contingent relations to a stable ground of intelligibility beyond ourselves the ultimate *Why* (to which Einstein referred in connection with unified field theory), the reason or justification of all law in God. This implies, as Clerk Maxwell and Albert Einstein both realised in their different ways, that there is and must be a fundamental harmony between the laws of the mind and the laws of nature, that is an inherent harmony between how we think and how nature behaves independently of our minds.

Thus the more profoundly our understanding penetrates into the rationality of the universe of space and time, the more clearly and fully a pre-established harmony between mind and nature becomes manifest, between the way we think and what we think about. All this applies no less to the interrelations of theological science and natural science, although they are both concerned in their different ways with a kind of intelligible order immanent in the created universe, that is with the *contingent* rational order with which all empirical and theoretical science have to do and upon which they are grounded.

In pursuit of ways in which to work out the cognitive relations between theology and science, I wish to direct thought to John Philoponos. He was a sixth century theologian and scientist in Alexandria who did more than anyone else to transform the foundations of ancient philosophy and science, and helped to lay the foundation upon which, as we now know, all our empirical and theoretical science ultimately rests. Unfortunately, John Philoponos was anathematised by the Aristotelian Churchmen in Byzantium, so that what he achieved through working out a profound relation between Christian theology and natural science was largely lost for more than a thousand years. From what we now know of his thought in the sixth century, it is clear that he anticipated the way in which James Clerk Maxwell in the 19th century brought his Christian theological convictions to bear upon his mathematics and physics in such a way that, as Einstein declared, "it transformed the logical structure of science".

Already changes in the foundations of science were being brought about in the fourth and fifth centuries through the preaching of the Gospel and the teaching of the Holy Scriptures about the creation of the world out of nothing and the redemptive incarnation of the Word of God in space and time in Jesus Christ. This had the effect of destroying the dualist structure of Greek philosophy and science, and of revealing the *contingent* nature of the universe and its God-given *rational* order. The doctrine of the mighty living and acting God undermined the rationalistic and inertial system of Aristotelian philosophy and science, and made possible the rise of empirico-theoretical science as we know it.

Here I shall limit myself to three principal ways in which Christian faith has made effective cognitive contributions to science: in respect of 1) Rigorous scientific method, 2) Direct input, 3) Regulative impact.

1. Scientific method

Rigorous scientific method was worked out by Christian theologians in Alexandria from the second to the fifth centuries in the face of Aristotelian, Neoplatonic, and Sceptical philosophers. John Philoponos played a leading role in this effort at the great Academy at Alexandria. Careful thinking in theology and science alike, it was held, proceeds strictly in accordance with the nature or objective reality of what is being investigated and/or interpreted, that is, in accordance with what it really is. This called for a process of positive questioning of realities or framing of thought experiments designed to let their actual nature disclose itself - a method which became known as *kataphysic* or *dogmatic science*. These terms describe a science in which thinking and knowing are positively governed by the objective nature or reality of things, operate holistically rather than analytically, and develop a modality of the reason that is appropriate to the specific nature of the object, whether it be a rock, tree, an animal, or a person. Thus a switch in the modality of the reason takes place when one moves from one objective reality to another - the scientific method remains the same: to know it as strictly as possible in accordance with its nature, whether an inanimate or animate reality, a static or an active reality. But a more radical change takes place in the case of a human being: another rational agent over whom the inquirer can have no control, but where the inquirer responds to him/her and reveals something of his/her inner self. Here there takes place a two-way relation, a personal interaction, between the knower and the one known. While the modality of the reason changes accordingly, the scientific method remains the same, knowing and thinking of the other strictly and adaptively in accordance with his/her nature.

When we turn to inquire of *God* and seek to know him in accordance with his nature, the modality of our reason undergoes a very radical shift, but the scientific method remains the same: knowing him strictly and holistically in accordance with his divine reality and nature. Here human thinking undergoes an epistemic reorientation, under the creative and self-revealing impact of God's personal interaction with us. Thus there takes place an *epistemological inversion* of our knowing relation but in strict accordance with the nature of God as he makes himself known to us. With creaturely realities we seek to know them in accordance with their nature as they become "disclosed" to us under our questioning, but with God our knowing of him in accordance with his nature takes place under the constraint of his activity in "revealing" himself to us. Here scientific method, pursued strictly in accordance with the nature and reality of God as he makes himself known to us, is up against a measure of objectivity that we encounter nowhere else, under the compelling claims of his transcendent nature. This means that we may know God truly only out of God himself, that is, through his self-revelation and grace, and hence know him only in the mode of worship, prayer, and adoration, in which we respond humbly and obediently to his divine initiative in making himself known to us personally and savingly through his Word as our Creator, Lord and Saviour.

It is a form of the same scientific method that was held by Christians in the Early Church to apply to the understanding and interpretation of the Holy Scriptures which call for a deep-seated change of mind, appropriate to the reality and nature of God's Word as it is mediated to us in and through the Scriptures. That is to say, the Holy Scriptures were to be interpreted objectively in accordance with the nature of the divine Realities and Activities to which they direct us. In them, God has adapted his self-revelation to human language in such a way, that human statements in the Scriptures direct us beyond themselves to God, so that in seeking to understand and interpret the Scriptures as given us by God, the divine reality they mediate, the very Word of God himself, is not to be subordinated to the human word, but the human word to the divine reality to which it refers. Scientific method requires us, therefore, to give careful attention both to the human character of the Scriptures and to the transcendent Nature of God, but in so doing to take the Reality of God's self-revelation to us in the Scriptures so seriously that we look through the human word to the divine Reality of God's self-revealing Word mediated to us in and through the Scriptures.

It was much the same relation that Christians found to obtain between the activity of natural scientists and the realities they seek to understand: when the scientist inquires into the nature of the contingent world, he does that not by looking at God but by looking away from him at the world; but when the theologian inquires into the nature of God, as he has revealed himself to us, he does that not by looking at the nature of the world, which God created out of nothing, but by looking away from the world to its Creator. In both instances the scientist and the theologian seek to act strictly in accordance with the nature of the objective reality into which he inquires.

