Balzan Prizewinners

Interdisciplinary Forum

2009

Terence Cave (Literature since 1500)
Michael Grätzel (The Science of New Materials)
Brenda Milner (Cognitive Neurosciences)
Paolo Rossi Monti (The History of Science)

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Foreword

Alberto Quadrio Curzio, Chairman of the Joint Commissions established by the International Balzan Foundation "Prize", the Swiss Academies of Arts and Sciences and the Accademia Nazionale dei Lincei:

It is a great honour and indeed a remarkable satisfaction for me to write the foreword to this Balzan Interdisciplinary Prizewinners Forum, which marks the effective beginning of the Agreement on Collaboration between the International Balzan Foundation "Prize"[1] (hereafter referred to as the Balzan) and two Academies: the Swiss Academies of Arts and Sciences[2] and the Accademia Nazionale dei Lincei[3] (hereafter referred to as the Swiss Academies and the Lincei, respectively).

As Chairman of the two joint commissions, established to make such collaboration flourish, I think it necessary to make a brief comment.

Ever since becoming a member of the Balzan "Prize" Board, I have appreciated the fact that its Chairman, Ambassador Bruno Bottai, has stressed the fully international nature of the Balzan, while at the same time noting its strong historical roots in Italy and Switzerland.

This is why I proposed that the Balzan Board evaluate a possible collaboration with the Swiss Academies and the Lincei. Thus, with the Balzan Board's permission, I have had several separate meetings with the representatives of the Swiss Academies and the Lincei, that is, Professor Dr. René Dändliker and Professor Giovanni Conso, respective Presidents of the Swiss Academies and of the Lincei. I would like to take advantage of this occasion to thank them for their constructive attitude toward the proposal of collaboration.

The main points of the agreements with the Swiss Academies and the Lincei are:

1) The promotion of the Balzan Prize and the presentation of the Prizewinners through the academies' channels of communication, in Italy and Switzerland as well as abroad. By virtue of the relations of the Swiss Academies and the Lincei with academies of other countries and with international academic organizations, they will contribute to more widespread circulation of news related to Balzan;
2) On the occasion of the Awards ceremony of the Balzan Prize, held in alternating years in Berne and Rome, each academy will contribute to the scientific organization

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of an interdisciplinary Forum, in the course of which the Prizewinners will present their scientific work and discuss it with other scientists proposed by the academies. In the years when the ceremony is held in Rome, one of the Prizewinners will give a Balzan Distinguished Lecture in Switzerland, and when the ceremony is held in Berne, a Balzan Distinguished Lecture will be organized at the headquarters of the Lincei in Rome;

3) After the commencement of the abovementioned activities, the academies will contribute to a series of publications in English (ideally with summaries in Italian, German and French), created by the Balzan, with the collaboration of the Balzan Prizewinners.

To promote and supervise all these initiatives, two Commissions have been set up, one between the Balzan and the Swiss Academies (composed of Professors Dr. René Dändliker and Peter Suter as well as Dr. Markus Zürcher) and another between the Balzan and the Lincei (composed of Professors Sergio Carrà, Lellia Cracco Ruggini and Claudio Leonardi). Both commissions are chaired by myself as a representative of the Balzan, which is also represented by Professors Enrico Decleva and Paolo Matthiae, while the Balzan Secretary General, Dr. Suzanne Werder, has been appointed Secretary of both Commissions.

I am confident, especially after having witnessed the success of this year's Forum, that the abovementioned opportunities for collaboration will be beneficial. These activities will certainly not interfere with the institutional activities of the Balzan – especially not with those of the General Prize Committee, which is composed of twenty eminent European scholars and scientists, and has its own statutory competence within the Balzan.

The collaboration among these institutions will in fact contribute to spreading knowledge of the International Balzan Foundation on the international academic scene, thus consolidating its image as one of the most prestigious forms of recognition in the sciences and the humanities.

International Balzan Foundation

The International Balzan Foundation was established in Lugano in 1956 thanks to the generosity of Lina Balzan, who had come into a considerable inheritance on the death of her father, Eugenio. She decided to use this wealth to honour his memory.
Eugenio Francesco Balzan was born in Badia Polesine, near Rovigo (Northern Italy), on 20 April 1874 into a family of landowners. He spent almost his entire working life at Milan's leading daily newspaper, *Corriere della Sera*. After joining the paper in 1897, he worked his way up from editorial assistant, to news editor and special correspondent[4]. In 1903 editor Luigi Albertini made him managing director of the paper's publishing house; he then became a partner and shareholder in the company. He was not only a skilful manager but also a leading personality in Milan. In 1933 he left Italy due to opposition from certain quarters hostile to an independent *Corriere*. He then moved to Switzerland, living in Zurich and Lugano, where for years he had invested his fortune with success. He also continued his charitable activities in favour of institutions and individuals.
He officially returned to Italy in 1950. Eugenio Balzan died in Lugano, Switzerland, on 15 July 1953[5].

The *International E. Balzan Prize Foundation – "Prize"* aims to promote, throughout the world, culture, science, and the most meritorious initiatives in the cause of humanity, peace and brotherhood among peoples, regardless of nationality, race or creed. This aim is attained through the annual award of prizes in two general fields: literature, the moral sciences and the arts; medicine and the physical, mathematical and natural sciences.
Nominations for the prizes in the scientific and humanistic fields are received at the Foundation's request from the world's leading learned societies. Candidates are selected by the *General Prize Committee*, composed of eminent European scholars and scientists. Since 2001, each prize has been worth one million Swiss francs, half of which the prizewinner must allocate to research work, preferably involving young researchers.
At intervals of not less than three years, the Balzan Foundation also awards a prize of varying amounts for humanity, peace and brotherhood among peoples.
The *International E. Balzan Prize Foundation – "Prize"* attains its financial means from the *International E. Balzan Prize Foundation – "Fund"* which administers Eugenio Balzan's estate.

[4] Renata Broggini (a cura di), *Eugenio Balzan. L'emigrazione in Canada nell'inchiesta del "Corriere"*, Fondazione Corriere della Sera, Milano, 2009.
[5] Renata Broggini, *Eugenio Balzan 1874-1953. Una vita per il "Corriere", un progetto per l'umanità*, RCS Libri, Milano, 2001. Renata Broggini, *Eugenio Balzan 1874-1953. A Biography*, Hoepli, Milano, 2007.

Swiss Academies of Arts and Sciences

The Association of the "Swiss Academies of Arts and Sciences" includes the Swiss Academy of Sciences (SCNAT), the Swiss Academy of Humanities and Social Sciences (SAHS), the Swiss Academy of Medical Sciences (SAMS), and the Swiss Academy of Engineering Sciences (SATW) as well as the two Centres for Excellence TA-SWISS and Science et Cité. Their collaboration is focused on methods of anticipating future trends, ethics and the dialogue between science and society. Scientific knowledge shall and must be for the common good; however, always subject to the oversight of Government and Society. It is the aim of the Swiss Scientific Academies to develop an equal dialogue between science and society and to advise Government and society on scientifically based, socially relevant questions. The academies stand for an open and pluralistic understanding of science. Over the long-term, they mutually commit to resolving interdisciplinary questions in the following fields:

- They offer knowledge and expertise in relation to socially relevant subjects in the fields of Education, Research and Technology.
- They adhere to the concept of ethically-based responsibility in gaining and applying scientific knowledge.
- They build bridges between Science, Government and Society.

Accademia Nazionale dei Lincei

The Academy promotes excellence through its Fellows who have included, among many other renowned names, Galileo Galilei. The Accademia Nazionale dei Lincei is considered the most prestigious Italian cultural institution. Since 1992, the Academy has provided specialized advice to the President of the Italian Republic and has recently received the 'High Permanent Patronage' of the President of the Italian Republic.
The Academy's mission is "to promote, coordinate, integrate and spread scientific knowledge in its highest expressions in the context of cultural unity and universality". To this end, the Accademia Nazionale dei Lincei organises national and international conferences, meetings and seminars and it's members participate in similar Italian and foreign initiatives. The Academy promotes and carries out research activities and missions, confers awards and grants, publishes the reports of its own sessions and the notes and records presented therein, as well as the proceedings of its own conferences, meetings and seminars. The Academy further provides – either upon request or on its own initiative – advice to public institutions and when appropriate drafts relevant proposals.

Opening Remarks

Dieter Imboden, President of the Research Council of the Swiss National Science Foundation:

Former President of Switzerland Ruth Dreifuss,
Prizewinners,
Chairman of the Balzan General Prize Committee,
Colleagues,
Ladies and Gentlemen,

I welcome you to the Balzan Prizewinners Interdisciplinary Forum 2009, which is dedicated to a discussion of: 'what the implications of the Prizewinners' achievements are for science as a whole'.

As President of the Research Council of the Swiss National Science Foundation, it is a great honour for me to open this meeting and to learn from you how the ever-growing number of specialized disciplines and sub-disciplines ought to work together to tackle the great challenges of our society.

The organizers of this meeting have posed three questions:

1. How do the Prizewinners' scientific contributions help to overcome the boundaries between the humanities and the natural sciences?
2. What consequences do the findings entail for other disciplines?
3. What implications do these findings have for the future development of science?

These are challenging questions, indeed.

But above all I would like to congratulate you, dear Prizewinners, for your remarkable achievements. Who other than you, all distinguished members in your respective fields, could answer these questions and build the necessary bridges between the disciplines?

Fate – or good fortune – has brought together four excellent representatives of different fields of science: a cognitive neuroscientist (Brenda Milner), a specialist in European literature since 1500 (Terence Cave), a materials scientist and specialist in energy and solar power (Michael Grätzel), and a historian of science (Paolo Rossi Monti). Can these four fields learn from each other? If combined, are they more than the sum of these four individual fields?

Imagine for a brief moment, dear laureates, that fate has put you together on an island in the middle of the Pacific Ocean, like the famous Robinson Crusoe. How would you use and combine your skills in order to survive? That would be a wonderful experiment for an empirical scientist, but I am not going to let my imagination go astray. In

all seriousness: in principle, isn't that the sort of question which the layperson, or the taxpayer, if you will, would like to ask us scientists? **How can scientists solve insurmountable problems and improve the state of our world?** And isn't it also the type of question which we ask ourselves from time to time, especially when we have doubts about the usefulness of our work, when we are tempted to leave everything for a normal run of the mill job?

You will have ample time, I hope, to discuss such questions during the Forum. But before you begin your discussions let me say a few words about the meaning and the value of Prizes.

What is the meaning of prizes in scientific research? Why do private persons, as well as public institutions, award Prizes with their money?

Prizes for special achievements have a very long tradition. They go back at least to ancient Greece, where Prizes were given for outstanding physical achievements. Sports, art and research have one thing in common: usually, they don't have an immediate direct economic or practical impact unlike say the production of goods. Why should somebody want to run in circles as fast as possible, why do people draw pictures on the walls of caves, and why does a mathematician want to find the proof of a useless theorem? For fun, out of curiosity, out of ambition? Such motivations – as opposed to survival – are part of our culture. Prizes become the counterpart of a purely economic reward, like a salary for instance, which one receives for doing a normal job producing a well defined output.

I personally find Prizes like the ones we are celebrating today especially rewarding since one can neither apply for them, nor try to orientate one's career strategically in order to win a particular Prize. On the contrary: to obtain such a Prize, one has to concentrate their efforts on their work, on their chosen path as a researcher or an artist, who cares deeply about their own work, and one has to forget all about Prizes. The more one craves such a Prize, the less chance one has of actually winning one. The less one thinks about Prizes, the higher the chances are that one might receive one.

The Prize is an unexpected and unintended result of the effort of research. This is one side of the picture which, at least for me, illustrates a central point of research, which is our passion and should not degenerate into a business. The other side is reflected by the act of donation, impressively exemplified by the donator of the Balzan Prize. The aim of the Balzan Prize is described as follows: "To promote culture, science and the most meritorious initiatives in the cause of humanity, peace and brotherhood among peoples throughout the world". By honouring people who have made a special contribution to science, the Balzan Prize contains the clear message that the language of science, the special way to look at things as opposed to prejudices, fanaticism and

superstition, should guide the thinking and action of humankind. How often has this message been forgotten or suppressed in our recent history!
The more we know, the larger our responsibility becomes for our fellow human beings, for all living creatures on earth, for the environment and our globe. Lina Balzan, who half a century ago founded the Prize in honour of her father, was wise and visionary when she combined both the natural sciences and the humanities as the aim of the Prize. Today, we know that these two important domains of knowledge should not only have an equal right to exist side by side, but that they should overlap, mingle with each other and create the synergism which we need to continue our path and to tackle the many big problems of our time. In this sense, I am very happy that the International Balzan Foundation and the Swiss Academies of Arts and Sciences have decided to celebrate this year's laureates with an interdisciplinary dialogue. I wish you a successful and interesting discussion!

Welcome Address

Salvatore Veca, Chairman of the Balzan General Prize Committee:
Thank you very much, President Imboden, for your opening remarks, and in particular for the definition of the three central questions that are at the centre of our Forum, and for the 'Gedankenexperiment', in relation to your mental experiment concerning Robinson Crusoe and the island.
On behalf of the Balzan General Prize Committee, I welcome you to the Balzan Prizewinners Interdisciplinary Forum 2009, and first of all, I am very pleased to offer my heartfelt congratulations to Brenda Milner, to Terence Cave, to Michael Grätzel and to Paolo Rossi Monti. I also want to thank the Swiss Academies of Arts and Sciences and the Swiss National Science Foundation for their heroic and extraordinary collaboration and hospitality.
Before I ask President Suter to start with the first session of our Forum, let me say just a few words. I believe – and I am sure our Prizewinners share with us of the Balzan Foundation – a strong commitment to a simple basic idea: that a mature and responsible culture must strive for consistency, if such a thing is possible, or at least for interaction between the answers emanating from scientific research and the answers to those questions in the field of humanities that have emerged from our ongoing attempt to make sense of humanity.
The commitment to interdisciplinary work on the part of the Balzan Foundation has been remarkable over time. Building on this legacy, we held an International Balzan Symposium on the very challenging theme of Truth in the Humanities, Science and Religion, last year at the Università della Svizzera Italiana in Lugano. The proceedings of this Symposium, attended by Balzan Prizewinners, other international scholars of various backgrounds, members of the Balzan Foundation, of the Swiss Academies, and of the Accademia Nazionale dei Lincei, will soon be available in print[6].
I want to take this opportunity to thank Professor Nicolette Mout and Professor Werner Stauffacher for their fantastic work as the editors of that volume. It is also important for me to note that a group of young researchers, selected by the Swiss Academies and by the Accademia Nazionale dei Lincei, attended the Symposium.
I am looking forward to today's presentations and discussions, and I consider it a very special occasion. In fact, this Forum marks the beginning of a partnership between the

[6] M.E.H. Nicolette Mout and Werner Stauffacher (edited by), *Truth in Science, the Humanities, and Religion – Balzan Symposium 2008*, Springer, 2010 (ISBN 978-1-4020-9895-6)

Balzan Foundation and the Swiss Academies, and with the Accademia Nazionale dei Lincei, which hosted last year's Forum and which will host next year's Forum, too.
I am confident that this partnership will bring interesting and important results, enriching the already strong intellectual, cultural and scientific relationship between Italy and Switzerland, and will make a significant contribution to interdisciplinary and international dialogue, which is very important for us all. Thank you very much indeed.

Chair I

Peter Suter, President of the Swiss Academies of Arts and Sciences:
Thank you very much, President Veca, for your introduction to this interdisciplinary Forum, the participation and collaboration in which is a very important event and venture for the Swiss Academies of Arts and Sciences. Indeed, we are very honoured to host this afternoon's Forum, the first of its kind, here in Berne. We are very grateful to the Balzan Foundation for giving us the opportunity of working together, not only for the Prizewinners Fora, but also in other areas of interest to both our Institutions.
Let us now proceed to this afternoon's "raison d'être", which is the presentation by the Prizewinners of their work, and the subsequent discussion of their presentation by colleagues in their field and by the Plenum. Therefore, I now ask Werner Stauffacher, Professor emeritus of Medicine at the University of Basel in Switzerland and Co-Vicepresident of the Balzan General Prize Committee, to introduce the first Prizewinner, Professor Brenda Milner, the grande dame of this afternoon.