2. Direct input

Never in all the history of science has Christian theology had such a transforming impact on science as through John Philoponos of Alexandria in the sixth century. His was a biblical and Christocentric theology in which he developed the Christian conception of the creation of the universe out of nothing, and sought to give an adequate account of its contingent rational order. Of particular importance for him was the Biblical teaching about the incarnation of the Creator Word of God in Jesus Christ, the Light of the world through whom all things were made, and of the intrinsic relation between the divine Word and the divine Light. Working with a distinction between uncreated Light and created light, he put forward a theory of light and a theory of impetus. Together, these overthrew the static inertial notions of Aristotelian science, and produced a dynamic understanding not only of sciences such as optics, physics, and meteorology, but of the unitary universe of heaven and earth. In the course of this transformation of classical science, he advanced relational conceptions of time and space, defining them in terms of the dynamic behaviour of what he called “light force”. This called for a new holistic and dynamic way of thinking of real intelligible relations, with which traditional Aristotelian and Euclidean logic, concerned with static patterns and relations, could not cope, and which came under severe attack particularly from Aristotelian philosophers and scientists like Simplicius, known as The Commentator. However, the overthrow of a static for a dynamic theory of light, and the transformation of physics it involved, was an astonishing anticipation of the role of light put forward by Clerk Maxwell and Einstein more than a thousand years later.

It should be added that in accordance with Philoponos’ conception of the contingent nature of the universe and its rational order, as also in accordance with his doctrine of the creation of the world out of nothing freely through the Word of God incarnate in Jesus Christ, Philoponos would have nothing to with any attempt to argue from the nature of the world to the existence of God, for that not only assumes that there is a logical bridge between ideas and reality, but would mean that God is necessarily related to the world. And that, in turn, would imply that the world was not freely created by him out of nothing, while nevertheless endowed with a form of rational order utterly distinct from God but dependent on him. While science, transformed under the impact of Christian theology, points properly away from itself to God, that is because of the Christian theological input into understanding of its contingent nature.

The work of John Philoponos represents an outstanding instance of the direct cognitive *impact of Christian beliefs* in the development of natural science. Of signal importance in it was the relation between the uncreated Light and Word of God, and created “light” and creaturely “word”. This relation between light and word involved an *informational* input into scientific theory beyond what could be extracted by way of reflection upon the activity of the physical light in the cosmos by itself. Physical light was, and had to be, understood not merely through its empirical behaviour, but through the bearing upon it of information which shaped its theoretical content. Expressed otherwise, it was through a “meta-relation” of light to “word”, and above all to the Word of God, that it came to be understood and deployed by Philoponos in his transformation of science. It was thus through the cognitive content of his faith that Philoponos actually developed his epoch-making light theory and impetus theory. This raises for us the importance of what we call "information theory", and the need to take into account some sort of transcendent order, or "meta-plan" (as Paul Davies calls it), in developing scientific theory especially at boundaries between being and non-being. That is, of course, particularly clear today in respect of the human genome which is laden with more information than would fill a vast encyclopedia, and which by its astonishing complex nature could not have arisen in some sort of accidental or self-organisational way.

John Philoponos' development of dynamic science led to a significant *feed-back* (what Adam Smith called "the invisible hand") into Christian theology, not in content but by way of developing its dynamic character in accordance with the redemptive activity of the incarnate Word of God in space and time. This had already been taking place, particularly through the thought of the great theologians, Athanasius and Cyril of Alexandria. Now, however, the interrelation between this theology and science, which had given rise to dynamic science, rebounded upon Philoponos' theology in respect of his scientific method and technical terms, giving them a more dynamic form.

The crunch came when basic theological terms were given a dynamic slant in accordance with the dynamic nature of the realities to which they referred. That meant that they could not be interpreted in their classical literary sense, that is, as read in accordance with the meanings they had in classical Greek literature, and as read particularly through the twin spectacles of Plato and Aristotle. Thus crucial terms and expressions referring to the nature and oneness of the incarnate Son of God came under severe attack from the Byzantine Establishment. For example, when Philoponos cited Cyril's expression, "the one incarnate nature of the Word of God", and interpreted it holistically in accordance with his one dynamic reality and not analytically, he was accused of being a *monophysite heretic* - one who denies that Christ was both divine and human. He was condemned, and his writings banned, with the result that science, and the cognitive relation of theology to science, not least the cognitive input of theology in science, were obstructed until modern times. The rejection of Philoponos had the disastrous effect of allowing Aristotelian science, with its inertial concept of God as the Unmoved Mover and its logico-analytical modes of thought in theology and science, to overrun Western culture and to give rise to the dualist and deterministic conception of the world that stems from Galileo and Newton.

3. Regulative impact

In modern times there arose a new Philoponos, James Clerk Maxwell, a devout evangelical believer, whose light theory and impetus theory together also gave rise to a dynamical way of scientific thinking, which broke free from the kind of mechanistic science based on Newton's Principia Mathematica, and opened up the way with his dynamic field theory of light for the transformation of science through relativity and quantum theory. The decisive change came with the publication of Clerk Maxwell's epoch-making book, Dynamical Theory of the Electromagnetic Field, 1864, which brought about the greatest change in the axiomatic basis of physics and correspondingly in our conception of reality. This was followed by Clerk Maxwell's two-volume work Treatise on Electricity and Magnetism in 1873, which must be reckoned with Newton's Principia Mathematica as one of the two great works on which modern science rests.

Clerk Maxwell did not intrude theological ideas specifically or directly into his scientific theories, but the Christian faith deeply entrenched in his being exercised a *regulative* role in the choice and formation of his leading scientific concepts. Thus through his "union with Christ", of which he spoke frequently, he gained an intuitive apprehension of the relation of God to his creation, which provided him with what he called "a fiducial point or standard of reference" for discriminating scientific judgements. It directed him to real ends external to himself, and to the kind of objectivity he needed for critical scientific activity, not least in grasping and bringing to appropriate expression the contingent intelligible relations inherent in nature.

This called for a holistic rather than an abstractive way of thinking, in which he could let real dynamic relations have their full value, without being mauled by abstract Aristotelian logic which applies only to flat space. Hence he inverted the current mathematical and scientific way of beginning with analytical particulars and building up the whole by synthesis, and made primary a mathematico-conceptual mode of interpreting dynamic realities and real ontological relations without distorting them. At the same time, his Christian faith provided Clerk Maxwell with certain "analogical truths", root ideas, and fundamental conceptions, for which natural science could not account but which guided him in the scientific task of wedding thought with reality and developing appropriate ideas. He spoke of these as "modes of thought" and "physical truths", matched to the unveiling of processes inherent in nature, which called for a corresponding mode of "physical reasoning" and a "new mathesis in mathematics" particularly concerned with ontological relations of space and time. In that connection he called for a new way of mathematical thinking, involving time relations, which was later echoed by Einstein.

Clerk Maxwell became convinced that "in a scientific point of view the *relation* is the most important thing to know". The kind of relations he wanted to express and develop were not of a putative kind but real relations of an ontological kind inhering in reality, for the inter-relations of things are ontologically constitutive of what they really are. The relations between things, even of persons, belong to what they are. That was a conviction deeply rooted in Scottish theology and metaphysics (from Duns Scotus and Robert Boyd to William Hamilton) which Clerk Maxwell was to call to his aid when again and again he failed to offer a satisfactory explanation of the behaviour of the moving lines of force in the electromagnetic field in terms of Newtonian physics and mechanics. Thus when he developed an explanation of the behaviour of electro-magnetic particles, in particular of the way in which light particles relate ontologically and dynamically with one another moving at the speed of light, he came up with the concept of the *continuous dynamic field*, which had the effect of transforming the laws of classical Newtonian mechanics, and opening the way toward a new understanding of physical reality in terms of relativity and quantum theory.

This was a revolutionary counterpart to the transformation of Aristotelian science by John Philoponos in the sixth century through the combination of light theory and impetus theory. It was not that Clerk Maxwell imported theological conceptions as such into his science, but rather that the pressure of his Christian understanding of God and his creation of the world led him to put forward new ideas and ways of thinking that transformed the basic structure of natural science, and were congenial to the Christian understanding of the universe of space and time. In other words, it was his basic Christian beliefs that prompted his new scientific thinking and exercised a regulative role in the choice and formation of his leading scientific concepts.

What, then, about the relation of *light* to *word*, created light to the uncreated Light and Word of God, the transcendent Source of all contingent order in the universe? It is to Clerk Maxwell that we owe the discovery that light has mathematical properties. Everything we know in the universe, macrocosmically or microcosmically, we learn from light signals, but their mathematical patterns have to be deciphered and coordinated with word in the formation of scientific theory and the development of knowledge. That is to say, as Philoponos taught, *information* is needed in understanding the behaviour of light and its divinely given dynamic role in the universe. Created light by its very nature, points away to the uncreated Light and

Word of God, the ultimate ground of all rational order and the transcendent source of the crucial information needed in the heuristic progress of science. John Philoponos and Clerk Maxwell together thus point us in seeking understanding of the universe toward some meta-source of knowledge or meta-order to guide our research and develop appropriate scientific theory. It is, I believe, along these lines that we may profitably think out for our generation the cognitive bearing of Christian belief upon the advance of scientific knowledge of the universe that God has made and within which his Word became incarnate in space and time.

I believe that when we explore the way in which the Christian faith of John Philoponos in the sixth century and of James Clerk Maxwell in the nineteenth century exercised a cognitive input and a regulative impact upon natural science, we see something of the way in which we today working at the conceptual interface between theological science and natural science may contribute to genuine advance in scientific knowledge. But in doing so it will have a powerful feed-back upon Christian theology of the dynamic kind it needs today, and a recovery of what Karl Barth called the God who acts, the God whose Being and Act are dynamically one and the same.

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Theology and Modern Physics

Dr. Peter Rowlands

Physicists, such as Einstein and Stephen Hawking, are famous for invoking God as the ultimate arbiter of physical theory, and modern physics has often been noted for its quasi-theological tone, its conviction that there is some ultimate simple underlying truth. In fact, this idea is not quasi-theological at all, but actually theological. Its origin is in the work of theologians of a particular period, which has been subsequently imported into physics for fundamentally theological reasons, and it is the necessary extremism of that theology which is responsible for the success of physics in claiming universal application.

Physics, in the sense of the creation of a set of powerful and simple abstract concepts, applicable to a wide variety of cases, really began in the fourteenth century, at the height of mediaeval scholasticism. Working mainly at the great centres of Oxford and Paris, the fourteenth-century schoolmen developed a terminology for dealing with abstractions in a way that was ultimately theological, but also, as a by-product, produced a powerful new mathematics and mathematical physics. This was because they based their most fundamental thinking about God and the universe on an investigation of the two great metaphysical concepts of space and time, which had long been recognised as the two most simple abstract concepts available to the human mind, and which, even today, are the ultimate and only source of all human knowledge of variation in nature. What we would call the increase and decrease of variable quantities, they called the "intension and remission of forms". The relationship between space and time variation became the discussion of motion, variously "uniformly difform", "nonuniformly difform", or "difformly difform", leading to the modern concepts of velocity, acceleration, momentum, force, and also to the new mathematical techniques needed to describe such variations.

More important than any of these technical contributions was the method which was encapsulated in William of Ockham's famous "razor": the idea that "entities must not be multiplied unnecessary" - the idea that "forms" must be as few as possible, that explanations must be refined to the greatest pitch of simplicity, using ideas as abstract as could be found. Only in this way could we begin to approach to a knowledge of the work of the all-powerful Creator and universal spirit. The lack of perfection in human reasoning, perceived by theologians who put all ordinary physical explanation second to the infinite power of God, created a situation in which scientific thought became an enterprise which required continual renewal, and was never allowed to fossilise into a doctrinaire pseudo-intellectual discipline shoring up the foundations of society.

The work of these cloistered theologians eventually passed on to secular masters trained at the same universities, like Galileo Galilei, trained at the University of Pisa, who was heir, through Domingo de Soto, and the Ockhamist John Major, to the fourteenth century tradition of the mathematical treatment of uniformly accelerated motion. Perhaps surprisingly, however, this tradition was rejected by Galileo's immediate successors in favour of a new "mechanistic" style of thinking, influenced by ancient atomism. The mechanists thought that the mediaeval schoolmen were hopelessly out of date, and their chief propagandist, René Descartes, took the opportunity to develop a kind of "constructivist" view of physics, in which there would be little need for the direct action of the all-powerful creator or active universal spirit.

The mechanistic style became dominant in the Royal Society of London and the Paris Académie, achieving significant results in the hands of such masters as Huygens, Hooke and Boyle. Here, individual problems were solved by devising a particular hypothesis relating to the particles of matter or their properties and following it through to the desired conclusion. There was no suggestion of a universal method; each problem was tackled on its own merits. What changed all this was the startling success of Newton in applying a universal method to the problem of planetary motion and all other large-scale physical phenomena in 1687. The story of modern physics is, in my view, that of the gradual coming to terms with the Newtonian legacy.