Presentation of Brenda Milner, 2009 Balzan Prize for Cognitive Neurosciences

Werner Stauffacher, Vice-Chair of the Balzan General Prize Committee:
Professor Brenda Milner is a British and Canadian citizen. She started her academic training in experimental psychology in Cambridge in 1939, and has been in Montreal since 1944, first at the Université de Montréal, and then at McGill since 1952. She is currently Dorothy J. Killam Professor of Psychology at the Montreal Neurological Institute and Professor at the Department of Neurology and Neurosurgery of McGill University.
Brenda Milner is one of the pioneers – some call her the mother – of cognitive neurosciences, a field of research, which aims to link mental processes, such as memory, empathy and perception (i.e., cognition) to the anatomical structure of the brain. She has made fundamental contributions to our understanding of how memory is processed and stored by our brain, and these contributions have been so seminal that they have earned her more than twenty honorary university degrees from around the world, as well as awards and honorary memberships which fill more than four pages of her official curriculum.
At the time when Brenda Milner started her work in the 1950s, it was not at all clear whether or not particular parts of the brain were involved in memory. In fact, the famous

Harvard psychologist Karl Lashley published a paper in 1950 entitled *In Search of The Engram*, in which, after many years of study, he concluded that no specific part of the brain was the locus of memory, but that it was distributed throughout.
Brenda Milner's work overturned this conclusion. By the meticulous clinical study of a small number of patients who had undergone very specific types of brain surgery to alleviate epilepsy, she not only discovered that particular parts of the brain are crucial for memory processing, most notably the region called the hippocampus. More crucially, she showed that there are different kinds of memory in humans, and different stages and types of memory processing.
In a moment, she will tell us how she did this and what exactly it means. For the moment, suffice to say that, with her pioneering discoveries starting in the middle of the last century, Brenda Milner has initiated and stimulated a whole research agenda on the relationship between memory and the brain. Indeed, more recent research, undertaken with the sophisticated technical means available today, has proven how dramatically right Brenda Milner was as early as fifty years ago with her intelligent conclusions drawn from "simple" anatomical and clinical observations. For these reasons, Brenda Milner is a most appropriate recipient of the 2009 Balzan Prize for Cognitive Neurosciences, and I look forward to listening to her.

Brenda Milner on **Early Clues to the Cerebral Organization of Memory:**

Thank you very much for that extremely kind introduction. I am already feeling a little overwhelmed to find myself here, but of course absolutely delighted.
Mr. President, fellow Prizewinners, colleagues and friends, I am going to take you back a long way, to the early days of the Montreal Neurological Institute (MNI), where I still have the privilege to work, and where we just celebrated our 75th anniversary.
How did I come to be there in the first place? Well, you will not get far in any field without some luck along the way, as I am sure my colleagues would agree. We need it. And I had that luck in 1950, when my research adviser at McGill, Donald Hebb, gave me the opportunity of going to the Montreal Neurological Institute to do my Ph.D., studying the patients of the neurosurgeon Dr. Wilder Penfield, who founded the institute and whose pioneering work focused on the neurosurgical treatment of epilepsy, and particularly on temporal-lobe epilepsy, in which seizures arising from one temporal lobe of the brain may be extremely hard to control by pharmacological means. Very little was known back then about what the temporal lobes of the human brain did, though fortunately we had some guidance from work on the monkey and

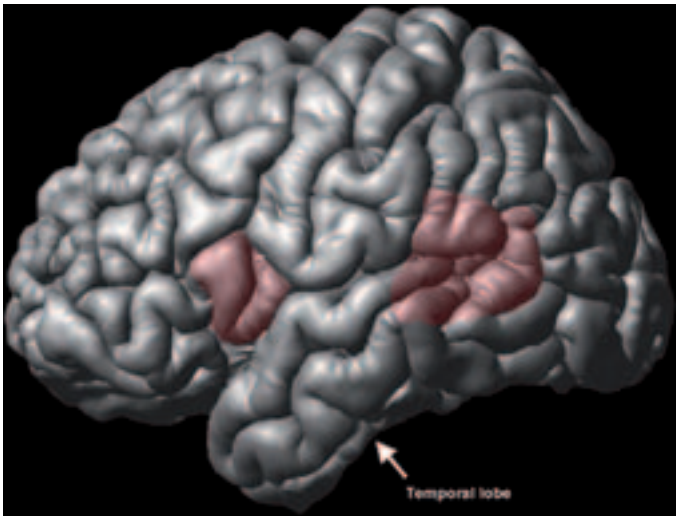


Figure 1

Lateral view of the left cerebral hemisphere, showing (in red) the anterior and posterior speech areas in the typical right-handed individual.

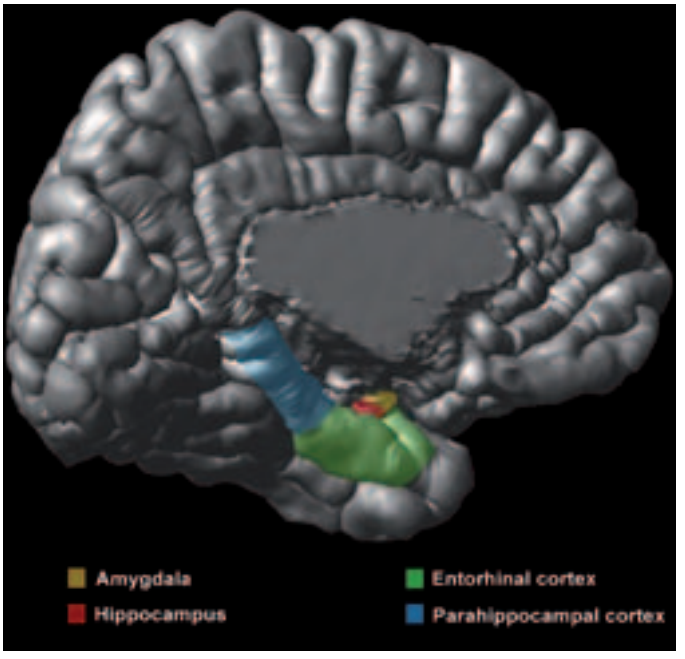


Figure 2

Medial view of the left hemisphere, indicating the various medial temporal-lobe structures.

other experimental animals. And here you really have to cast your minds back and imagine what it was like then without the wonderful technical tools that we have now. It was impossible to know what was going on in the brain, or even what the brain looked like, until it was exposed at the time of surgery. All we had to go on preoperatively was a picture of the ventricles of the brain and of the plain films of the skull, but beyond that we were really relying on clinical skills (including any psychological tests that one was lucky enough to devise), as well as on the very beginnings of electroencephalography (EEG), the recording of electrical activity from the brain. The EEG is of course of major importance in tracking down the source of the epileptic discharge, and if the surgeon is going to operate on a part of the brain to treat epilepsy, it is very important that he should feel confident beforehand that he is operating on the correct side of the brain. And here I must emphasize that all the Montreal operations were unilateral (involving one hemisphere of the brain), with the assumption that the corresponding region on other side was working normally. You can get along with one eye, one kidney and so on, but you must not lose both of these paired structures, and so it is with the paired structures of the brain. So that was the diagnostic challenge.

In the human brain, the two cerebral hemispheres differ in their cognitive functions, with over 97 percent of right-handers having their language represented in the left hemisphere. It is more variable with left-handers, but for today I am going to assume that we are all right-handers with speech in the left cerebral hemisphere. Figure 1 shows the left cerebral cortex of the typical right-handed person, in which the red areas are forbidden territory for a surgeon operating for epilepsy, because this is elective surgery and damage to the primary speech areas in the adult can cause lasting language impairment. These patients are not faced with some life-threatening brain disease. They are trying to have the quality of their everyday life improved. So you must not have them paralysed afterwards, or speechless, or suffering major memory loss. That is the clinical situation. And so the typical anterior temporal lobectomy would be well in front of the temporal speech zone (shown in red), but by the time that I got to the MNI, in most cases, the removal would also include structures (shown in Figure 2), on the medial surface of the temporal lobe, including the hippocampus and neighbouring structures, because these are often the culprits in temporal-lobe epilepsy.

Initially, I was studying the cognitive changes in groups of patients having an anterior lobectomy from the left hemisphere, and comparing them with groups of patients having similar removals from the right hemisphere. And I suppose that is one of the areas in research where I could claim to have made some new contributions, because

neurologists in those days tended to focus on the dominant hemisphere for speech, whereas I was always interested in the so-called minor hemisphere. This was partly because you can then use animal models; one cannot study language in monkeys, but other functions you can, and I got help from studies in the monkey for devising tasks, both visual and auditory, to explore the functions of the right temporal lobe in the human brain.

And so, how memory? I was not particularly interested in memory when I went to the MNI in 1950, because by then it had become an unfashionable topic, since, following Lashley's work on the rat, memory was thought to be a function of the whole brain, rather than of specific regions. But then the patients came to me, and especially the ones with injury in the left temporal lobe, and they would say: 'You know, I have a terrible memory'. And then I questioned them and found that they just had a bad memory for words, for what they had read and what they had heard. These were young adults, who should not have had bad memories like that. It's a disadvantage and it's annoying if you can't think of people's names when you are only 20 years old. And so they complained. And if the patient comes to you – this is the first rule – and complains that he has trouble with his memory, you don't say: "Go away, I'm not interested in memory, I'm working on the motor system", or "on visual perception"; you start studying memory. And so I began to study memory, which proved to be another great stroke of luck. What I found first was that patients with removals from the left temporal lobe did indeed have a selective impairment of verbal memory. It did not affect their ability to recall the events of everyday life, such as what they had had for breakfast that morning; they were just not very good at recalling verbal information, whether read or heard. In contrast, patients with similar removals from the right temporal lobe had no trouble with verbal memory, and so they rarely complained of memory difficulty, because our society values verbal skills so much that you could get by, maybe not even notice, that you have a bad memory for other things. But what I found when I tested them, and this was quite new, was that these patients with right temporal-lobe lesions had an impaired memory for nonverbal material, such as faces, places and tunes. Thus, we saw a complementary specialization of the two temporal lobes of the human brain in memory processes. These results have stood the test of time. They were interesting to me then, and they are still of interest to me now.

In the midst of all this work, we got quite a shock, a disagreeable shock for the surgeon. A patient I shall call PB, an engineer from New Jersey, who had had a small removal from the left temporal lobe a few years before, now came back still having seizures, and Dr. Penfield then decided to complete the temporal lobectomy by

removing the hippocampus and surrounding medial temporal-lobe structures, at this second operation. But after that, this patient, who was a very intelligent man, said: "What have you people done to my memory?" He was quite understandably bitter, because, from that day forward, he had what we would call a continuous anterograde amnesia, a forgetting of events as he lived them, of his life as he lived it. He had no idea whether his wife had been to see him that morning, what he had had for lunch, and so on. But fortunately I had tested PB extensively before the hippocampal removal and could show that the memory impairment occurred in the context of preserved high intelligence, including, and this is a very important point, an excellent short-term or "primary" memory, as I like to call it, following William James. What is primary memory? To illustrate, suppose I were to say to you now: "I am going to give you a short list of numbers and I want you to repeat them in the same order." You would all succeed with a list of five or six numbers (e.g. 62913), but with longer lists you would soon reach your limit. Thus, short-term memory is a limited-capacity system. It is what you can really keep on the stage of your consciousness, until your attention shifts. This primary memory capacity is intact in these amnesic patients, but the minute their attention is diverted (and life is constantly diverting us), they forget what happened just before. And so we have this patient PB, his intelligence unimpaired, his memory of the past seemingly intact, but from then on not building up new experiences. I think this has great relevance to the first question you are raising here, the relevance of our work to the humanities, because memory is a real topic going back to antiquity. What we now call "episodic memory", or the ability to recollect the past, is really the core of our being, of what we are as humans. We are our memories, and so you can imagine what it would be like if you lost that capacity. I think we can all imagine that. So this instance of postoperative memory loss was very disconcerting, to put it mildly.

At this point, Penfield and I asked ourselves: Why is this? And we speculated, in 1953, that perhaps what this patient had, unknown to us because we could not see into his brain, was damage in the hippocampal region of the opposite side, in the right hemisphere. This meant that when Penfield removed the left hippocampus, he effectively deprived the patient of hippocampal function in both hemispheres. We emphasised the hippocampus because PB had had a two-stage procedure, and it was only after the second operation, in which the hippocampus was removed, that we had this result. Shortly thereafter, we had a similar case of memory loss in a young man (FC), after a left temporal lobectomy that also included the hippocampus. We reported these findings at the American Neurological Association Meeting in Chicago in 1954. And that is where we come to what is much better known in this story: The American

neurosurgeon, Dr. William Scoville, working in Hartford, Connecticut, telephoned Dr. Penfield and said: "I think that what you and Dr. Milner are describing is what I have seen in a patient, in whom I have carried out my operation, also for epilepsy. And I would like to invite Dr. Milner down to Hartford, to study this patient and any other of my patients that interest her. I may say parenthetically that our hypothesis in the case of PB was proved true on his death 12 years later, when we did indeed find atrophy in the hippocampus of the unoperated right hemisphere, but of course at the time we made the suggestion, it was conjecture only.

We come now to the story that people read about these days: my visits to Hartford to study Scoville's patient, Henry Molaison (HM), who died about a year ago, at the age of 82. As a young man, HM had suffered from a severe form of epilepsy, which failed to respond to any of the medications available at the time. This led Scoville to carry out an operation on the medial structures of the temporal lobes (Fig. 2) in an attempt to control HM's seizures. Dr. Scoville was a very good surgeon, but a very bold one, and he believed, following Penfield's work in Montreal, that the medial temporal region played a critical role in the genesis of epilepsy. But Scoville's operation differed in two important ways from those carried out in Montreal. First, it spared the lateral neocortex and second, it was a bilateral procedure, removing the amygdala, the perirhinal and entorhinal cortex, and the bulk of the hippocampus, in both hemispheres. We know now, from subsequent magnetic-resonance-imaging studies, that Scoville's description of this operation was very accurate and that he did indeed spare the lateral cortex on both sides. This operation did in fact control HM's epilepsy to a remarkable degree, but it also left him with a continuous anterograde amnesia similar to that of PB and FC. Over subsequent visits to Hartford, I was able to delineate more precisely the main features of this profound memory loss.

HM was operated on by Dr. Scoville when he was 27, and I met him first when he was 29, in 1955. So I did not do the pre-operative evaluation, which was limited to IQ tests. And now we'll talk about HM. From the first, I found him a very friendly young man. But in all the time that I worked with him he never learned to recognise me, or know my name. He was always very polite and cooperative, while doing tests, but he never got to know me, nor any of the people from MIT who worked with him over the years. You have to think of me in 1955 as very naïve but very excited about what I might discover. I first established that HM had a normal short-term memory, as was the case with PB and FC. So I then gave him a three-digit number (584) and told him to remember it until I came back. I then left the room and had a cup of coffee with Dr. Scovillle's secretary. I came back 20 minutes later, and said: "What was the number?"

HM replied: “five eight four”. I was very surprised, and said: “That’s very good. How did you do that?” And he replied: “Well 5, 8 and 4 add up to 17. Divide by 2, you get 9 and 8. Remember 8. Divide 9 by 2; you have 5 and 4; 5, 8, 4. It’s simple!” I said: “That’s very good! And do you remember my name?” and he answered “I’m sorry, the trouble is my memory.” So you see immediately the dissociation between HM’s inability to build up anything in long-term memory as soon as he is distracted and his amazing motivation. There is no question of poor motivation; these amnesic patients all try very hard, and they make up all these tricks to try to remember. But they don’t succeed.

We come now to this question of examining the limits of this memory loss and also to trying to find an animal model. Given the general feeling at the time that memory was a function of the whole brain, you don’t imagine that the entire scientific world was saying: “Oh, isn’t this interesting?” They were all very sceptical, the neurologists in Europe being perhaps the least sceptical. But in North America the general view was that you could not possibly have seen these huge effects, these huge changes in memory, from such a restricted brain lesion. So it was important to show that monkeys with similar brain lesions to those of HM would have the same pattern of memory loss. And so I and my colleagues elsewhere were working hard on this problem.