The Newton methodology is based on a universal, all-powerful God, the direct source of physical attractions for which mechanical sources need not be sought. Newton's method separated the abstract system from physical measurement. The system had a perfection that could never be physically realised. The principle that appeared in his work for the first time was that there were a few certain types of information which were more fundamental than others, and that these were abstract and could be defined precisely in an abstract way without regard to any model of nature based on concrete terms, and Newton, as an Ockhamist who out-Ockhamed Ockham, had a special ability at reducing these concepts to the few that turned out to be particularly significant. For Newton, though not for his mechanistic contemporaries, the ultimate causes of things were abstract rather than mechanical. The laws describing the system did not depend on any physical hypotheses.

There are many elements of directly theological origin in Newton's system. Universal laws are abstract definitions and do not primarily describe nature. All other physical laws are solutions of general equations which are ultimately approximate or local. Mathematically, universal laws are expressed by differential equations of which there is no exact solution. The laws of motion define an absolute condition (no force in a system), and the third law is universal in acting on all bodies equally. Gravitation is the result of an active power, the spirit acting directly - hence it is abstract and requires no mechanism, and the universal law of gravitation - everything attracting everything else - means that the system is fundamentally indeterminate. There is no perfection in observed nature, only in the abstract system. Planetary ellipses are merely an approximation - they have no fundamental significance. Physical systems (including the Solar System) cannot be maintained in perpetual motion because of dissipative forces.

There is also the definition of a fundamentally absolute space and time, which presumably apply to the abstract system, as well as a relative space and time, which presumably apply to measurement. The indeterminacy of physical measurement was the real reason why Newton introduced the concepts of absolute space and absolute time, and distinguished them carefully from relative space and relative time, which were the quantities commonly used in measurement. Newton's absolute space and time are aspects of the abstract system, not the measurement process applied to individual events. The argument that special relativity does away with Newton's absolute time is fallacious because absolute time, in the same sense, an absolute sequence of events is also required by Einstein's use of the principle of causality. Further justification for the Newtonian concepts is to be found in the concepts of quantum nonlocality and entangled quantum states; here, the absolute sequence of events is maintained by the indeterminacy caused by an instantaneous universal "interaction" at a distance, just as in Newton's theory.

The power of Newton's methodology is apparent, but why does it work? The answer seems to be that he incorporated mass into his system as a fundamental parameter on the same level as the age-old principles of space and time. Mass introduces the property of conservation, which can be described in absolute terms, leading to a whole series of conservation principles, which are invariably the bases of dynamical systems. The conserved property of mass also shows up the contrasting, nonconserved natures of space and time, which are incorporated into physics in the differential forms with which these quantities are associated in fundamental equations. Newton's second law merges the contrasting properties of the fundamental parameters by defining force as a product of the conserved mass and the differential forms of the nonconserved space and time, and then establishes the conservation property of mass through the third law (which, through the notion of mass as "impressed force" was directly equated by Newton with mass conservation).

Newton's system becomes powerful because it is extreme, and it is, of course, extreme because it stems from theology. His successors - Euler, Maupertuis, Lagrange, Hamilton - produce improved versions of his dynamics, but each uses an *extremum* principle of some kind, defining a quantity involving mass and the differentials of space and time, and showing its extreme behaviour. In virtually exact repetition of the Newtonian pattern, there is always a law which defines a quantity (force, momentum, energy, action, Lagrangian, Hamiltonian) and another which sets this quantity to zero, or a constant value, or a maximum or minimum. At the same time, a further ("physical") law specifies the operation of the source of the defined quantity, as Newton's law of gravitation had defined the operation in his system of the quantity force.

What might be called Newton's "programme" is followed by Laplace and many others in the eighteenth and nineteenth centuries. This is to seek forces of other kinds, which are analogous to gravity and equally inexplicable. The idea that this must be so is an aspect of Newton's Ockhamist procedure. The eighteenth century struggles to establish the electrostatic force as inverse-square, like gravity, while Kant shows that this is a natural result of 3-dimensional space. Eventually, Priestley uses an argument by direct analogy with one of Newton's gravitational theorems, before Coulomb establishes the point conclusively by direct experiment. Out of this comes a new mass-like quantity, charge, and this is probably the last truly fundamental addition to the physical parameters, because, even though two new forces, the strong and weak nuclear interactions, are discovered in the twentieth century, they can be conceived of as being produced by charge-like source quantities, which, under ideal conditions, would behave the same as electric charge.

Current electricity and electromagnetism complicate the picture, but eventually, Maxwell sets down, in mathematical form, all the laws that were known to be valid for electric and magnetic fields - in particular, those of Coulomb, Ampère and Faraday - and in doing so notes that there is an asymmetry which could be corrected by the addition of another term to the law of Ampère. Characteristically, Maxwell's theory of the electromagnetic field was for many years disregarded, on account of its intrinsically abstract nature. However, all the physical explanation and ingenious mechanistic hypothesising once used to explain electromagnetic and optical effects has now been swept away and all that remains is Maxwell's purely abstract system of equations.

Following the special theory of relativity, the whole of electromagnetic theory became explicable as an extension of Coulomb's inverse-square law by the addition of a fourth dimension onto that of space in Minkowski's space-time, which did away with the need even of Einstein's simplified kinematics, and which itself had a remarkable analogy (which has been little explored) with the mathematical structure known as *quaternions*, discovered by Hamilton in 1843. The simple parallel between electromagnetism and gravity (or between mass and charge) had at last been established. The method of analogy, which led to this relation, ultimately has no justification except that of "the uniformity of nature", which is, in essence, a purely theological concept, recognisable to such as Ockham or Newton. However, the method is widely pursued even today, for the modern programme of uniting all the forces and all the particles is essentially that of Faraday and others in the nineteenth century, and ultimately of the programme originally laid down by Newton.

The method of analogy has been widely used purely because it has been successful, and not because of any ultimate theological origin it may once have had. The method of analogy presupposes the more fundamental concept of symmetry, and this, I will argue, is the magic ingredient which makes physics "work". Symmetry allows us to do what Newton wished to do: to define an abstract, unknowable reality, combined with a process of observation or measurement of its parts. Symmetry between two concepts means absolute identity in most respects, combined with absolute opposition in one. So symmetry allows us to characterise a part of reality without characterising the whole. Only through symmetry can unity result in diversity. And physics works in such a way that when you characterise a part of reality in a certain way, you are necessarily characterising the rest as different (i.e. opposite). This is what explains Newton's success in introducing mass as a conserved quantity opposed to the variables space and time. But he didn't consciously set out to do this; he developed by analytical means the only procedures that would work. Symmetry makes it possible to avoid characterising reality, and this seems to be the unconscious aim of the modern physicist, just as it was the conscious aim of Newton. If to every concept there is an exactly symmetrical opposite, then we never have to specify reality if we use both at the same time. Symmetry can also be exact, in a way that no specific idea can.

The interesting thing about the history of modern physics is the fact that it seems to be gradually fulfilling the Newtonian programme in spite of its own manifest preferences for something different. Though Newtonian and other related ideas, such as the Maxwellian theory of the electromagnetic field, were long resisted on account of their intrinsically abstract nature, quantum mechanics has forced modern physicists into the same abstract positions in an amazing repetition of the Newtonian development. When Werner Heisenberg introduced his new mechanics, strongly influenced by the formalised dynamical tradition dating back to Lagrange, in which relations were expressed only between observable quantities, he abandoned the reality of Bohr's physical electron orbits and the concept of orbital radius, in order to retain the measurable quantity of frequency as a fundamental quantity. This led to Bohr's Copenhagen interpretation, in which the abstract system was effectively separated from the physical measuring apparatus. The subsequent development of the ideas of nonlocality and entangled states, backed up by strong experimental evidence, has led physics back to the indeterminate infinity of interacting states postulated in the Newtonian theory, but ignored by his successors. It begins to look as if modern physics is intent on restoring all of Newton's most extreme positions.

It is clear that the search for a unified theory is essentially at one with the originally theologically-inspired project of the fourteenth and seventeenth centuries, and we now have a better understanding of what such a theory would actually look like. It would certainly be characterised by abstraction, simplicity and symmetry. It would also be, in principle, extreme, no compromise being allowed in the best theological tradition. There would be no mathematics, other than that derived through symmetry principles, no model-dependent structures of any kind, and no arbitrary cosmology. It would certainly look different from any theory yet devised for a particular aspect of physics, yet these would all be ultimately deducible from it. Though purely secular in itself, such a theory would derive much of its power from the fact that its ultimate origin was in theology.

Volta and the Invention of the Electrochemical Battery

Report by Neil Brown, on the meeting held in Oxford on 23rd October 1999

The year 2000 marks the 200th anniversary of the publication in Philosophical Transactions of the paper in which Alessandro Volta announced the invention of his “pile”. It is easy to claim that particular events changed the world, but in the modern era the long-term effects of Volta’s discovery are paralleled or surpassed perhaps only by the consequences of the development of steam power a few years previously. Volta’s pile was the first source of electricity as a continuously flowing current (unlike the instantly dissipated static charges produced by the electrical machines previously known) and the first electrochemical battery. As such it was the starting point of the modern electrical age.

It was, of course, not without precursors. About ten years previously, Luigi Galvani had described what he believed to be animal electricity. Volta disagreed: he believed the source of the electricity was the contact between different metals. In his efforts to prove the point he invented his pile. Volta was also wrong, for the source of the electricity in the pile was in the chemical reactions, but it took some time to prove that point. Neither was the pile the only landmark on the road towards the utilisation of electricity. Ørsted’s electromagnetism of 1820 and Faraday’s electromagnetic induction of 1831 were other key events, each building on the preceding ones. Even so, it was some years before electricity was used, first for telegraphy and then for electroplating. Many decades elapsed before the first electric lighting systems were built, and over a century before the first electronic amplifiers appeared.

The History of Physics Group used its Autumn meeting, in Oxford on 23rd October, to discuss Volta, his life and work, and its consequences. We were pleased to welcome two speakers from Italy, to look at events from a different perspective. Lucio Fregonese, from the University of Pavia, opened the meeting with a paper on Volta’s theory of electric force. He began by showing slides of some of Volta’s apparatus preserved at Pavia. (Little survives because much was destroyed in a fire in 1900.) Fregonese emphasised what should be an obvious point: that Volta’s work should not be interpreted according to later schemes of thought, in this case schemes based on Coulomb's law. Volta's education in physics took place within an older tradition expressed by Descartes in his Principia and favoured by continental European scientists such as Nollet and Beccaria. However, in his own work, Volta turned against this and opted for an alternative, Newtonian-style philosophy, based on action-at-a-distance instead of mechanically transmitted forces. In this he followed Franklin and Boscovich, his predecessor at Pavia. This allowed him to develop a concept of electrostatic induction, and so to develop the instruments for which he is known, the electrophorus and the condensing electroscope and, of course, the pile.

The second paper, on European travels of Lombard scientists in the second half of the 18th century, given by Pasquale Tucci of the University of Milan, was very different in content. In an age of almost instant communication by telephone or e-mail, it is salutary to be reminded of the very different modes of communication two centuries ago. Ideas were exchanged more freely than we might imagine, most often by letter, but eminent scientists did travel. By the end of the 18th century, however, it was becoming difficult for the ideal of the cosmopolitan scientist to co-exist with proud nation states. Volta, despite not enjoying travel, was exceptional in making five trips outside Italy. The first was very much as a scientist going to exchange ideas and meet counterparts in other countries. By his third trip he was a national figure, and in Vienna he was received by the Emperor. During his last trip, in 1801-1802, he demonstrated his pile to the Emperor Napoleon. Volta was anxious to judge reactions to his invention, but the University of Pavia was also anxious to thank Napoleon for allowing it to reopen after the upheavals in Europe of the previous decade or so.

Willem Hackmann, of the Museum of the History of Science in Oxford, spoke next, on the history of the concept of contact potential and the dry pile. The dry pile was a voltaic pile with no extra moisture, and the elements reduced to minimum thickness - pieces of metal foil and thin paper - so that many hundreds of elements could be used. Contrary to what is often stated, the dry pile was not invoked just to try to prove the contact theory of electricity against the chemical theory. The reality was much more complex. In any case, instrumental evidence is rarely conclusive in such a dispute. Hackmann pointed out that scientists try to explain new phenomena in terms of the old and familiar. From about 1770, interest in electricity had shifted towards small-scale phenomena. Contact electricity fitted with this, and with instruments such as his condensing electroscope, Volta had the apparatus to investigate it. Contact electricity was also within the familiar realm of static electricity. A truly dry pile would support the contact theory, but almost no-one believed that a pile could work with no moisture at all and the evidence was inconclusive. Static effects could be produced from a pile without any apparent chemical action, but galvanic effects were always associated with chemical reactions. By 1830, interest in dry piles had almost died out. Low tension sources had become familiar, and there was another type of electricity, thermoelectricity, to investigate as well. Contact electricity returned in about 1915 with the concept of electron affinity. Dry piles were used again during the Second World War, as sources of high voltage for infrared night-vision equipment.