The first idea was to teach the monkeys something, then to distract them with another task, on the hypothesis that they would forget what had happened before. And of course we did not find this. And why not? Because on most learning tasks then in use with the monkey, it could take hundreds of trials for the monkey to know what the examiner wanted them to learn: to know that a picture of a triangle was going to have a bit of banana under it and that there would be nothing under the picture of a square. The monkeys have to find this out by trial and error, whereas you can say to a human subject “I want you to remember that”, and then, a few minutes later, you can test their memory. This is a different task. My colleague, from NIH, Dr. Mortimer Mishkin (also a former student of Donald Hebb), would call learning over many trials an instance of “habit learning”, or procedural learning, a different kind of learning from memory of a single experience. So we were a bit challenged in our search for an animal equivalent. The big advance came when Mishkin (following a suggestion from David Gaffan at Oxford) began to test memory in monkeys over a single trial.

Let me illustrate the procedure. If I were to show a picture of a blue bucket to HM and say “What is it?”, he would reply: “A blue bucket”. And then I would say “I want you to remember that, because, in a minute or so, I am going to show you two

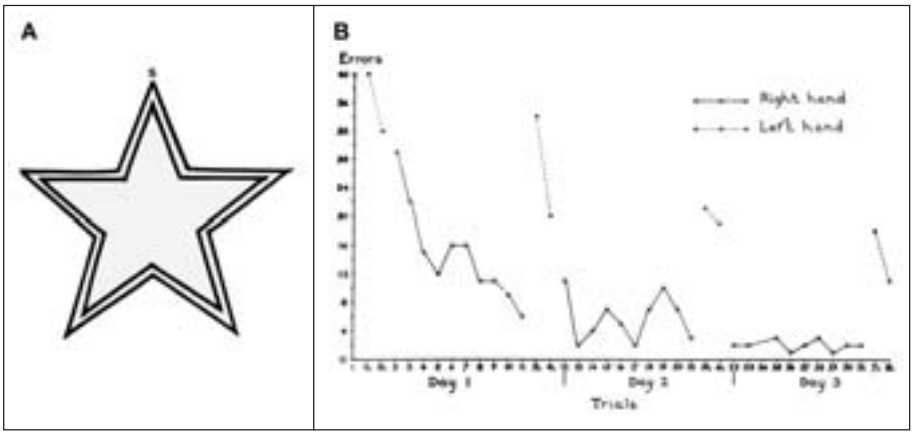


Figure 3A: *Five-pointed star used in the mirror-drawing task. The subject is instructed to draw a pencil-line, starting at point S and keeping within the double outline of the star. The subject's hand and the star are only visible as reflected in a mirror.*

Figure 3B: *Learning curve for the amnesic patient H.M., showing his progress over 30 trials, spread over three days.*

pictures, and I shall want you to tell me which is the new object." So you have to remember the object you have seen. And in this case HM would sit there, and you would see his lips moving as he said: "Blue bucket, blue bucket, blue bucket", and that's how he would keep it in mind. And then, after a short delay, I would show him two objects (the bucket and a ball) and he would know that the ball was the new object. Now imagine instead that you are the monkey and you cannot say "blue bucket". But normal healthy monkeys, with training, can learn very well to bridge considerable delays and succeed on such a task. We've got Michael Petrides here, who can attest to this. Monkeys like to choose the novel object; maybe babies do too, I don't know. So that is why we use a non-matching task "choose the new object". And what we found was that monkeys that had had the same surgical removals from their medial temporal region as HM, failed miserably on this delayed non-matching-to-sample task. They forgot the object they had been shown. These were wonderfully valuable data for which we had had to wait 20 years. It was in 1976 that Mishkin published this finding; it was in 1955 that we were publishing the work on HM. It took that long to get an insightful, meaningful animal model. But then memory research took off. It suddenly became extremely fashionable, and now it

seems as if everyone is working on memory, and students find it hard to believe that memory was not a popular field as recently as 30 years ago.

But this is a history talk, so I want to take you back again, to my work as a young psychologist in the 1950s, when I was exploring the extent of HM's memory impairment and finding that he was forgetting everything. Yet you could not just say: "Oh, well he can't remember anything'", because I had not tested everything, and you cannot prove the null hypothesis. So, in search of a solution, I went over to the Psychology Department at McGill and picked up a couple of learning tasks (ones that I could carry easily). I took the night train down to Hartford, arriving at three in the morning, and having at most three days to work with HM. He failed some of my learning tasks, as I had predicted he would, but I struck lucky with one of them, which was a simple, really a very simple task, illustrated in figure 3A. It shows a five-pointed star with double contours on a simple 8 inch by 10 inch sheet of paper. You instruct the subject to start at the point S and to trace a pencil line, keeping within the narrow contours of the star, until he gets back to the starting-point. It sounds easy, except that he only sees his hand and the star as reflected in a mirror. Under these conditions we would all do badly at first, especially when we come to a point in the star; but the wonderful thing is that we learn with practice and eventually achieve a perfect performance. And now we come to what was the most exciting moment; I think that in all the years I've been working, this was the most exciting moment for me. Figure 3B shows you the learning curve for HM, depicting steady progress in reducing his errors over three days of testing. (You can disregard the few interpolated trials with the left hand; HM is strongly right-handed.) From one day to the next, he still did not know me, nor recall that he had done the task before. Each day, we start again and we see this normal learning curve, and his beautiful performance on Day 3. At the end of Trial 30, he stood there in front of the apparatus, where he'd been working, and he said: "You know, this is funny; looking at this, I would have thought it would be rather difficult, but it seems I've done pretty well". He had absolutely no memory, no awareness of those 30 trials over three days of training that I had taken him through. For him, it was a new experience each time, and he was very proud of himself for having done so well on the last trial. And this really made me think: well this is a new kind of learning, a different kind of learning. Experimental psychologists had often thought that motor learning was different because it follows different rules from many other kinds of learning. Motor skills are acquired best when you are young and they are remarkably stable over time. You learn to ski in the winter and you can still do it the following winter. These are skills that you learn by doing. If you are trying to improve your stroke at tennis or golf, and then you ask yourself what you

have learned today, and you try to analyse why your performance is better today than it was yesterday, not only can you not do so, it impairs your performance, because it is a totally inappropriate sort of question. You learn by doing. And HM's success demonstrated that this kind of learning, the acquisition of this motor skill, is quite independent of the medial temporal-lobe system that is so important for memory as we know it, thus showing the existence of more than one kind of memory system in the brain. I do not, myself, work on the motor system, but since then other scientists have gone on to show the importance of another part of the brain, the basal ganglia, for this kind of motor learning. We also know now that there are various kinds of perceptual learning that depend, for example, on the visual cortex and not on the medial temporal-lobe system. But this medial temporal system is critical for life as we live it, for re-evoking past experience, for looking back and looking forward. Looking back, if you remember events, you may just remember a fact, that this is the date something happened, or you may say that you have seen something before, without any awareness of when or where. But the kind of memory that makes our inner lives so rewarding is being able to recall the context of past episodes in all their richness. I can go back to Montreal and sit in a British Airways plane, as I expect to do in a day or two, and I shall sit there and think about this meeting today, and the new friends I have met, and the historic surroundings. That is episodic memory, and it depends on the integrity of these deep systems of the brain, which interact with the overlying cerebral cortex of both hemispheres. So this is what looking back does, and I think it does engage the humanities. But, looking forward is the challenge, and I have to say that it is an incredible challenge to be given a lovely lot of prize money to do new research at the age of 91. You are impressed that I am still working at 91, but I am impressed that someone is giving me money at 91 to foster young people, to do research. I have spent a large part of my life delineating the complementary specializations of the two cerebral hemispheres of the human brain in memory processes. But there are huge tracts connecting the two sides (most notably the white matter of the corpus callosum), and neither hemisphere functions well on its own. My challenge for the future is to explore further how these two hemispheres work together, in health and in disease.
Thank you very much.

Peter Suter:
Thank you so much, Brenda Milner for this wonderful presentation. After each presentation we have a specialist in the domain who makes a short commentary and maybe asks a few questions, and I have the pleasure to invite Professor Dominique de

Quervain, who is Director of the Division of Cognitive Neurosciences at the University of Basel. Please, Dominique.

Comments, Questions and Preliminary Discussion

Dominique de Quervain:
It is a great honour to be the discussant of your talk, it was a brilliant talk, thank you very much Dr. Milner.
Dr. Milner's prize-winning studies on the role of the hippocampus in memory have had a profound and manifold impact on neuroscience. A search in PubMed (U.S. National Library of Medicine and the National Institutes of Health) for hippocampus and memory reveals more than 14,000 studies conducted on this topic – the first one by Dr. Milner back in the fifties. A closer look at this vast body of research indicates that scientists from various disciplines are examining the role of the hippocampus in memory, including molecular biologists, chemists, pharmacologists, anatomists, geneticists, neurologists, psychologists, and psychiatrists. In fact, the pioneering work of Dr. Milner was the starting point for exploration of the function of the hippocampus at various levels. Research activities range from studies of the molecular machinery underlying the growth of new synapses to clinical studies of patients with neurological or psychiatric disorders. Dr. Milner's work not only enabled and promoted multidisciplinary research, but also played a crucial role in the merger of the field of psychology with the various disciplines of neuroscience. Today, fast development of the field of cognitive neuroscience – a multidisciplinary research field focusing on the neural substrates of mental processes – can be seen as a direct result of this merging process. In the light of the complexity of human mental functions, it seems evident that a synthesis of bottom-up approaches to molecular biology with top-down approaches to psychology, neurology, and psychiatry is needed for better understanding of human cognitive processes.
In addition to its impact on the various disciplines of neuroscience, the work of Dr. Milner also has philosophical implications. Especially after reading Dr. Milner's impressive reports on amnesic patients, we might wonder, who we are without memory. Is memory the core of our identity? Can we modify Descartes' "I think, therefore I am" to "I remember, therefore I am"?
Dr. Milner's work has also direct clinical implications for the diagnosis and treatment of patients with memory disorders and for pre-surgical evaluation of patients undergoing neurosurgery for brain tumours or epilepsy. Moreover, Dr. Milner's contributions to the better understanding of memory, language, and hemispheric lateralization have important implications for clinical research on devastating disorders such as

Alzheimer's disease. More recently, the role of the hippocampus in the pathophysiology of psychiatric disorders such as major depression is also being discussed.
My first question to you, Dr Milner: After a traumatic event, for example torture, the victims build very traumatic memories of that event and start suffering from these and eventually even develop post-traumatic stress disorder in extreme cases. So I was always wondering, if you have a patient with hippocampal damage, who is unable to build new conscious memories, if he were to suffer from such a traumatic event in the future, would he develop post-traumatic stress disorder?

Brenda Milner:
I think that the critical structure here is not the hippocampus itself, but the amygdala, the amygdaloid nucleus, which is just in front of the hippocampus and is very much involved in fear and avoidance. If a child burns his hand on the stove, it doesn't approach the stove any longer; it is a one trial learning, a rat being shot. It is a simple kind of learning, very important logically.
I am not an expert on this, though there are people at McGill, who attempt to treat this by re-instating the fear, the post-traumatic stress disorder, having the person experience it, which they do very easily, and then interfere. In the animal you can interfere directly with protein synthesis, which would interfere with the formation of the memory, or would wipe out the memory that you have activated. In a human you cannot do anything like that, but there are chemical approaches along those lines.

Question from the audience:
(*Stephanie Clarke*) I am a physician and neuropsychologist and have a question for Dr. Milner. The role of memory is very important in our daily life; and patients, who lose memory because of lesions as we have shown, remain amnesic for almost the rest of their lives. And yet we know that patients who have had a stroke, and lost speech abilities, language, recover. What makes memory so different from speech, for instance, in recovery?

Brenda Milner:
If we just look at the speech, I think it is questionable if they will recover. If you think of a typical right-handed person with language in the left hemisphere, the stroke is due to damage to the vascular system in the left hemisphere, and it is deep in the cortex, not just towards the surface.
There are areas that are devoted to particular functions, and if you have partial damage within that, it is possible to have regrowth just around it. The same area, gradually,

gets some recovery of function. If you destroy the whole language area in the adult, you do not get recovery. Fortunately strokes do not do that.
Now, the reason why you do not get recovery with the memory is because it is bilateral, because you have got this system in both hemispheres.

Peter Suter:
Thank you very much, Dr. Milner, and again congratulations. To introduce the next laureate, I have the pleasure to present Professor Karlheinz Stierle. He is Professor emeritus from the University of Constance, and is a member of the Balzan General Prize Committee.

Presentation of Terence Cave, 2009 Balzan Prize for Literature since 1500

Karlheinz Stierle, Member of the Balzan General Prize Committee:
What would literature do without memory? Literally, literature wouldn't exist. Perhaps literature is the place, where the potentials of memory are translated into ideas and visions that cannot be replaced by anything else, and perhaps this could be a good topic to investigate further.
But now it is my great pleasure to introduce Terence Cave, winner of this year's Balzan Prize for Literature since 1500, which does not mean that 1500 is exactly his starting point. Terence Cave is Professor emeritus of French literature and Fellow at St John's College in Oxford. He is an outstanding figure in the history of European literature since the Renaissance. He is well known in Renaissance studies as well as in comparative literature. If I were to try to illustrate all the seminal works he has offered to the scientific community, I would take up all of his time. So let me just say a few words on some of his very important works, which have been the Committee's motivation for awarding the Prize to Terence Cave.
I begin with his study *The Cornucopian Text. Problems of Writing in the French Renaissance*, first published in 1979 and subsequently translated into many languages. With this study, one must really say, he has given an entirely new direction to Renaissance studies insisting upon the concept of plurality – *copia*, abundance – both a new device and a new experience in European Renaissance literature. This is a point which in the past has been rather neglected by humanist studies, which were more directed towards the traditions of integrity. Terence Cave has been the first to show that, especially in French Renaissance, there is an entirely new mode of writing. We can find it in Rabelais, in Ronsard, in Montaigne – and they have to be considered together – to understand that there is a real break in tradition and a new dimension of literary possibilities. So this work by Cave has been of the greatest importance

for opening new directions in literary studies in the Renaissance. It is a work that is outstanding in its attention to detail, in its scholarship, and also in its originality.
His second masterpiece is *Recognitions. A Study in Poetics* of 1988, which can be seen in close relation with Erich Auerbach's famous work on *Mimesis*. Terence Cave had the brilliant idea of taking an Aristotelian concept, *Anagnorisis*, into consideration, which, once again, in the past had been rather neglected. He makes it the central point of a literary development, a debate which goes on, both in theory and in the literary practice, from the Renaissance up to our own time. This is the moment where he expands his horizon from French Renaissance, or from the Renaissance in general, to a European context of literature that comes from a new discussion and perception of that very central concept of Aristotle. So he becomes a comparativist of literature and I must say, he is one of the very few comparativists, who are able to read all the works in their original edition, and to translate them, and to have all this enormous European context of literature at his disposal.
As I said before, with its wide European horizon, *Recognition. A Study in Poetics* has often been compared with Erich Auerbach's *Mimesis*, and I think it is as important as the work of Erich Auerbach has been. Right from the beginning in all his meticulously precise studies, Terence Cave has pursued a more general topic. He never indulges in pure materialism, but is interested in building configurations, in building literary corpuses in order to understand the single work in its own contextuality. What would work as a point of view in order to obtain new configurations, and thus to shed new light on the literary works themselves has yet to be found. I think, his main questions in this context are: What does it mean to understand literature? In what way is literature itself a specific way of understanding,……..of cognition and recognition? What is the interaction between literature and literary theory? What is the interaction between the theory of literature and understanding literature?
Terence Cave is a literary historian, who has learned from the very vivid literary debate on literary theory in the sixties and seventies, but he has not become, as many others have, an ideologist of one or other persuasion. He takes advantage of all. He is a 'critical' literary critic and as such, he will now address you.

Terence Cave on **Thinking with Literature:**

Now you know who I am, Mr. President, fellow Prizewinners, colleagues, ladies and gentlemen.
I must first thank the Balzan Foundation and the Swiss Academies of Arts and Sciences for organising this event. I'm extremely happy to be here, and not only because I have

been fortunate enough to win this amazing Prize, but also because this is the kind of intellectual interdisciplinary discussion I most enjoy. A conversation, I hope, as it will eventually become in the later part of the afternoon. Professor Milner is a very hard act to follow, especially as I am left-handed. I hope it won't be held against me, it probably will confuse some of my operations.

My research activities cover a period of nearly half a century: I began working on my doctoral dissertation in 1960. Rather than providing a linear narrative of that period, I think it will be more interesting and productive to focus on my central preoccupations and working methods, which, as it now seems to me when I look back over my career, have remained surprisingly constant. I say "surprisingly" because, in the course of that half-century, the field of literary studies has undergone a transformation which a doctoral student of the early 1960s could not possibly have foreseen: the rise of "structuralism", which borrowed from both linguistics and anthropology, and the fierce debates that it provoked between traditionalists and the avant-garde around the symbolic date of May 1968; the mutation of structuralism into a sometimes arcane post-structuralism, which drew on the philosophy of Jacques Derrida and the post-Freudian psychoanalytic theory of Jacques Lacan; the advent of an exorbitantly relativistic postmodernism; and out of that again the broadly "ethical" agendas that flourished above all in the 1990s – feminism, gay studies, postcolonialism, the new historicism – and still make their presence felt today amid the current preference for a cultural history in which literary texts are always read for their social and historical import alongside other kinds of document.

The first of my "constants" arises directly from that brief external history of fifty years of debate – often acrimonious debate – in the field of literary studies. Fascinated in the earlier stages of my career by this ever-changing intellectual landscape, I did my best to assimilate the various new approaches as they appeared over my horizon: they were after all the product of some remarkably brilliant critical thinking, and they were fired by the energy of a whole new post-war generation. I always believed that, at the very least, they had the merit of stretching the arguments of literary criticism to their utmost limit, often through paradoxical expressions such as the celebrated "death of the author" announced by Roland Barthes. They prevented us falling back on reassuringly comfortable habits disguised under the name of "common sense" or "real scholarship". However, I also believe that there is such a thing as good scholarship, which must be based on a scrupulously empirical foundation, and which is as difficult as the most excruciatingly complex arguments of the theorists. No single theory or method is guaranteed to deliver the goods. Each has its insights, each may be appropriate to a particular critical or historical task.

Although structuralism now appears to be as dead as Barthes said the author was (biographical criticism is flourishing again in a new guise), it taught me things that remain to this day part of my *outillage mental*, my intellectual tool-kit. Indeed, what I have attempted to do as successive waves of literary theory washed like a tsunami over the field of literary studies is to *read for the insight*, to look for the decisive inflection of thought that drove each major contribution to that unrelenting series of reappraisals. The mistake, in my view, is to espouse a literary theory and assume that it can be applied systematically to a whole range of different texts and literary periods; in general, those applications rapidly become mere repetition, the theory reducing the text to a caricatural image of itself. The primary interest of literary study, I believe, lies in the fact that the modes of thought *inherent in literature itself* are infinitely diverse and flexible. Our task as academic specialists of literature is, delicately and painstakingly, to uncover those modes of thought, to make them accessible, rather than overlaying and obscuring them with a programmatic theory or logic of our own making.

So my first constant is "reading for the insight", and it applies to the reading not only of critical theory and methodology, but also of literary texts themselves, and of whole configurations of texts: for every potential literary corpus, there will be a core problem or cluster of problems that one seeks to resolve. My second constant is a working method that remains uncertain of its outcome until the project or study is complete (or even later). When I started my doctoral work, my supervisor suggested that I should have a look at late sixteenth-century religious poetry. I spent a lot of time reading dozens of minor poets, but had no idea where it was all leading to until two things happened: I began to explore devotional treatises of that period in the hope that they might throw light on the poetry; and a friend who was working on English literature suggested I might look at Louis Martz's classical study *The Poetry of Meditation*, which demonstrated systematic links between English poetry of that period and the methods of religious meditation that flourished in the Counter-Reformation. Suddenly the whole thing began to make sense; a shape emerged out of a random heap of materials. Ten years later, I was planning a book on the myth of Bacchus in the French Renaissance; at the same time, I was reading humanist treatises and handbooks on how to write, and especially on how to imitate ancient authors. Those two tracks were already connected in my mind, but in what one might call a weak way: the connection didn't tell one anything new. Then I saw that, while Erasmus and other humanists were promoting the concept of *copia* or stylistic abundance, French vernacular writers seemed fascinated with the image of the cornucopia, which they used as a metaphor for several different domains of experience. That convergence or collision produced

an explosion: my book became a study of *copia* and cornucopia, using a figurative device to link what would otherwise have been mere rhetorical theory to essential human values and problems. My next book *Recognitions* had a similar history, which I shall not recount here; I would simply say that I now understand it, twenty years after the event, as a contribution to a cognitive view of literature. I would not have put it in that form at the time: cognition has only emerged gradually as a central theme in my work, but that there is a connecting thread is now quite evident to me.

A last example to bring the record up to date. The book I am completing at present, on the afterlives of the character Mignon from Goethe's novel *Wilhelm Meisters Lehrjahre*, began with a potentially enormous corpus comprising novels, poems, plays, songs and operas in German, French and English over some two hundred years. When I gave lectures on it, my audiences often looked puzzled or frustrated: they kept asking, "But where's it all going? what's your central argument?" I had a lot of local and partial arguments, but no all-embracing rational. I'll come back later to how I have resolved this problem: for the moment, I'll simply leave it hanging in the air.

One thing is clear: this way of doing research has some practical disadvantages. In 1984, I applied for a British Academy Readership which would have given me three years of research leave in order to write *Recognitions*. Unfortunately, at the time when I applied, my sense of what the book was about was still somewhat embryonic; the interviewing committee, who asked me the same kinds of questions as those lecture audiences, understandably decided to select another candidate, and I was obliged to write the book in the interstices of a busy teaching career. I have had other similar experiences since then: no institutional authority has ever liked my projects in advance.

As I have always told my doctoral students, the open-ended heuristic approach to research means living with uncertainty, which can be extremely uncomfortable, but in my personal experience it is far more productive. The Balzan Foundation has in fact proved that point, for me at least: the very studies that failed to achieve major grant support while they were being written are the ones now cited as the reasons why I have been awarded the Prize.

The third of my constants is what I would call the principle of connectivity. The most promising subjects for research are often ones that lie at the point of intersection between two apparently quite different domains. What I said a moment ago about the bringing together of *copia* and cornucopia is one example; another is the interplay, in *Recognitions*, between the history of poetics and the form that recognition scenes take in works of imaginative literature. Why are these intersections or fusions so

productive in literary studies? Because literary works are not composed of linear rational discourse: they themselves are full of interconnectivity. They connect things that our minds connect in everyday experience, things that logic separates in order to achieve clarity. One of the consequences of this is that they have a value as historical evidence, a value that is particular to literature: they show how the different perceptions and modes of perception that were habitual at the time when they were written might have been connected in that world. My work on the French Renaissance in the later part of my career focused on the writings of Rabelais and Montaigne as virtual encyclopaedias of the ways in which it was possible to think and feel in that period: as large and complex cultural objects inscribed with the signs of their provenance. Of course adjustments have to be made for fiction, because it is not, and is not meant to be, an exact representation of the world. One needs to use control samples. But at the same time, it is important to avoid what I would call the contextual fallacy. Nothing can be understood without context, but if we assume that externally constructed contextual materials can tell us everything we need to know about the meaning of a work, we only get a mirror image of what is already known. Context in that sense is only the beginning. It has to be used to filter out false perspectives, illuminate obscure references, and so on, but in the end, the process should work the other way round: the literary work itself will tell us, in its unique way, how to perceive the context as someone in that period might have perceived it. To take a straightforward example, the doctor figures in *Madame Bovary* and *Middlemarch* do not merely confirm what we know about the status of provincial doctors and the state of everyday medical practices in those cultures; they provide us with a complex, holistic, joined-up picture of medical practice and its interface with the life of the community.

Clusters of texts, literary and other, are clearly much better instruments for reading the past than single works. Such clusters multiply the possible number of strands and of points of connection between them. They also serve as checks and balances for one another. We thus come here to a further constant which is in fact an extension of the last one: the power of the corpus. Literary history has always been concerned with aggregates of texts, either to designate what are usually called literary "movements" or to uncover the continuities and discontinuities of literary tradition (for example, the reception in modern times of the works of classical antiquity). My conception of a corpus, however, is rather different from that. In the first place, I would insist, once again, on the principle of connectivity, of finding points of intersection between *different* clusters of texts. If one constructs a uniform corpus that is meant to demonstrate a single theme, or represent a single category, one may well be excluding from the outset the very things that will prove to be interesting. For an example,

I return here to my study of Mignon's afterlives. Mignon reappears after *Wilhelm Meister* in the German Romantic novel, in Walter Scott's romances, in the Victorian novel, in novels by Balzac and Zola and innumerable minor writers in France, in the opera *Mignon* by the French composer Ambroise Thomas, first performed in 1866, which became the smash hit of the later nineteenth century opera scene across Europe and beyond, in Frank Wedekind's *Lulu* plays and Alban Berg's opera, in a late novella by Gerhard Hauptmann, in Angela Carter's *Nights at the Circus*, and in English, German and Italian films, not to mention the hundreds of settings by nineteenth- and twentieth-century composers of the songs she sings in the original novel. The Mignon corpus is thus not only large but also heterogeneous. It moves across several different genres, across three major European cultures (with offshoots elsewhere), and between different levels in the cultural hierarchy: Mignon appears in the work of canonic writers like Goethe and George Eliot, but also in popular stories, novels, dramas and musical dramas. In short, she is a crossover figure, a character who virtually personifies the impossibility of constraining literature within conveniently separate, rationally constructed categories. The question "What is the object of study here?" could be answered by saying, for example, that it is a certain kind of connection between narrative prose and lyric poetry, or between literature and music; that it is the shifting representation in the last two hundred years of female adolescence and its vulnerabilities; that it is the representation of the exploited street-child or child performer; and so on. All of those themes and issues are central to Mignon's afterlives. But instead of choosing one of them and relegating the others to the background, I decided in the end that the primary object of study was the corpus as such, in all its heterogeneity, all its dendritic outgrowths.

Of course, I still had to structure the materials and present them to the reader in an assimilable form. And by "assimilable form", I mean a 300-page book, not an encyclopaedia or a catalogue. The solution I have come up with in the last few months is to present the Mignon corpus as an exhibition, a designed collection of materials, in a series of four chapters that are the equivalent of different rooms in a museum. But I have also provided an extensive first chapter that sets out the methodological principles on which the exhibition is based, and a final chapter offering a synthetic overview and an answer, or a set of converging answers, to the question those lecture-audiences put to me five years or so ago.

This is not the place to go into the detail of what the answers look like. I shall simply pick out two central points. The first is that the corpus is a sample and an example of how cultural history (including literary history) itself operates. The Mignon story is a story told over and over again in different ways, like a myth – except that this

myth was invented in modern times and is distinctively a myth *of* modern times. It is also a story set to music and experienced by thousands and thousands of people collectively. It generated a whole series of popular images in France and Germany, and those images themselves circulated throughout Europe, for example on a series of late nineteenth-century German postcards carrying photographs of Mignon look-alikes in sentimental poses. The story remains for an astonishingly long time in the collective memory: Angela Carter's powerful late twentieth-century version shows that it is still capable of generating new imaginative forms in our own day. The book will thus be structured primarily as an investigation into the methodology of cultural history and of the workings of cultural memory.

The second point brings me to a further constant. I said earlier that I now think of my book *Recognitions* as a contribution to a cognitive view of literature. The word "recognition" (and the Greek word *anagnorisis* on which it is based) carries in its etymology the theme of knowledge, and fictional works in which recognition scenes play an important role may be regarded as having in some sense a cognitive structure: they feature characters who are groping towards some truth that eludes them, often until it is too late. In such cases, knowledge, when it arrives, creates an explosion, a sudden transformation of all the known reference points, a drastic reinterpretation of the situation: one only has to think of Oedipus to get the point, although there are of course joyful and healing recognitions as well, for example in Shakespeare's romances. Mignon's story, too, is a recognition story, and I would argue that it provides nineteenth- and twentieth-century writers and their readers with a template that enables them to reimagine and rethink (for example) what it is like to be a vulnerable female on the threshold of sexual maturity, how difficult it is for her to speak about the traumas and the abuse that she has suffered, and what that state means in relation to the ethical assumptions of the particular culture shared by those writers and readers. Of course it is true that philosophers, psychologists and social commentators of the day wrote about these things in a rationally ordered and explicit way, but I would argue that the literary corpus represents a process of collective rethinking that exceeds any such reflection or commentary.

Let me offer you a metaphor for what I have in mind. There is a famous drawing known as the "duck-rabbit" picture which has provoked interesting reflections from, among others, the philosopher Ludwig Wittgenstein and the great art critic Ernst Gombrich. The drawing looks like the head of a rabbit from one angle, the head of a duck from another. It is impossible to see both together: one either has to see the duck or the rabbit. Yet the picture itself does not change. In literary study, it often happens that a single work produces diametrically opposite interpretations; there are also fierce

debates between those who read literary texts as historical documents and those who prefer to treat them as aesthetic objects. It seems to me more helpful to regard the work itself as a single object which can hold in suspension as it were many different strands and perspectives, some of which may seem incompatible with one another when seen from a rational perspective. In addition to ducks and rabbits, they may be readable as foxes or swans or fish or even human beings. Our job as specialists of literature is, first, to keep that multiplicity in play in our readings, and then to understand it as a unique alternative way of thinking about the world.

I ask you to bear all that in mind as I come now to the last of my constants, which is a belief in the value of methodological enquiry. The word "method" is derived from the Greek *hodos*, a road or pathway, with the prefix *meta* connoting pursuit: the overall sense might be rendered by the phrase "the way forward". In his Seventh Letter, Plato refers to philosophy itself as the "marvellous pathway" (*hodon thaumastên*), and Descartes chose the title *A Discourse on the Method* for the little treatise of 1637 that radically transformed philosophy, not so much in its content as in its working principles. I would like to insist here on the distinction between methodology and the kind of literary theory that I evoked in my rapid historical sketch at the outset. I have always been interested in literary theory, but I could never have been a theorist: abstract thought eludes my grasp. I like working with the untidy, unpredictable but endlessly fertile materials we refer to loosely as literature. On the other hand, I have always regarded it as essential to be aware of one's own working methods and to make them explicit as part of any literary study. For over a quarter of a century in Oxford, I ran methodological seminars for doctoral students; since my retirement, I have conducted short-term seminars and workshops at the universities of London and Oslo on interdisciplinary methodology. What I like most of all is to get people who are working on quite different things to sit round a table and enter into a dialogue with one another, using samples of their own work as a point of departure (just as we are doing today, thanks to the Balzan Foundation). The basic rule is that they should explain their work to the non-specialists in the audience precisely by focusing on their working method, on questions such as how they constructed their corpus or archive, the relation between empirical and theoretical perspectives, the logic and rhetoric that are particular to their discipline, the way in which their work overlaps or intersects with other disciplines, and where the limits of that interdisciplinary relation lie. I have found that in nearly all cases, this approach results in a lively and productive debate, so I have decided that it should represent a central thread in my proposed project for the Balzan Foundation. I shall use the resources the project puts at my disposal for discussion groups and

methodological workshops rather than for large formal conferences. The dialogue I want to set up will be open-ended, heuristic, Socratic in character, although of course I expect it also to result in excellent specialist publications by the individuals involved. And the subject I have chosen for the project is "Literature as an object of knowledge", both in its historical aspect and in its contemporary interdisciplinary embodiment: what are we, who profess to study literature, actually studying, and how can we justify that study in relation to our sister disciplines? What (to put it in another way) is the *cognitive* value of literature and literary study? That question has remained with me throughout my career, and it is the one I want to leave with you here today.

Peter Suter:
Thank you, Professor Cave, for this very interesting contribution. I would like to invite now Professor Frédéric Tinguely from the University of Geneva, where he holds the position of Director of the Department of French Literature and Language, for a short comment and maybe introduction of the first questions.

Comments, Questions and Preliminary Discussion

Frédéric Tinguely:
There are at least two models of interdisciplinary dialogue, which I will simply call models A and B. According to model A, an interdisciplinary dialogue takes place when scholars from different academic fields share a common aim and collaborate effectively. The famous Macy Conferences (New York, 1946-1953), which laid the groundwork for what would later be called Cognitive Sciences, seem to offer a good example of this kind of fruitful collaboration between specialists of widely different fields (Psychology, Biophysics, Anthropology, Mathematics, etc.). This model is of course very restrictive: it necessitates that various disciplines find a common object and establish a common goal. In addition, it assumes that the research findings are transferable from one domain to another.
I am not certain that model A is of great relevance in the context of our Forum. What would be the concrete results of a collaboration between Brenda Milner, Terence Cave, Michael Grätzel and Paolo Rossi Monti? In what way could Terence Cave's work have a direct effect on the evolution of Cognitive Neurosciences or the Science of New Materials? It would be better to avoid such simplistic questions, dependant on a rigid perception of interdisciplinarity, and concentrate rather on other possible articulations between the different areas of knowledge. It would be better to turn to

the more flexible model B, according to which interdisciplinary dialogue functions in an indirect and nonprogrammable manner and concerns a discussion of the different methods rather than an exchange of research findings that are often heterogeneous.