John Roche, of Linacre College, Oxford, opened the session after tea, speaking on the concept of voltage. He began by claiming that almost every concept in electricity and electromagnetism is ambiguous, and the concept of voltage is one of the most incoherent. Its evolution is difficult to follow. Abbé Nollet, in the 18th century, distinguished quantity and degree of electrification. Others made similar distinctions between quantity and intensity or tension or pressure - what we would call voltage. Roche showed how the term "voltage" had come to be used nowadays in three different ways: for electromotive force, potential difference and (absolute) potential. Volta defined electrical tension as the endeavour of the electric fluid to escape from a body. Volta's tension was more akin to a force, unlike the modern concept of electromotive force, which is a misnomer, being defined in terms of energy. Ohm carried Volta's concept to closed circuits with the idea that current was proportional to the difference in tension between the ends of a conductor. For Ohm, it was the gradient of electrical tension that drove the current. Poisson introduced an entirely different concept, of charge divided by distance to a point, which Green called the potential function. This was an analytical device only, arising from an analogy with Laplace's gravitational potential function. Kirchhoff reconciled Volta's tension with Poisson's potential function through the concept of energy or *vis viva* introduced by Helmholtz. From Kirchhoff, current is driven by the electric field in a conductor and voltage is related to the energy supplied, but physicists and electrical engineers do not usually think of them in this way. All the earlier interpretations remain current, but with different weights, and most of the time voltage is seen as a driving agency.

Neil Brown, from the Science Museum in London, gave the final paper of the meeting, on electrochemical batteries from Volta to Leclanché, looking at how practitioners improved on Volta's pile. The pile gave a limited current, and had to be dismantled and refurbished frequently. The first improvement was Cruikshank's "trough" battery, soon followed by Wilkinson's "plunge" battery. Some huge batteries of these types were built. In 1810, Humphry Davy at the Royal Institution used a battery of

2000 pairs of plates to isolate the alkaline earth elements. There were still problems: batteries polarised quickly, and local action dissolved the zinc electrode. The first cell to overcome these problems was devised by J. F. Daniell in 1836, and batteries of Daniell cells were used for electric telegraphs. The Grove cell, the Bunsen cell and the bichromate cell were more powerful non-polarising cells. The bichromate cell was widely used from the 1860s in the form of Grenet's "bottle" cell. The last significant battery of the 19th century was the Leclanché cell introduced in 1868 and produced in recognisably similar form for over 100 years. However, the original "wet" form was surpassed by the "dry" version introduced by Gassner in 1887. This was the first of the throw-away zinc-carbon cells made in millions during the 20th century for portable electric appliances. The modern zinc chloride cell is very similar and still accounts for a large proportion of battery sales, though new types of cell have been introduced since about 1940.

Thanks are due to Willem Hackmann for acting as the local organiser and for arranging much of the programme, and also to the Modern History Faculty for allowing the meeting to be held in the appropriate surroundings of the library in the faculty building. The original intention had been to meet in the Museum of the History of Science, but this was in the hands of contractors building an extension, and presented an alarming sight, supported on steel beams over a large hole in the ground. As with so many meetings (and not just those of the History of Physics Group) the attendance was not as large as hoped for, but for those who were able to attend it was an interesting and worthwhile afternoon.

The Group's Website:

www.iop.org/IOP/Groups/HP/

Future Meetings arranged by this Group

It's About Time

Half-day meeting

Saturday 26th February 2000 ***[this date may have passed]***, 13:00
Fellow's Room, The Science Museum, Exhibition Road, South Kensington, London SW7

The start of the year 2000, whether or not one regards it as the beginning of the new millennium, has reawakened interest in the concept of time and how it is measured. The unit of time was one of the three historic base units that formed the root of all measurement prior to the twentieth century. Mass and length were defined in terms of material standards, differing from place to place, but time was defined in terms of the solar day and most of the world has used the same system of hours, minutes and seconds. Only quite recently have atomic clocks led to a redefinition of the unit of time, and time is now the most accurately known of all of the fundamental quantities. The unit of length has been redefined in terms of the speed of light and the unit of time.

This meeting will explore how time has been measured and understood over the last hundred years, and the importance of accurate time measurement in the modern world. The speakers will be Dr. John Laverty, Mr. Tony Seabrook, Dr. Christopher Ray and Mr. Neil Brown. The meeting will conclude with a visit to the "It's about Time" exhibition at the Science Museum, and an opportunity to look round the Science Museum.

If you wish to attend the lecture, please contact …

Post: *S. Duncan, Honorary Secretary, History of Physics Group, Science Museum, South Kensington, London, SW7 2DD*
Fax: *0171 942 4102;* *Telephone:* *0171 942 4170*
e-mail: *s.duncan@nmsi.ac.uk*

What's in the name?

Howard Watson

Monday 12th June, 1800 for 1830
Phillips Room, IOP Headquarters, Portland Place, LONDON

Looking for ways of celebrating the 125th Anniversary of the Institute, one of the ideas which emerged was to search for 125 pubs which had names directly or accidentally related to Physics, physicists or other scientists. The result is a fascinating list containing names of both the well-known and the not so known. The aim of the talk is to delve a little into the lives of the people concerned, especially the lesser known facts about them, with a passing reference to the establishment that commemorates them. Even those whose interest in the beverages which the hostelries sell is marginal, should find it interesting!

We propose to follow this talk by a **visit to a pub** in the vicinity of the IOP. Everyone is welcome, although there is, of course, no obligation!

Further details will be sent out nearer the time. For information before then, please contact Lucy Gibson:
Post: *56 Priory Avenue, LONDON E17 7QP*
e-mail: *lucy.gibson@bbc.co.uk*

Planck - one hundred years on

Half- or Full-day meeting

A Saturday in October 2000 (details to be confirmed)
Manchester

It is intended to commemorate the centenary of Planck's discovery of the Quantum theory, in deriving the true black body radiation law in 1900. The speakers will cover the history and development of the subject from the time of Planck to the present day.