This is where the methodological reflection of Terence Cave proves invaluable. First and foremost because it shows that great scholars, no matter their field, consistently adhere to a few principles that are not affected by a succession of fashionable theories. The continuity of Terence Cave's research, as he himself describes it, is by no means the product of a retroactive interpretation. Every careful reader of his work can actually feel this continuity and, even if unable to conceptualize it clearly, understands that Terence Cave's very personal way of writing, of addressing problems, is the expression of an original style of thought.

Three of the methodological constants put forward by Terence Cave in his very stimulating paper seem to me particularly propitious to the kind of interdisciplinary discussion to which we are committed.

I will begin with constant 2, "living with uncertainty". One could think that the open-ended process that Terence Cave describes, for which it is so difficult to find institutional support, is somewhat specific to the study of Literature or the Humanities. My feeling is that it does not really have to do with a specific field, but rather with the epistemological level of the research involved. His works at a very deep epistemological level, as does, for example, the theoretical physicist. When exploring new questions does the theoretical physicist know where he is going? Does he have a hypothesis? Does he even have an object? He may be merely facing a problem. Perhaps the identification of an object or the formulation of a hypothesis is the result (and not the starting point) of his research. I would not be surprised to learn that fundamental research, in a great diversity of fields, works in much this way.

Constant 3, "the power of the corpus", raises the fundamental question of the dynamics between the subject and the object in a cognitive relationship. Does science belong to an attempt to domesticate, or dominate, through which a knowing subject succeeds in taking control over an object, in trapping it in its web? Or is it not that the subject must be completely open to the characteristics of the object and let himself be guided by it? By insisting upon the power of the corpus, Terence Cave suggests that the study of Literature brings out above all the ability to adapt and to be flexible, which in turn allows one to restore the complexity of the object without forcing it into predetermined molds. One would naturally expect to find this cognitive strategy, *mutatis mutandis*, in different domains of knowledge.

Finally, a word about constant 4, "the principle of connectivity," which refers to the pluridisciplinary dimension of the material considered by the scholar. The literary

objects on which Terence Cave focuses in his research are at the intersection of various bodies of knowledge; they connect different dimensions of human experience. They are like cultural webs, interdisciplinary in their very essence. Now, taking into account this characteristic might help us answer his final questions: "What is the place of Literary Study on the interdisciplinary spectrum?" "What is the cognitive value of Literary Study?" One could suggest that Literature, as Terence Cave understands it, is a cornucopia of cultural connections, and that by carefully studying these connections, one can discover new ways of linking clusters of phenomena, of linking different aspects of human knowledge and experience. Now, would the heuristic value of Literature be acceptable for, let us say, specialists of Social or Natural Sciences? Would it really make sense to them? In other words, would there be any recognition of it beyond the field of Literary Study? It is not my role to answer these questions, but merely to point out that any response will depend, at least in part, on the model of interdisciplinary relationship to which one has decided to subscribe.

Terence Cave:
This is a question to be answered by social scientists and not by me, but just let me make one comment on that. As you walk around and as you live your life, you will find there is music everywhere. People are playing music in the restaurant, they are playing it on their headphones, and so on. Music is a part of our lives, and now anybody, who wanted to study human anthropology, human comportment, would need to take music into account as part of how we operate. If you walk around, you also see quite a few books around you, you go into shops, people are buying books to read on the train, they have the little square things, they look in the screen, and they read stuff. And a lot of that is something we could loosely call literature. It is certainly not only books, but includes music, reports and so on. So that is also a fundamental aspect of what humans need in order to live their lives. What they need it for, may vary a great deal. It is clearly not for a single function. But it is so very central to human life that if social scientists want to leave it out, there is something wrong with them.

Question from the audience*:*
(Erwin Koller): Professor Cave, as a theologian and member of the Swiss Academies of Arts and Sciences, I would like to pose a question related to the field of 16th century religion. It is known that Jean Calvin and Ulrich Zwingli were quite close to Erasmus and other humanists of this period. Are there consequences for the understanding of the Reformation from the perspective of the Renaissance you have established?

Terence Cave:
I need to go back thirty years in time to when I was doing that work. Although I said I have constants of thought, I am not always thinking about the Renaissance. I would think that one would need to look for an answer to that question in the different ways in which, what I thought of as 'the aesthetics of abundance' – the liking for copias and an open ended style which then became linked to other aspects of human experience – was picked up by the different religious confessions. And it is certainly the case that in some more austere Protestant contexts that kind of style is denied, is suppressed, or not allowed. One quite interesting example is the sister of François Premier in France, Marguerite de Navarre, who herself had leanings in that direction, preferring the austere style. But she still wrote stories in the manner of Boccaccio, said they were supposed to be true, but they were not true. The idea that they should be like the truth was very important. So this would be kind of a counter example, to the 'aesthetic' I discussed. And it is certainly also the case that the poet Ronsard, who cultivated this, became a vehicle for a Catholic orthodoxy in France. So you might want to say that there is kind of a divide between a more Protestant aesthetic and another, which is, if you like, going to become a Counter Reformation, baroque aesthetic. That is very simplistic, and all the other answers to this question would, I think, require more details, and I postpone them to another day, or, as Rabelais says, "postpone them to book five, or six, the one I haven't written yet".

Frédéric Tingueley:
Professor Cave, you said that you expressed a preference for methodology over theory. My question would be: is it possible to have a methodology without even an implicit theoretical frame?

Terence Cave:
It certainly is possible to have a methodological frame without an explicit theory. I know a lot of friends and colleagues, who absolutely hate literary theory, and they always say they will never touch it. They tell you about how they are going to write their book, or what their rules are for writing the book. So they would not like to be told that they are doing theory. The big trick question, or trick device that was used in the Sixties and Seventies by people, who liked literary theory, was to try to show that all of those people, who resisted theory, were actually doing theory implicitly. You can always show that something has implied theory, because, what is theory? It is constructing the implied principles, and making a kind of system out of them. I suppose this is not a question of yes, or no, or switched on, or switched

off. Everybody chooses a point, at which they want to stop turning their implied ideas into a system. If you go on without stopping, you become a philosopher in the end; you stop doing critical work, you do aesthetics, or you create beautiful abstract systems.

Peter Suter:
Thank you for these presentations and comments. The next session will be chaired by my Colleague René Dändliker, President of the Swiss Academy of Engineering Sciences.

Chair II

René Dändliker:
As President of the Swiss Academy of Engineering Sciences I have the honour to open the second part of the 2009 Forum of the Balzan Prizewinners and to ask Professor Werner Stauffacher, Co-Vice-Chair of the General Prize Committee, to present Michael Grätzel, the 2009 laureate for the Science of New Materials.

Presentation of Michael Grätzel, 2009 Balzan Prize for the Science of New Materials

Werner Stauffacher, Vice-Chair of the General Prize Committee:
Professor Michael Grätzel was born in Germany and is a Swiss citizen. A physical chemist, he trained at the Free University in Berlin and joined the Swiss Federal Institute of Technology in Lausanne in 1977. There he is Full Professor of Physical Chemistry and heads the Laboratory of Photonics and Interfaces. Professor Grätzel has invented and developed an entirely new class of solar cells, devices that are intended to transform the sun's light into electricity. In what is now known as a Grätzel cell, quanta of light from the sun are captured by dye molecules, which release electrons to a network of semi-conductor-oxide nano-particles. This process generates the energy for electricity. Thus, the Grätzel cell mimics the natural process of photosynthesis used by green plants to convert light to energy. In the Grätzel cell, light-sensitive dye plays the role of chlorophyll. In plants, the sun's energy is used to synthesize sugars, while in the Grätzel cell it is used to produce electricity. In contrast to commonly used silicone cells, which require highly purified and expensive silicone, Grätzel cells use relatively inexpensive materials and therefore represent an extremely promising approach to the exploitation of solar energy around the world. Indeed, as an efficient, stable converter of sunlight into electricity which is also cheap to manufacture, the Grätzel Cell is destined to play an important role for small scale operations generating electricity in the developing world. Apart from his work in the development of solar cells, Professor Grätzel is currently conducting ground-breaking research related to the transformation and storage of solar energy in the form of a very flexible fuel. If confirmed, the results of this research could revolutionize our current concepts of the future use of solar energy.
Thus, Professor Grätzel is a most appropriate Balzan laureate for his fundamental discoveries, which have important practical applications in the production of sustainable energy – which may soon be lacking – for our world.

Michael Grätzel on **Light and Energy, Molecular Photovoltaics Mimic Photosynthesis**.

Perhaps the greatest challenge for our global society is to find ways to replace the slowly, but inevitably vanishing fossil fuel supply with renewable resources and at the same time avoid negative effects from current energy system on climate, environment and health. The quality of human life depends to a large degree on the availability of clean energy sources. Worldwide power consumption is expected to double in the next four decades due to the increase in world population and the rising demand of energy in the developing countries. This implies enhanced depletion of fossil fuel reserves, leading to further aggravation of environmental pollution. As a consequence of dwindling resources, a huge power supply gap of 14 terawatts is expected by 2050. This equals today's entire consumption, and thus threatens to create a planetary emergency of gigantic dimensions. Solar energy is expected to play a crucial role as a future energy source. The sun provides about 120,000 terawatts to the earth's surface which amounts to six thousand times the present rate of the world's energy consumption. However, capturing solar energy and converting it to electricity or chemical fuels, such as hydrogen, at low cost and using abundantly available raw materials remains a huge challenge.

Chemistry and materials science are expected to make pivotal contributions to the identification of environmentally friendly solutions to this energy problem. Learning from the ways green plants capture solar light and convert it to chemical energy, we have developed a photovoltaic cell based on films of nanometer-sized semiconductor oxide particles. The most advanced embodiment of the new solar cell employs the sensitization of mesoscopic titanium dioxide film by a molecular dye or semiconductor quantum dot [1-3]. The overall efficiency for solar energy conversion to electricity has already reached more than 12 percent, rendering the new photovoltaic cells competitive with thin film silicon devices. For the first time, dye sensitized solar cells accomplish the separation of light harvesting and charge carrier transport, opening up vast options for the choice of the molecular absorber material. The sensitizer or semiconductor quantum dot is placed at the interface between an electron and hole-conducting material. Upon photo-excitation the sensitizer injects an electron in the conduction band of the oxide and is regenerated by the injection of a positive charge in the electrolyte or hole-conductor. Impressive stability both under long-term light soaking and high temperature stress has been reached, fostering first industrial applications [4]. This field is currently receiving enormous attention, with a great increase in the number of publications over the last decade.

The advantage of dye sensitized solar cells (DSSCs) is that they can be produced at low cost, i.e. potentially less than 0.5 US$/peak Watt according to industrial projections.

The DSSC does not require the expensive and energy-intensive high vacuum and materials purification steps that are currently employed in the fabrication of all other thin film solar cells. The low cost and ease of production of the new cell should benefit large-scale applications. Mass production of flexible light-weight modules by a role-to-role method and their commercial sales have started recently.

The materials used to make DSSCs are abundantly available so that the technology can be scaled up to the terawatt scale without running into feedstock supply problems. This new solar cell will promote the acceptance of renewable energy technologies, not least by setting new standards of convenience and economy.

Literature:

1. Grätzel, M., and O'Regan, B. "A Low-Cost, High-Efficiency Solar Cell Based on Dye-sensitized Colloidal TiO_2 Films" *Nature,* 353, 737-740, 1991.

2. Grätzel, M. et al., "Solid-state Dye-sensitized Mesoporous TiO_2 Solar Cells with High Photon-to-electron Conversion Efficiencies." *Nature*, 395, 583-585, 1998.

3. Grätzel, M., "Photoelectrochemical Cells." *Nature* 414, 338-344, 2001.

4. Grätzel, M., "Recent Advances in Mesoscopic Solar Cells." *Acc. Chem. Res.* 42, 1781-1798, 2009.

In 2008, the photovoltaic industry produced about 8 gigawatt peak of electric power, and the projection is that the capacity will reach about 300 gigawatt peak in 2030. The term "peak" indicates that this power would be generated in full sunshine. However, taking into account the seasonal and diurnal cycles, the average power is about 3-10 times lower. The goal is to cut down on fossil consumption and use renewable sources to cover energy demands. As mentioned above, the sun, in particular, supplies 120,000 terawatts to the earth, compared to the 14 terawatts of power the earth requires to cover all its present energy needs. The photovoltaic market has been growing, but still depends strongly on subsidies. There is thus plenty of room for new cells and new concepts. In the end, radical breakthroughs are needed to bring the costs down below the 0.05 US$/KWh level, in order to become competitive with conventional energy suppliers. Moreover, we need to use readily available materials. A brief presentation of this discovery follows.

As Professor Stauffacher pointed out, the solar cell we have invented is the only photovoltaic device that uses dye molecules to absorb light and generate positive and negative charges, resulting in the conversion of solar to electric power. In this fashion, it mimics the primary process of natural photosynthesis, which has been operating in green plants and organisms for 3.5 billion years and hence is a well established

principle. In the green leaf, chlorophyll molecules absorb sunlight and generate electric charges, which, however, are not collected as electric current. Instead, they are converted by redox reactions at the membrane level to generate oxygen from water and reduce carbon dioxide to carbohydrates.

Using this principle of natural photosynthesis, our voltaic cell is the first to achieve the separation of the two functions of light absorption and charge carrier transport. In a conventional photovoltaic cell, these tasks are actually assumed by the same material. Thus, in silicon solar cells, the semiconductor – a sandwich of positively (p) and negatively (n) doped silicon – absorbs sunlight, resulting in the generation of electric charges. These need to be separated from each other first by the local electric field present at the p-n junction, which is followed by transport to the charge collectors. Thus, the silicon has to absorb light, separate the positive from the negative charges and conduct the charges to the two electric current collectors. Things get quite complicated, and ultra-pure materials are required to accomplish the photo-electric conversion at high efficiency. Solar grade silicon requires 99.9999 percent purity, which makes it expensive and energy-intensive to produce. The approach we have been taking is radical, but it is not entirely new, because the light energy conversion in photosynthesis uses a very similar principle.

Figure 1

Figure 1 gives a fair summary of the whole invention. It shows a solar cell that appears as a coloured glass, where the photo-sensitized pigment is sandwiched between the front glass panel serving as the front electric contact and the back panel serving as the counter-electrode of the cell. The ease of fabrication of these cells is illustrated by the fact that the photoactive pigment layer can be applied to the front panel by screen printing, thus offering a large variety of options for different colours and patterning of these films. The cells can be made in ambient laboratory conditions without having to follow any expensive procedures like high vacuum deposition methods. Here we have printed the logo of the Ecole Polytechnique de Lausanne using a sensitizer with a beautiful red colour. That the patterned film really acts as an efficient photovoltaic converter, can be shown by the fact that the electricity produced by the solar cell spins a fan even under ambient light conditions. Note also that the coloured glass panel is transparent. In fact, our cell is the only one that can be made truly transparent, thus rendering it attractive for applications such as energy producing windows or glass facades in buildings. It also absorbs light from all angles, just as the green leaf renders its operation particularly efficient in diffuse light, i.e. cloudy skies or indoor conditions. A conventional photovoltaic cell captures light from one side only. Thus, the device shown in the picture captures ambient diffuse light and turns it into electric power. I could have shown the same experiment in this very room here, producing electricity from the light that is emitted by the fluorescent tubes. One company that has seen an immediate application for this effect is Logitech, which would like to power the keyboard of computers using our cells. They selected our cells because they are the most efficient in converting ambient light to electricity.

Ruth Dreifuss, the former Conseillère Fédérale, who is present today in the audience, personally witnessed this experiment some 15 years ago. At that time, she was the President of Switzerland and visited the Ecole Polytechnique Fédérale de Lausanne. She was accompanied by Queen Beatrix from the Netherlands with her husband Prince Bernhard, who were on a state visit to Switzerland. We built a solar cell glass panel that turned a small model of a windmill under illumination. Both the Queen and the Prince were enchanted by this demonstration, which received widespread press coverage in the Netherlands. This visit had a strong impact, and in fact, the Netherlands became the first country where our principle was adopted. First, our Dutch colleagues checked it out of course – they are very careful people – and they afterwards built a very strong research community that helped us to develop this technology.

Figure 2 is a schematic representation of the solar cell we presented in the seminal paper "A Low-Cost, High-Efficiency Solar Cell Based on Dye-sensitized Colloidal TiO_2, Films", published in *Nature*, vol. 353, in 1991. The paper has been cited over

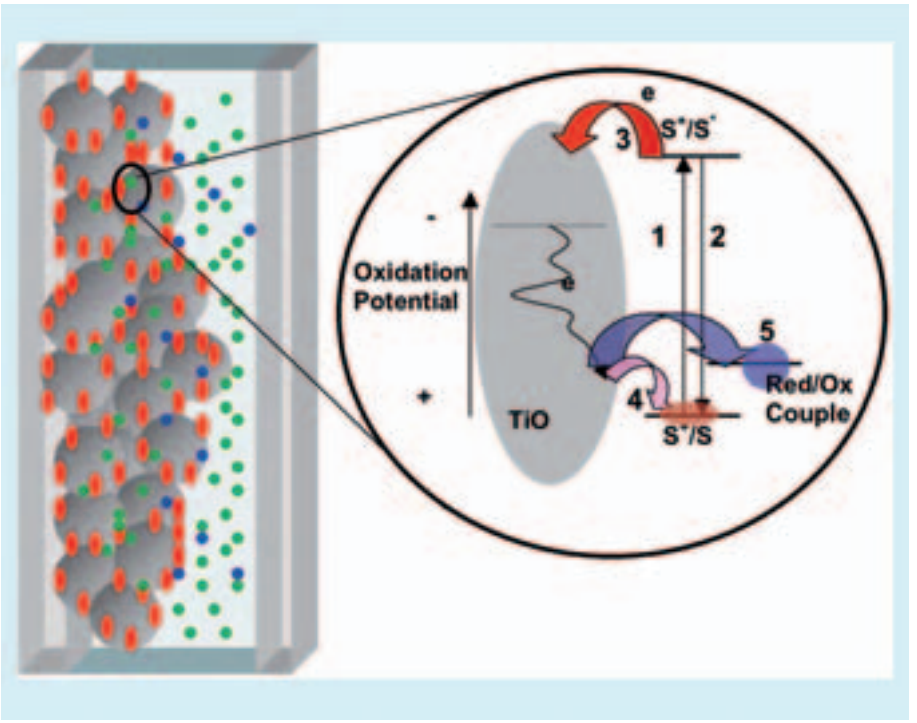


Figure 2: *Schematic presentation of the operation of a mesoscopic dye sensitized solar cell. Light is captured by the sensitizer (S) that is attached to a nanometer-sized TiO_2 particle producing the excited state S* (1). This enables the sensitizer to inject an electron into the conduction band of the TiO_2 (3). The interfacial electron transfer competes with deactivation of S* (2). The oxidized sensitizer is regenerated by the electron donation from the reduced form of the redox couple present in the electrolyte. The conduction band electrons move through the TiO_2 particle network to be collected as electric current. Competing with this process is their recapture by the oxidized form of the sensitizer (4) or redox couple (5).*

5,000 times, so has since then become a classic. It shows the principle of operation of the dye-sensitized solar cell. The electron transporting material is constituted by a network of very small titanium dioxide (TiO_2) particles, whose size is in the 20-30 nanometer range. These TiO_2 particles are represented as grey balls in the diagram. The medium transporting the positive charges (holes) is either an electrolyte or a solid

p-type semiconductor, which is infiltrated in the porous network. Electric charges are generated from light by dye molecules that are anchored as a monomolecular layer at the surface of the nanocrystalline TiO_2 film. These dye molecules are presented as red dots in the diagram. Following excitation by sunlight, the dye molecules inject electrons in the TiO_2 particles and holes in the electrolyte or solid p-type conductor. In order to reach high conversion efficiencies with the solar cell, it is very important to collect these photo-generated charge carriers as electric current before they recombine. In order to achieve this goal, the charge carrier collection has to be significantly faster than their recombination. Contrary to conventional photovoltaic devices where electrons and holes are generated – and recombine – in the same semiconductor solid, in our cell, their recombination has to take place across the interface that separates the electron transporting material from the hole-transporting material. This offers the opportunity to retard the charge carrier recombination by judicious engineering of this interface. For present state-of-the-art solar cells, the transport of charge carriers is at least 100 times faster than their recombination. Hence, over 99 percent of the charges produced by the sensitizer under illumination can be collected as electric current, which explains why the solar cell operates very efficiently despite a highly disordered structure.

As research advances in this field, new nanostructures emerge, showing great potential to move the conversion efficiencies to higher levels. For example, Figure 3 shows an electron microscopy picture of beads consisting of agglomerated nanometer-sized TiO_2 particles that have been sintered together to produce round balls of 500-800 nm size.

The mesopores in the interior of these beads generate a large internal TiO_2 surface area, which is covered by dye molecules for efficient solar light collection. Amazingly, when visible light strikes these beads, it can be quantitatively converted to electric current, their light harvesting capacity being increased markedly over a simple nanocrystalline film by multiple scattering of photons increasing the optical path length. Thus, these new mesoscopic structures enhance photon capture by exerting a dual function to scatter light and photo-generate charge carriers. We can use different dyes in order to realize solar cells in a variety of colours, i.e. yellow, red, blue, green and black. The discovery of a new green dye has been remarkable, as dye sensitized solar cells based on this molecule achieve over eleven percent conversion efficiency. The chemical structure of this new green dye resembles that of chlorophyll, i.e. it is a macrocyclic compound composed of 4 pyrrol rings coordinating a zinc ion. The Japanese company Aisin Seiki in cooperation with Toyota has made artificial green leaves using a green dye which provides electric power under illumination.

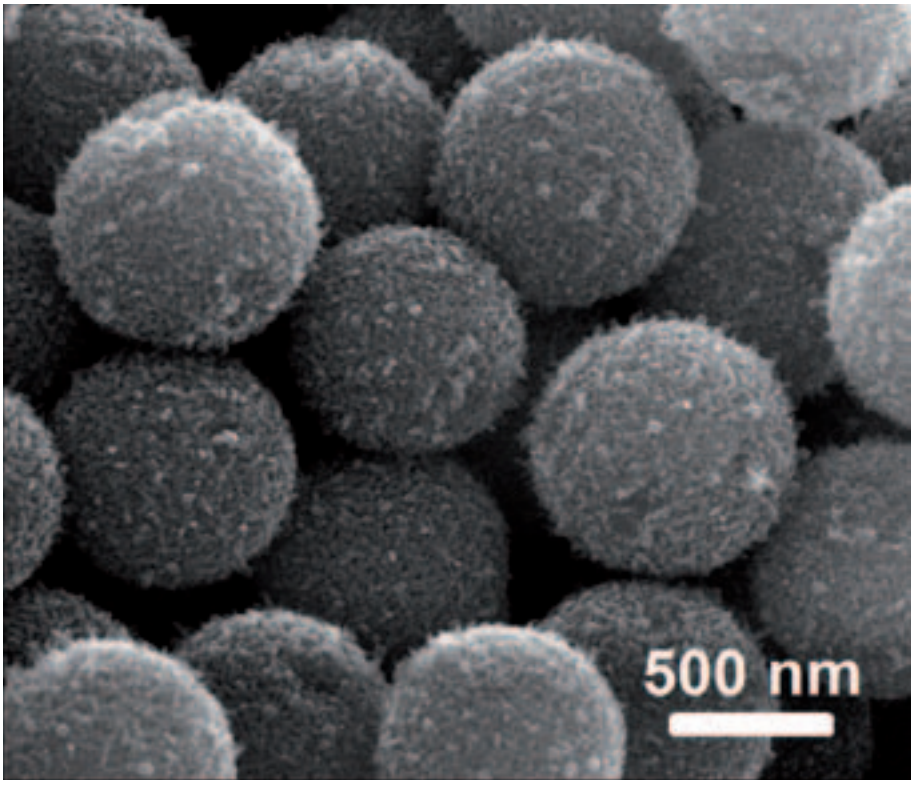
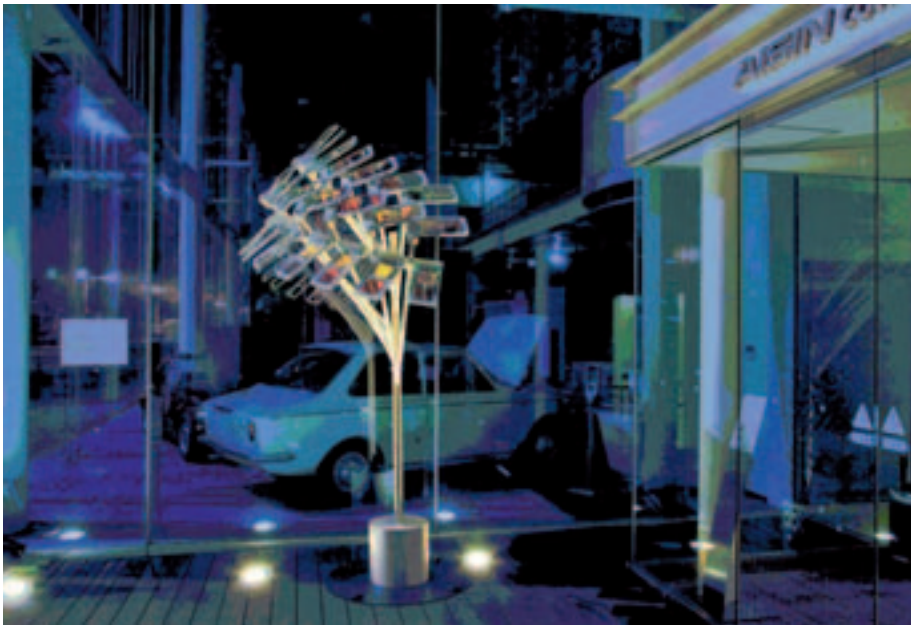


Figure 3: *TO_2, new porous structures.*

There is a great enchantment with dye sensitized solar cells in Asian countries. I have just returned from an international photovoltaic congress in Korea, where seven sessions were held on our cells. Many interesting lectures on dye sensitized solar cells were presented there, illustrating the excellent level of research of the numerous groups working in this field. I shall now illustrate our invention with a few applications. Figure 4 shows multicoloured streetlamps in Japan, where transparent dye sensitized cells are used to charge a battery during the day, and then at night, the stored electric energy is used to power a light emitting diode (LED).
The beautiful lamps and electric power producing windows developed by Sony have a similar function, except that they capture ambient light and convert it to electricity,



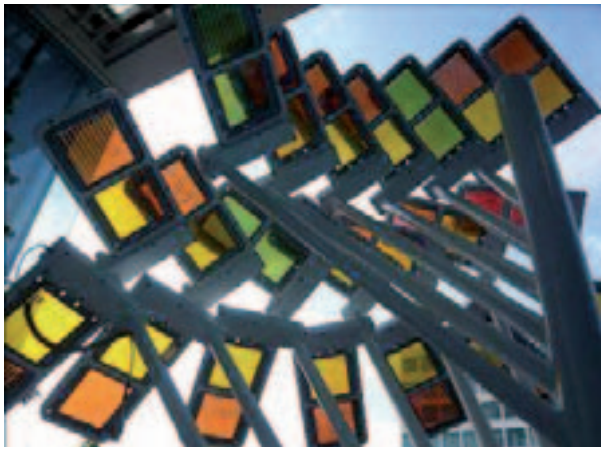


Figure 4: *Streetlamps in Japan.*

which is again stored in a battery and used to power the LED. So we do not need any electric power supplies to run these lamps. Their appearance is extraordinary, as Sony designers have printed the dye-sensitized pigments in the form of beautiful motifs on the glass screen of the lamp. These cells look more like artwork than photovoltaic devices. I think that in the future, we shall not only increasingly mount conventional photovoltaic panels on the roof, but that we shall also see them penetrate our living space more and more. One particularly attractive application of dye translucent dye-sensitized solar cells – pursued by the Australian company Dyesol – is the electric power producing glass facade.

Dye sensitized solar cell modules are undergoing stability tests in outdoor conditions, for instance, on a building of 3G Solar Ltd in Jerusalem. The photocurrent flowing out of the modules in bright sunshine is 3 amperes, and the voltage is over 20 V. This is a very significant electric power output for each module. When we started our work we first measured microamperes of photocurrent with small laboratory cells. Hence the scale up of the devices has been over 1 million times.

The company G24 Innovations started the mass production of flexible solar cells in Cardiff, Wales, in October 2009. The cells are fabricated by continuous roll-to-roll production, and hence are low cost. They are used on bags or rucksacks to power electronic equipment – such as portable telephones – by ambient light.

For the future it is very important to motivate the younger generation to work in the renewable energy sector. Thus, in Japan a group of young people raised about 6,000,000 yen to build a race car powered by dye sensitized solar cells. It participated successfully in a race in Japan last year. I think that we shall witness a shift to electric or hybrid cars in the near future, and they could be powered at least for city traffic by solar energy.

Last but not least, I would like to again express my profound gratitude to the Balzan Foundation for selecting me as one of the laureates for this prestigious Prize. I am deeply indebted to my co-workers who have contributed in a decisive fashion to the success of our research. I would also like to acknowledge our sponsors. In particular, I must mention the Swiss National Science Foundation, which has generously supported our curiosity-driven, fundamental research over many years.

René Dändliker:

Thank you very much Professor Grätzel. For the first comments I invite to take the floor Dr. Frank Nüesch, Head, Laboratory for Functional Polymers, Swiss Federal Laboratories for Materials Testing and Research, or better known as EMPA. Please, Dr. Nüesch.

Comments, Questions and Preliminary Discussion

Frank Nüesch:
The 21st century will see an immense revolution in the way we deal with energy. The Swiss vision of the 2000-Watt Society has led the way in defining strategies in Politics and Economics. Generation and consumption of energy is of course a world wide issue as can also be inferred from president Obama's 2010 budget blueprint: to generate revenue of $150 billion over 10 years that will go to develop clean energy technologies, industries, and jobs. Another global goal which is cross-linked to the latter consists of reducing greenhouse gas emissions. Solar energy is abundant and has a large potential to contribute to the latter goals. Photovoltaic electricity generation in particular has many advantages and benefits from a very high degree of acceptance within the population. However, its market and energy price has to be cut further in order to accelerate large scale dissemination.
As Professor Michael Grätzel said, dye sensitized solar cells – also called "Grätzel cells" or DSCs – are about to enter the market. Contrary to pessimists' misleading complaints of insufficient reliability, DSCs have taken a big step towards mass production. Since their fabrication relies on printing processes, DSCs and derived technologies such as organic solar cells represent a serious and major step forward in producing cost efficient thin film photovoltaics. Such solar cells can have different colours, can be transparent and are starting to inspire architects. Will we soon have photovoltaic windows in our houses? Flexibility and lightweight are further unique selling points of this emerging technology. Will it be able to provide electricity to 1/4 of the world's population, with all the advantages this may bring in terms of standard of living, communication or education? And under what conditions? Certainly these questions can not be answered by invoking arguments solely from the natural sciences but should rather be enlightened by an interdisciplinary approach including the humanities.
The invention and the development of the "Grätzel cell" is nothing short of amazing. As explained by Professor Michael Grätzel, the cell mimics microscopic processes found in natural photosynthesis. Curiosity and passion for unravelling pertinent questions are a common driving force in many fields of science. Long before nanotechnology became ubiquitous, Professor Grätzel was already creating highly porous oxide films with an effective surface area a thousand times larger than the projected area. In his presentation we have heard about its impact on the DSC application, which is first to provide the necessary surface for adsorbed dye molecules to absorb enough sunlight and second to create continuous paths to collect charge carriers for the production of useful

electricity. Professor Grätzel and his group were by no means limited to the solar cell application of the highly porous and transparent oxide films. Intercalation of lithium cations in these films pointed the way forward in making efficient batteries. Redox reactions of surface adsorbed molecules lead to the development of electrochromic windows and displays. Also heterogeneous catalysis was demonstrated to benefit from mesoporous oxide films. The capacity to capture essential physical mechanisms and to apply them in creating novel systems and devices best demonstrates the innovative and interdisciplinary potential of a scientist like Michael Grätzel.