Further details will be sent out nearer the time. For information before then, please contact Dr. Peter Rowlands by e-mail: *prowl@hep.ph.liv.ac.uk*

Other Lectures and Meetings, at home and abroad

This information has kindly been supplied by the BSHS and is their copyright. Nearly all these meetings are open to people who are not members of the society concerned, sometimes at a slightly higher cost. We remind readers to check before departure that the event has not been cancelled. All dates are in 2000 except where otherwise stated.

British Society for the History of Science

ACE 2000
at Science Museum and National Physical Laboratory, Teddington (to be confirmed)
on 18-19 May 2000

The ACE 2000 Event, hosted by the Computer Conservation Society, will mark the 50th Anniversary of the Pilot Model Automatic Computing Engine, the electronic stored program general-purpose digital computer designed principally by Alan Turing and built at the National Physical Laboratory. The Pilot Model ACE ran its first program on May 10, 1950 and was the third stored-program computer to function in Britain. With a clock speed of 1 MHz it remained for some time the fastest computer in the world. ACE 2000 at the Science Museum of London on 18 May will celebrate the Pilot Model ACE and survey the ACE family of computers and the impact of these machines on British computing. Speakers will include many of those who constructed and programmed the Pilot Model ACE and its successors. ACE 2000 at the National Physical Laboratory, Teddington on 19th May will focus on the history of computation at the NPL. Speakers include David Anderson, Martin Campbell-Kelly, David Clark. David Clayden. Jack Copeland. Mary Croarken, Donald Davies, George Davis, Bob Doran, Geoff Hayes, Harry Huskey. Eileen Magnello, Henry Norton. Teresa Numerico, and Mike Woodger. Enquiries to the organiser, Jack Copeland, The Turing Project, University of Canterbury, New Zealand. Tel and Fax: +64 3 341 1053. Email: bjcopelend@canterbury.ac.nz

Portraiture and Scientific Identity
at National Portrait Gallery, London
on 23-24 June 2000

This conference is being organised by the National Portrait Gallery and the

British Society for the History of Science. The likely pattern of conference will be four plenary sessions and a number of shorter sessions with papers of 25 minutes. Professor Ludmilla Jordanova is responsible for the programme. A copy of the final programme can be sent to those who provide the Education Department of the National Portrait Gallery (St Martin's Place, London, WC2H OHE) with a stamped addressed envelope marked "BSHS conference". The meeting is being held in association with a small exhibition at the National Portrait Gallery, which will explore portraiture in relation to practitioners of science, medicine and technology since the seventeenth century in Britain. The exhibition will open in late March or early April and will close at the end of June 2000. It will contain works in all media, and suggestions of unusual, visually interesting items that might be included can be made to Professor Jordanova, who would be particularly interested to hear of relevant self-portraits and of portraits made within domestic settings. The practice of portraiture is one of the main themes of the exhibition, so preparatory sketches are of particular relevance. Professor Ludmilla Jordanova can be contacted at School of World Art Studies and Museology, University of East Anglia, Norwich, Norfolk, NR4 7TJ. Email: l.jordanova@uea.ac.uk

History of Science, the Public Understanding of Science and Education
in July 2000
The surge of interest in Public Understanding of Science over the last decade has had significant implications not just for the communication of science and technology to non-specialists but for the practice and teaching of science itself. This conference will explore the history of "science communication" to diverse audiences, including schools, and ask what roles history of science can play. Further details from. and offers of papers to: Dr. J Hughes, CHSTM, Maths Tower, The University, Manchester, M13 9PL. E-mail: hughes@fs4.ma.man.ac.uk

What is to be done? History of Science in the New Millennium.
at St Louis, Missouri
on 3-6 August 2000
This is the fourth British-North American Joint Meeting of the BSHS, CSHPS and HSS. Following successful meetings in Manchester (1988), Toronto (1992). and Edinburgh (1996), the British Society for the History of Science, the Canadian Society for the History and Philosophy of Science, and the History of Science Society will be undertaking their fourth international joint meeting in St Louis, Missouri, August 3rd – 6th 2000. The program committee, with members drawn from the three participating

societies, has chosen as the meeting theme: “What is to be done? History of Science in the New Millennium”. Session proposals have been invited on topics that address particularly:

- critical historiographical issues in the history of science, past, present and future
- master narratives in the history of science, including reassessments of earlier narratives and presentations of new ones
- evaluating the relationship between the history of science and other disciplines, such as sociology, literary studies, social history, cultural history, environmental history, natural science (the “science wars”).
- important absences in the history of science: what’s been missed? what can’t be said?
- differing modes of investigation in the history of science, including museum and material culture studies, history of popular culture, history of printing and publishing, and others.
- re-examinations of particular chronological (e.g. Enlightenment or medieval science) and thematic fields (e.g. the history of biology, science and gender, science and popular culture).
- the development of history of science as a discipline and as a profession, in particular to provide an international perspective to the issues that the HSS is considering at its 75th anniversary meeting in 1999.

The meeting will be organised into sessions of three or four papers with commentator. Participants will be able to experience the many enticements offered by St Louis, host to the Blues, the Gateway Arch, major-league baseball, and the magnificent Missouri Botanical Gardens. The conference will be held at the Hyatt Regency, Union Station, which features a spectacular lobby and many nearby shops.

Proposals *were* due at the HSS Executive Office by 15 December 1999. For further details contact the HSS Executive office at hssexec@u.washington.edu or the program committee: Jon Agar, agar@fs4.ma.man.ac.uk; Bernie Lightman, lightman@,yorku.ca; and Paul Theerman, paul_theerman@nlm.nih.gov. Jon Agar’s address is CHSTM, Mathematics Tower, Manchester University, Oxford Road, Manchester M13 9PL.
Royal Society grants are available for historians of science attending conferences overseas. See http://www.royalsoc.ac.uk/gr_poc.htm. More information on St Louis can be found at http://depts.washington.edu/hssexec/2000/joint2000.html

American Association for the History of Medicine

Meeting
at Bethesda

on 17-21 May 2000.
Further information from Harry M Marks, Department of the History of Science. Medicine & Technology, The Johns Hopkins University, 1900 E Monument Street, Baltimore, MD 21205, USA.