These very important breakthroughs have provided new openings in natural sciences starting with the synthesis of new materials, such as charge transferring dyes absorbing in a broad range of the solar spectrum and nanoscopic oxide semiconductors. Fabrication of useful devices, solar cells above all, and the understanding of device physics have further stimulated the research field. The impact of these breakthroughs is clearly visible today in hundreds of research laboratories tackling open questions in the areas mentioned above as well as numerous start-up companies and large corporations which have decided to invest in these future technologies. In the future this tendency will most likely be enhanced and the discoveries of Professor Grätzel and his co-workers will continue to motivate research in numerous fields, particularly those related to nanoscience where materials with particular electronic and optical properties are sought.

The importance of Professor Grätzel's work goes far beyond a purely scientific and technological impact. As a matter of fact he was able to transmit his passion and enthusiasm to his fellows. Education in nanoscience for energy technologies is most important for the sustainability of new directions in future research and development. Numerous post-docs and PhD students that have left his group have carried along his passion for science and are further developing new directions in various fields of materials science.

Are there questions for Professor Grätzel from the audience?

Question from the audience:

(Irene Aegerter) I am Vice President of the Swiss Academy of Engineering Sciences, and I admire your concept for the development of cheap flexible cells, because they can really be used in developing countries. But the problem of solar energy of course is storage. We have pump storage power plants in Switzerland, which are very well adapted for solar energy. We will have to develop the grid, and you said you are producing hydrogen with your cells, and this is of course very important. My question is: What is the conversion rate in producing hydrogen, how many kilowatthours do you need, to get one cubic metre of hydrogen?

Michael Grätzel:
I teach solar dynamics and fortunately can answer this question. If you burn one mole: two grams of hydrogen, you will get 2.6 electron volts, which translates into about 250 kilojoules. So two grams of hydrogen = 250 kilojoules. Now, avec la règle des trois, as the French say, you can calculate this. So if you want a megajoule, how many grams of hydrogen...? And certainly, hydrogen is a good vector, it does have the problem of storage, but fortunately in Switzerland, there are many good scientists. At EMPA we have Andreas Züttel, who does pioneering work in the area of hydrogen storage. We had a discussion at the EMRS in Strasburg this year, when somebody from the nuclear fusion field gave a plenary talk, and after his lecture, there was a young scientist who got up and said: 'I would rather have the sun be the nuclear reactor than have the nuclear reactor on earth, a fusion reactor. What is wrong with capturing sunlight?' His only issue was storage, but let us just think about the cost. I mentioned to you these one billion cars, which pollute the world, using up our precious fuel, which actually should be kept for other uses. We should start storing and saving. Stop growing, and think about how to save. One way is for example to save on fuel and drive the cars on solar power. I would mention some other examples. With buildings and computers, there is a huge loss in energy. In the United States, very often buildings are air conditioned, where they are heating and cooling at the same time. I get very upset when I see that and I mention very often to my colleagues in the United States that we could use building facades to provide energy for the computers. It is not always necessary to make an AC conversion. In other words, go from DC to AC and back. You could use solar power, to power computers or batteries.

René Dändliker:
Thank you very much, Michael Grätzel, Werner Stauffacher and Frank Nüesch. Maybe the Historian of Science will help us to understand what we have to do in the future. But first, I would like to invite Professor Nicolette Mout to introduce Paolo Rossi Monti, 2009 Balzan Prize for the History of Science. She is Co-Vice Chair of the Balzan Prize Committee, and Professor of Modern History, and Professor of Central European Studies at the University of Leiden.

Presentation of Paolo Rossi Monti, 2009 Balzan Prize for the History of Science

M.E.H. Nicolette Mout, Vice-Chair of the General Prize Committee:
The History of Science emerged as a distinctive field of scholarship only in the course of the twentieth century. It soon blossomed and produced a whole library of books,

articles and text editions. Authors came to it from different fields: the Modern Sciences and Technologies themselves, Philosophy, History of Ideas. The early modern period, from the Renaissance to the Enlightenment, comes in for special attention. It is the era of exciting new discoveries and innovations, *Nova Reperta*: New Worlds with new inhabitants, animals and plants were studied, the heavens were observed with new instruments, the invention of the printing press proved itself invaluable for the distribution of knowledge, gunpowder, the compass, the mechanical clock and other devices changed what we now call 'science' and technology. The study of nature was transformed, and natural knowledge took on a new cultural meaning. The validity of knowledge claims, or epistemology, saw itself confronted with, for instance, questions about the status of hypotheses in astronomy or the value of mathematics and mathematical physics in the real world.

The History of Science in early modern times comprises the examination of both intellectual-philosophical and empirical-technological developments. Moreover, whoever wants to venture into this field, must know that he will have to deal with different and sometimes quite disparate and puzzling pursuits, practised by people from different professions, in different places and institutions. He is going to meet the university scholar, the court humanist, the medical man, the alchemist, the artisan, the engineer, or the gentleman of leisure – and the odd learned woman as well. What these persons studied, how they studied it, where and why, is now subjected to learned scrutiny.

Scholars have still not finished discussing the early modern period as the time of the so-called scientific revolution and the origins of modern science. Sometimes there has been a rather regrettable tendency to look back in hindsight to developments that are known to be important for the present, judging the past in terms of our present understanding of what science is or should be. Hence the emphasis on great men and great discoveries such as Kepler and Newton and their laws. Nowadays, historians of science focus more on the general question how and why science has become such an overwhelmingly important feature in Western culture. Certainly, they are still looking into the life and works of Kepler and Newton *cum suis*, but the History of Science is not depicted anymore as a triumphant procession of great men, going from strength to strength while climbing the mountain of knowledge, propelled forward, as it were, by the superiority of European culture.

Changes in the early modern study of nature coincided with the immense political, social, economical, cultural and religious transformations of the age. Historians of science have to take these into account. Wars demanded improved military technology, humanists contributed editions and translations of Greek and Roman texts which

were, more often than not, hotly debated, the Reformation and Counter-Reformation profoundly influenced the curriculum of schools and universities, and so on. And what to think of those aspects of the early modern study of nature that might strike us as rather strange or even beyond what we tend to view as 'true science': alchemy, astrology, magic? In the past, those elements of early modern science that did not make it into our modern world, were often pushed aside, forgotten even.
To do justice to the vanquished and the forgotten parties is among the most difficult tasks of the historian. Coming from Philosophy and the History of Ideas, our Prizewinner Paolo Rossi Monti, Professor Emeritus of the University of Florence, is not at all daunted by this task. His profound interest in the complexity of the intellectual processes on which early modern science was based led him to write his splendid books, breaking new ground in all of them. He concurs with the view that the History of Science can never describe its development as – I quote – "a linear process of progressive growth", but must of necessity "emphasise, on the contrary, the tortuous, non-linear and by no means inevitable nature" of the historical evolution of science. He is the champion of a subtle and detailed approach to the history of early modern science, which is always placed in the context of general European history. However, what is gained over the ages, can also be lost again, so Paolo Rossi Monti warns us – and I quote:

"The History of Science, and more explicitly the History of the First Scientific Revolution, can help us understand how logical rigour, experimental control, the public character of results and methods, and the very structure of scientific knowledge are not perennial facts of the history of mankind, but historical advances which can easily be lost."

As long as scholars such as Rossi Monti are among us, this lesson will not be forgotten.

Paolo Rossi Monti:
Thank you, Professor Mout, for your presentation.
My talk will be entitled **The Past is a Foreign Country**.
From my earliest years of education, when I lived in Milan through my time at the Warburg Institute in London and Wolfson College in Cambridge, several convictions that have variously accompanied my lifetime's work were consolidated. I will try to list those I consider most important: we must never forget that the distinctions between the disciplines have not always been delineated in the same way as they are today; that the truths presented to us as self-evident in the manuals of the various sciences are always *results*; that behind those results are long, complicated processes

and that struggles, contrasts, difficulties, attempts to identify crisis situations and then to get out of them underlie each of those results. As Walter Pagel (the twentieth century's greatest historian of medicine) stated in a paper entitled *The Vindication of Rubbish*, in order to write history, we must be concerned not with how *we* think, but more importantly with how *they* thought. *They* often considered certain things as evident that we would not think of as such. In order to understand them, we must also rummage around in matters that seem to be obsolete or even nonsense today. We must be interested in things that have been forgotten and that our ancestors and predecessors managed – not without great effort – to make disappear from the world. Like all other historians, historians of science must also consider not only the history of the victorious, but also that of the vanquished. Otherwise, they will continue to write those triumphal histories of fortunate discoveries which one segment of positivist culture has accustomed us to.

My research has concentrated on four main themes.

1) The relationship (which is both mixture and contraposition) between magic and science in the XVIth and XVIIth centuries and the emergence of new social figures in Europe (the engineer and *natural philosopher*, who were only called "scientists" in the XIXth century) and of a new evaluation of work, technology, and the mechanical arts. My book on Francis Bacon and the one dealing with "philosophers and machines" are my contribution to this theme, which I took up again in more recent times in a book dedicated to Giordano Bruno and the Magic of the Renaissance.
2) The tradition of the *ars memorativa*, or of techniques to strengthen the memory, and its being entwined with the tradition of the *ars combinatoria* of Ramon Lull in the period between the end of the fourteenth century and the age of Leibniz. My book, which came out in 1960 and preceded Frances Yates's study by many years, dwelt upon the theme of a universal encyclopaedia, or of an encyclopaedia that could contain all of the world's knowledge and identify an order among the things that make up the world. It also dealt with the theme of perfect or universal languages. In this context, the theme of a system of classification for plants and animals also emerged. In this case, too, in the 1990s, I took up these subjects in a broader historical perspective, with many references to literary and scientific culture. I went as far as the twentieth century, writing a long chapter on Memory in Immunology.
3) The third theme of my research concerns the so-called discovery of deep time. In the 1630s, men believed that they had a history of 6,000 years; in the age of Kant, they were aware of having a history of millions of years. The so-called "discovery

of time" (between the seventeenth and eighteenth centuries) marks a passage from a vision of the world in which the history of nature coincided with the history of man, and was confined within the 6,000 years of Biblical orthodoxy to an image of a "dark abyss" (as Buffon called it) that was hidden inside the present, and finally Kant's thesis of "a past of myriads of millions of years".

4) My fourth theme regards the philosophy of Giambattista Vico, whom I started to study in the 1950s. Vico was made to don the robes of eternal precursor (to Kant, to Hegel, to Marx). I have tried to show that Vico (who published his masterpieces in 1725, 1730 and 1744) did not study anything written after the 1680s, and I have upheld two theses whose unpopularity do not negate their veracity, ie. that Vico is often backward-looking in his positions and that Vico is the living demonstration that it is possible not to be "culturally up-to-date" and at the same time belong to the extremely small group of the great doyens of philosophy.

In the course of my career, I have preferred to cross traditional disciplinary borders, even stopping to dwell on "intellectual fossils" and on their unexpected rebirths (as in the case of magic or of the *arti della memoria)*. I tried – as R.H.L. Disney wrote in a review of my book *The Dark Abyss of Time*, published by the "Natural History Book Reviews", vol. 9, n. 2 – to "get inside the conceptual framework of the past and to convey the flavour of the contemporary debates and polemics from which our present ideas have eventually emerged". That contrasts with the approach of many authors who, starting from a currently accepted idea, go back towards the source, and minimizing every type of opposition to it, present us with a coherent history of its triumph. This type of approach, in my opinion, is suitable to clear exposition, but it is essentially a form of fiction or novel. I have never accepted the perspective of a History of Science of the "continuist" type. I have always rejected the idea of a "triumphal path" of science, just as I have rejected the worn-out image of science as reason incarnate. I have insisted on the relationship between theories and contexts as well as on the complex interweaving of "truths" and superstitions, uncertainties, contradictions, failed attempts. I have shown how philosophical traditions (the so-called *-isms*) have had significant influence on scientific theories, an influence which depends on metaphysical obligations and, above all, corresponding prohibitions. I have kept a distance from the sociological trends of the 1980s, and I have paid great attention to the History of Ideas, without denying scientific theories their autonomy, as do those who consider them simply as "systems of belief". The opportunity to put these convictions to the test was offered to me by Jacques Le Goff, when he asked me in 1995 to write a survey on the birth of modern science in Europe for non-specialists.

Whoever writes history finds him/herself in a position that is of necessity ambiguous. He/she also conjures up things that do not go well together: the attempt to identify oneself with and the attempt to keep a distance. As Jean Starobinski taught us all, historians should know beforehand that the truth lies neither in one attempt nor the other, but exactly and solely in the movement that inexhaustibly goes from one to the other. The idea of a distinct, clear, obvious and definite separation between an objective, unquestionable reality of facts and the subjective, arguable nature of interpretations belongs to a culture that is different from the one that characterises the vast majority of professional historians. I would also say that the thesis stating that historians must arrive at solutions for problems that are still open is untenable. Historians have an ineffaceable tendency: to consider all questions as open and to continue to debate and interpret in different ways. Very rarely do people labour under the delusion of closing questions. If this were not the case, we could not explain an undeniable fact. There was only one Descartes, but in today's culture there are many Descartes in circulation, and they are quite different from each other. And this is true for any philosopher or man of letters or poet or artist or politician or scientist. It is even true for imaginary characters – we meet many Hamlets who are different from one another, just as we meet many Madame Bovarys and not a few Raskolnikovs.

At the root of what we call historical research lies delight in research, the pleasure of discovery, relating ideas to one another and relating ideas to facts, above all and before any other thing, the pleasure of plotting out a route that is not entirely known or not entirely codified. We might very well speak of a passion for research, realizing that not just the future is unpredictable. When they discover new pathways, historians show that the past is also unpredictable; that the past, too, is full of new, unknown things; that the past also escapes classification, the pretences and arrogance of philosophers. And all this fatally leads us – directly or indirectly – to call the certainties of the present into question. It leads to cognitive Copernicanism, or definitive renunciation of the idea of being able always to be at the focus of world history.

It is now time to close. I have read almost all of what Clifford Geertz has written, and I have learned a great deal of things from him (although he is not a philosopher). In one of his books, I once found a brief story taken from the Sakuntara by Kalidasa, which is one of the most famous texts in Sanskrit literature. The story tells the tale of a wise man squatting before a big elephant that is standing right in front of him. The wise man says: "This is not an elephant". Only later, when the elephant has turned around and begins to go away, does the wise man start to wonder if after all there might not have been an elephant around somewhere. In the end, when the elephant has already

completely disappeared from view, the wise man observes the footprints that the beast left, and he declares with certainty: "An elephant was here".
Perhaps the History of Ideas also resembles this: to try to reconstruct elusive elephants, which have long gone away, starting with the footprints that they have left. If one dedicates his life to research of this type, and decides to spend the majority of his time in the company of people who no longer exist and pages written many centuries ago, he will certainly not derive great satisfaction, nor a sense of completeness, nor even the sensation of knowing for sure what he is looking for. The facts, a quoted aphorism confirms, are like cows: if you look them in the face hard enough they generally run away. However, I agree with Geertz's conclusion in his little book of 1995 entitled *After the Fact. Two Countries, Four Decades, One Anthropologist:* it is an excellent, interesting, disorienting, useful and fun way to spend your life.

René Dändliker:
Thank you, Professor Rossi Monti. We will now have an initial reflection from Dr. Raphael Scholl from the Institute of History and Philosophy of the University of Berne.

Comments, Questions and Preliminary Discussion

Raphael Scholl:
As Professor Rossi Monti reminded us in his speech, debates and controversies in the History of Science need to be understood not only from our present point of view, but also from the point of view of those who participated in them. History has to be understood not as tending toward some future goal, but as growing out of the past.
While this is an issue for all historical scholarship, the problem is particularly acute for the historian of science. As Professor Rossi Monti said in his speech, scientific theories are not mere "systems of belief". Rather, they are intended to tell us what the world is made of, and which causal relationships govern it. Thus, much more obviously than in other branches of history, there is a natural goal toward which science strives.
Researchers in the history of science are constantly aware of that goal – that is, of those bits of knowledge of the world which we today possess. There exists an intense temptation for the historian to pick out only those observations, experiments and theoretical assumptions which in some way foreshadowed present-day knowledge. Equally intense is the lure of the heroic tale of the lone scientist who single-handedly surmounts received wisdom and reveals novel facts, while the views of his (or her)

contemporaries who disagree are seen as those of benighted dogmatists. As Professor Rossi Monti rightly said, such an approach may be "suitable to clear exposition, but it is essentially a form of fiction or novel".