German Geophysical Society

History of Geophysics and Space Physics
at Munich
in March 2000
The topic of the meeting will be the development of geophysics over the last few decades. Further information from Dr. Wilfried Schröder, Hechelstrasse 8, D-28777 Bremen-Roennebeck, Germany.

History of Philosophy of Science Group (HOPOS)

Third international History of Philosophy of Science Conference
at Vienna
on 6th – 9th July 2000
Contributions to the history of philosophy of science from all time periods and from all scholarly approaches are invited. Further details from Institute Vienna Circle, Museumstrasse 5/2/17, A-1070 Wien, Austria. Email i_v_c@ping.at (write "HOPOS 2000' in the subject line) or http://scistud.umkc.edu/hopos/index.html

International Union for the History and Philosophy of Science

The XU Scientific Instrument Symposium
at Oxford
on 4th – 8th September 2000
This meeting is organised by the Scientific Instrument Commission of the International Union of the History and Philosophy of Science. Further details from Dr J A Bennett, Museum of the History of Science, Broad Street, Oxford, OX1 3AZ.

XXI International Congress of the History of Science
at Mexico City
on 8th – 14th July 2001
The theme of this congress will be "Science and Cultural Diversity". To

receive further details contact XXI International Congress of the History of Science, Apartado postal 21-873, 04000 México, DF, México.

Royal Institution

The following are research seminars organised by the Royal Institution Centre for the History of Science and Technology. They are held in the Council Room at 18:00, with tea available from 17:30. Further details from Dr. Frank James, Royal Institution, 21 Albemarle Street, LONDON, W1X 4BS.

A Century of Measurement and Computation at the National Physical Laboratory, 1900 - 2000
on Tuesday 29th February
speaker Dr. Eileen Magnello (Wellcome Institute)

M. V. Lomonosov (1711 – 1765), St. Petersburg and the Origins of Physical Chemistry
on Tuesday 28th March
speaker Dr. Michael Hoare (Independent Scholar)

Royal Meteorological Society History Group

Barometers
at Blythe House (Science Museum outstation), West London
on 8th March 2000
Speakers will be Richard Hill on James Watt's barometers; Philip Collins on aneroids, Anita McConnell on marines, and Patrick Marney on mercury barometers. Further details from Jane Insley, Science Museum, London SW7 2DD.

Meeting to celebrate the Society's 150th Anniversary
at The Royal Society
on 3-4 April 2000
This meeting, which is co-sponsored by the Institution of Civil Engineers, Royal Astronomical Society and Royal Geographical Society, will cover the history of the Society, its antecedents, its contemporaries - the Scottish Meteorological Society and the British Rainfall Organisation - and the societies with whom it shared many interests and members. Speakers are Malcolm Walker on the Society's origins and antecedents, Jane Insley on

instrument makers and the Society, Jack Meadows on astronomy and meteorology in the 19th century, Jim Burton on the Society's relationship with the Royal Society and the BAAS, John Monteith on the Society's involvement with the natural sciences, Marjorie Roy on the Scottish Meteorological Society, Margaret Deacon on maritime meteorology, David Pedqley on Symons, Mill, and the British Rainfall Organisation, Joan Kenworthy on the Society's relationship with the Royal Geographical Society, and Stan Cornford on the recent half-century. Further details from The History Group Hon Sec, Royal Meteorological Society, 104 Oxford Road, Reading, RG1 7LL.

Science in the Nineteenth-century Periodical (SciPer) Project

Science in the nineteenth-century periodical: an interdisciplinary conference
at University of Leeds
on 10th – 12th April 2000
The collaborative project "Science in the nineteenth-century periodical" (SciPer), recently launched at the Universities of Sheffield (Centre for Nineteenth-century Studies) and Leeds (Division of History and Philosophy of Science), is designed to identify and analyse representations of science, technology and medicine in the general periodical literature of nineteenth-century Britain. The project's inaugural conference will explore all aspects of the subject. Possible themes include: public images of scientific and medical practitioners; representations of key scientific ideas (e.g. evolution, energy); the construction of scientific orthodoxies/heterodoxies; gender and science; interactions of literary, political and scientific discourses; editors, contributors and proprietors; science and the politics of the press; science and the development of periodical audiences; scientific journalism; the positioning of science within journals; periodicals of empire/science and imperialism; science in the literary marketplace; reviewing science – books and meetings; science education; science as entertainment; illustrations and caricatures; and moral and religious representations of science. Further details from Dr. J. R. Topham, School of Philosophy, University of Leeds, LS2 9JTor email j.r.topham@leeds.ac.uk

Society for Social History of Medicine

Medicine - Magic - Religion
at University of Southampton
on 17th – 18th July 2000
This conference will aim to re-assess the boundaries and intersections

between medicine, magic and religion in the light of the current upsurge of scholarly interest in the area of pre-modern history of medicine, conceptual debates on the epistemological status of science and medicine *vis-a-vis* magic and religion, recent writing on “colonial medicine” and on the inter-relationships, hegemonic tendencies and conceptual incompatibilities of different cosmologies and systems of healing, recent contributions by post-colonial and subaltern histories to the critique of dichotomous categories such as “East” versus “West”, “rationality” versus “irrationality”, “science” versus “belief” and the rise of “alternative” medicine in western countries and its construction as a “holistic” and more “spiritual” alternative to “scientifically” based bio-medicine. Offers of papers (by 31 January 2000) and further information from Dr Waltraud Ernst, Department of History, University of Southampton, Southampton, SO17 1BJ. E-mail: WER@soton.ac.uk

University of Exeter

Work, health and illness: the comparative history of industrial diseases, accidents and occupational medicine
on 8-10 September
at University of Exeter 2000.
This conference is designed to review recent and current research in the history of working life and health at the workplace, covering all periods and countries. The conference is jointly supported by the Society for the Social History of Medicine, the Society for the Study of Labour History, and the UK Social History Society. Amongst the possible themes which have been identified are: work and illness in the ancient world; child labour and illness; occupational illness and hazards of employment; regional and national comparisons of occupational health; gender, work and illness; hazards, accidents and legal compensation in working life; rationalisation, productivity and fatigue in free market and planned economies; medical science and the idea of occupational illness from lead poisoning to ME; mental hygiene, personality testing and the right job; allergies. sick buildings and the working environment. Further details from Joseph Melling, Centre for Medical History, University of Exeter, Exeter, EX4 4RT. E-mail: J.L.Melling@exeter.ac.uk or Medarch@exeter.ac.uk