As Professor Rossi Monti has demonstrated in his work, in order to understand the emergence of new scientific knowledge, one must look at both sides of a controversy; neither side ever quite corresponds to its modern textbook caricature. Moreover, one needs to focus not just on those scientific theories which have by now stood the test of time, but also on unfinished and even failed theories.

Professor Rossi Monti's emphasis is often on pointing out how our retrospective notions of scientific progress do not align with historical facts. In his book *The Dark Abyss of Time* (1987), for example, he traces the history of our understanding of fossils. Before the 16th century, most scholars regarded fossils as one type of stones among many, stones which had somehow been shaped to look like living animals by what were called "plastic forces of the earth". Early modern scientists, such as Robert Hooke and John Ray, argued for the opposing view that fossils are the remnants of formerly living animals. Today we know the latter view to be correct, and it was clearly a major advance in our understanding of the world in which we live. Yet Hooke and Ray did not hold their seemingly modern opinions exclusively for reasons that we today would also recognize as correct or scientifically progressive. Instead, Ray in particular worried that the assumption of forces which could generate something closely resembling living matter would open the doors to atheism – a world view in which God was supplanted by "plastic forces" and was therefore no longer needed for the creation of the organic world. In this instance as in many others, careful reconstruction of historical arguments is required if we wish to understand the path by which our present knowledge developed.

In summary, one of the main insights we may take from Professor Rossi Monti's work is that the path towards scientific discovery is often tortuous. Any dividing line we may draw between heroes and villains in the history of science is usually doing violence to the actual course of history, preventing us from understanding the debates from which current views developed. Thanks to the work of Professor Rossi Monti and others, this insight is now deeply engrained in the thinking of most practitioners in the history of science.

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Question from the audience:

(*Urs Hochstrasser*) I am a retired director of the Federal Office for Science and Education (now the State Secretariat for Education and Research) and have a question for Paolo Rossi Monti. As our moderator said, when you prepare for the future, you need to know the past. The History of Science is an essential basis for science policy, which should prepare the future not only of science but of our society. There is an important problem, when you look at the History of Science. In the Middle Ages and later, scientists worked on applied problems and by doing so they enriched their theories. At present, there is instead an always more evident separation between pure and applied sciences. Basic research is nowadays separated from applied research. I think that to prepare for the future, it is important for the public to understand that there is a close relationship between applied and basic sciences. Is it possible for you, Professor Rossi Monti, to show this inter-relationship in the development of the sciences?

Paolo Rossi Monti:
I have no thesis concerning the future; I already have too many difficulties in studying the past…
The separation between basic and applied sciences has always been clear-cut, though in some fields it is now even increasing. But let us recall the *artes liberales,* which were those of the "free men", as opposed to slaves. The term 'mechanic' was still used as an insult in 1680, for example in the *Vocabulaire de la langue française* of Richelet. You can also find this negative use of the word in Alessandro Manzoni's *The Betrothed (*published in 1827, but the story is set in 1628*)*, when an arrogant man addresses an opponent with the words: '*vile meccanico; o ch'io t'insegno una volta come si tratta co' gentiluomini* ("vile mechanic, I'll quickly teach you the civility you owe a gentleman", Chapter IV). The term "mechanic" indicates here an inferior being, who has not reached the arts of free men. The transformation of "mechanic" into a positive judgement has been a very long process, which had to go all the way through positivism. Prior to positivism it was not possible to think, for the European upper classes, that marrying one's daughter to an engineer was a good thing.
There has been and there still is a great difference between the culture of "heads" and that of "hands". I would recommend here a rather old book (1947) by Benjamin Farrington (1891-1974) *Head and Hand in Ancient Greece: Four Studies in the Social Relations of Thought.* It was written by a very intelligent man, and it is one of the first books on this topic: it is a very important book, even though it was disparaged. The case of Galileo is difficult to understand without taking the separation between head

and hand into account. One of the main objections to Galileo was that he introduced, in astronomy, mechanical instruments. In fact, his telescope was considered dangerous by some of his opponents because, as they said, "it doubles the number of stars in the sky" (its lenses were supposed to duplicate the images). For many years, it was impossible for astronomers to accept the idea that mechanical instruments be used in astronomy, ultimately because of the belief that "God gave eyes to men to contemplate the sky, without instruments". Instruments, like the telescope, were supposed to be used only by less important people.
This situation has changed now, but the process has been very long, difficult and complicated.

René Dändliker:
I will now hand over to my colleague Peter Suter for the Prizewinners' panel discussion on the interdisciplinary perspectives.

Chair III

The 2009 Prizewinners' Panel
Interdisciplinary perspectives

Peter Suter:
I have prepared a few questions for you, dear 2009 Prizewinners, but the floor is open also for your questions, ladies and gentlemen, and dear colleagues.
Let me remind you of the three questions posed by President Imboden at the opening of this Forum:
How do the Prizewinners' discoveries, or their scientific contributions help to overcome the boundaries between the humanities and the natural sciences?
What consequences do the findings entail for other fields of knowledge?
What implications do these findings have for the future development of the sciences?
However, we also have a question for the Prizewinners from Professor Alberto Quadrio Curzio.

Alberto Quadrio Curzio:
I would like to start by considering innovations in techniques and technology used in productive processes. From an economic point of view, technological innovations may occur for many reasons, among which there are: military and defence reasons; the scarcity of natural resources, which generates the impulse to find new means of production; the desire to reduce physical strain among human beings.
Of course, we are perfectly aware that for innovation it is fundamental to have a scientific impulse (technology push), and we know that scientists consider science a value in itself without any connection to profits and practical applications. But even when scientific results are valuable for the well being of humanity, they are not always translated into technological innovation, because firms operating in the markets prefer not to introduce innovations when they are not yet profitable enough (lack of demand pull).
Have you any thoughts on the relationship between scientific research, scientific results and the market for technological innovation? Is this a problem for you?

Peter Suter:
I would recall here also the issue raised by Michael Grätzel, that fundamental research is curiosity driven, and would start with Brenda Milner: Yours is a very specialized type of research. Was your research also curiosity-driven?

Brenda Milner:
My research has always been entirely curiosity-driven. I do not come with a big theory that I want to test. I get excited, for instance, by the odd ways a person might behave or speak. It starts with simple curiosity about behaviour, and I think: 'Why did that happen and how can I measure it?'
And here methodology comes in. You have to devise tasks, or adapt tasks to satisfy that curiosity, and then you find you get more curious. It has always been empirical, I have been empirically driven and not theoretically driven.

Peter Suter:
Do you feel that behind this curiosity there is also a long-term view of the potential practical applications?

Brenda Milner:
I have to be honest in replying to that question. I am of course delighted when anything I discover is useful. Some of the things we found out about memory are relevant to Alzheimer's disease and to various other diseases. Nothing pleases me more, but it was not my original motivation. My personal motivation has always been sheer curiosity. It is curiosity that drives me.

Peter Suter:
Professor Cave, is the relationship between fundamental sciences and research, and applied research a problem in your field ?

Terence Cave:
No, it is not a problem, since research on literature and similar cultural phenomena has no obvious practical applications. However, I believe – and I am trying here to answer several of your questions at once – that science itself is always embedded in a culture. Professor Rossi's talk emphasised the degree to which he works – and it is the same for me – in a field where one familiarises oneself with the strange thoughts of others, usually from the past. They might not be only from the past; they might also be from different cultures and geographical regions. As you explore those strange thoughts, you learn, as it were, to adapt to entirely different ways of thinking about things, and you stop thinking that you have got a certain set of solutions of your own to the problems they are trying to grapple with. I think the problem with modern science – one could call it broadly 'Western science' with all those inverted commas around it – is that it has encouraged us to think that the only thing that really matters is 'practical applications', that culture is only a more or less agreeable extra.

But that is not the case. Culture is quite fundamental to the way we perceive and handle the practical solutions we come up with in the material world. If you try to introduce wind turbines, people say they don't want them on their beautiful landscape. You can tell them that if they won't have wind turbines, their landscape may be destroyed by climate change. They will still say that they don't want the turbines and will ask you to put them somewhere else. People don't like nuclear power, because they think it will give them terrible diseases. They may be wrong, but that is what they think. In Japan and Korea, on the other hand, they invent beautiful ways of incorporating Michael Grätzel's photovoltaic cell into their own culture. Both of these, the negative and the positive, are examples of ways in which science is dependent on the strange and sometimes irrational ideas that we call 'culture'. I have spent my life exploring those strange ideas, and I think that, in the end, there ought to be a deep connection between the work I do and the work scientists do.

Peter Suter:
I have a question now for you, Professor Grätzel, regarding a possible cross-fertilisation between your science and the humanities or social sciences. How can discoveries and insights like yours influence the humanities or social sciences, maybe to improve behaviour – for instance helping to solve the problem of air-conditioning in the United States you mentioned before?

Michael Grätzel:
The trouble is that a lot of people are just happy with what is going on. They are conservative and rather act for instance as if we still had enough oil, although we know there is only a trillion barrels left. We are consuming close to one hundred million every day, so we have ten thousand days left of oil. That is not so much; it is about thirty years.
If you ask somebody on the street: 'Do you know how many barrels of oil are left?' he would not be able to tell you, as long as he can buy it at a price he can afford. Only when the price of gasoline goes up, all of a sudden people wake up. And that is, unfortunately, how they relate to new solutions.
Research support has not always been adequate in my field. Problems with the supply of fossil fuels became clear after the first oil crises in the 70s during the Yom Kippur War, when all of a sudden there was neither oil nor gasoline. Only then people started getting worried. The public usually reacts only when things turn really bad, financially bad.

Peter Suter:
Is there a possibility to transfer, to contaminate the social sciences with problems like that?

Michael Grätzel:
It is a task of the social scientists, they should do more, and also the natural scientists should be reaching out to the public.
For example we give *demos* to the young kids, even at school age, and make sure they are aware of existent conversion technologies, regarding solar panels and other technologies like wind turbines. Education is extremely important and we need kind of a tsunami to move the whole field of renewable energy forward. It is not enough to just educate a few people. You need to have a major and strong wave there.

Peter Suter:
I would like to ask Professor Rossi Monti if, in history, we have problems like the oil shortage explained by Professor Grätzel. Are there examples of people who do not believe that there is an end to cheap energy in history? And what can we do to cross the borders from exact sciences to human sciences and to convince people?

Paolo Rossi Monti:
I remember one example of a shortage problem, which was later solved. There were fears that, because of the construction of ships, there would be no more wood. And then iron ships were built. This is one example, but there have been many other similar cases.
I do not believe that in the past there has been a real sense of natural resources running out. On the other hand, it is difficult to forget that during the age of William Shakespeare and Francis Bacon, many people (not just philosophers and intellectuals) thought that they were living at a time of decline – in the sunset of the world. Isaac Newton, too, in writing on the Apocalypse, referred to "the latter times into which we are fallen", recalling prophecies.
I am not optimistic about the future of the human race. However, I feel that optimism and pessimism are both indefensible positions. Ever since Adam and Eve were driven out of the Garden of Eden, we have always lived in conditions of uncertainty. We still are, even if there is a wealth of books that theorize on an imminent apocalypse and even if many believed, in the last century, in a radiant future and the possibility of heaven on earth. I believe that all arguments concerning the future (especially the distant future) ought to be addressed with great caution. From this point of view, it is worth referring to a book that contained a report written in 1972 by the Massachusetts Institute of Technology for the Club of Rome. After many pages of tables, statistics, grids, and explanations of what the model described, etc., a group of very authoritative scientists informed the trusting reader that we would have no more oil in 1992, no more mercury and silver in 1985, no more tin in 1987, no more zinc

in 1990, no more methane in 1994, and no more aluminium in the course of the year 2003. In 1993 we would already have been out of copper and lead, and we would already have long run out of gold and mercury. But the fact that this famous report on the limits of development, written by scientists of great fame, was rubbish is largely unknown to the public, even to those who read a newspaper every day. There is a very simple reason for this: futurologists, that is, the prophets of the future, are not very concerned about possible rebuttals. They come, when they do, after decades or even centuries.

Now, regarding your question on the relationship between the humanistic and the natural sciences, we must point out that there is a very big difference between the mode of studying sciences and the humanities. It is not necessary for a scientist to read Newton's works. Newton's truths can be contained in half a page. This applies to Kepler and to Darwin as well. If you read Kepler and you search for his three laws of the universe, you will not find them there as they are in manuals, in astronomy or physics textbooks. Somehow, natural scientists look at the past with indifference, even if such truths were discovered in the past and belong to the past. As Thomas Kuhn loved to say again and again, when paintings by Picasso arrive, those of Rembrandt are not moved to the cellar. In the sciences, books get old more or less rapidly. There are parts that must be rewritten and appear to have "grown old", things that were true but that are no longer so. There are terms that once described objects that we thought existed in the real world (for example, celestial spheres or phlogiston or caloric or luminiferous ether) but that today no longer have value, and thus only have meaning for historians of science. In rapidly growing sciences, manuals rapidly get old. All scientists obviously know that their science had a past, and they nurture a marked veneration for their founding fathers. Some even read them, but the *direct reading* of the pages written by Newton or Darwin is not *required* of them in order to be qualified or esteemed as scientists. Whoever reads those pages is more erudite than his colleagues, but reading or not reading a text of the past directly is, in the eyes of another scientist, a little like listening or not listening to music. One thing I know for sure: when, in a physics department, they talked about what was in those texts contained in those trunks that were opened and made public only two hundred years after the death of Newton (and that enabled Lord Keynes to write a study on Isaac Newton as the last of the magicians), most students of physics expressed a level of astonishment that bordered on incredulity.

Peter Suter

Brenda Milner, you are a living example of someone who has brought humanities and exact sciences together. Do you think that today it is easier to combine these two types of visions together than it was in the fifties or is it more difficult?

Brenda Milner:
Probably it was easier in the fifties. The field of cognitive neurosciences did not exist fifty years ago and it is having a very rapid growth. This relates not just to cognitive neurosciences, but to neurosciences in general. It is very hard to be up to date in one's own field because there is an overload of information. Within the field of neuroscience, we get narrower, we don't get broader. We do discuss general issues, but when it comes to the actual particularities of the work, we get narrow.
Of course, technology has led the way. We have new tools, such as imaging techniques. We can ask questions with more precision and questions that we would have been foolish to ask fifty years ago.
The real problem is handling all the information that is coming in.

Peter Suter:
What we know and see today on imaging techniques, does that influence human sciences, psychology and social sciences? Has imaging become a business and is there a danger of over-interpretation?

Brenda Milner:
I do not know about social sciences. I'm sure imaging techniques do influence many fields and perhaps too much. Imaging is an exciting tool, but limited at the same time. In functional imaging studies, one tends to see activity in many different areas of the brain, but not all these areas are critical to the task in hand. We perhaps get a little overenthusiastic about each new technique that comes along. So there is a real danger of over-interpretation, not only with imaging, but with any new fashion. There are in fact fashions in science. Suddenly everyone is focusing on the same technology and whole journals are flooded with it.
But there is another aspect to science related to what Professor Rossi Monti was saying. We should never forget, and I never forget it, that the next finding can disprove or modify ours: Science moves forward. This is why we, scientists, are not always reading in detail the writings of the past. It is because science is developing all the time. Whereas in the case of the arts or literature, the fact that you have a new style of art or writing does not invalidate the past. Past and present coexist, as Professor Rossi Monti was saying, in the 'Gallery'. For science there is such a thing as progress, which means that scientists and their findings are overtaken by their successors.

Question from the audience:
(Marco Ferrari) I am an Italian journalist, science editor of the monthly magazine Geo, and my question is about theory. Many academicians think that theory is a

useless term, or claim that they do not follow any theory to reach their conclusions. How important is theory for your work?

Brenda Milner:
When I say I am not theoretical, I mean it, because I start with a hypothesis, with something specific that I am looking for when I design my experiment. That is not a theory. A theory is something over-arching, which has many hypotheses coming from it. It is a whole 'Weltanschauung'.

Michael Grätzel:
In fact, we do not dislike theory and do use theory. It is very important to actually understand what one is doing. That means to master the theory and try to use it as much as possible to create the predictive. The trouble with theories is, very often, that one just explains retro-actively what happened. This predictive value is important and should be used. But the real drive for scientists is curiosity.

Terence Cave:
The problem with theory arises when a theoretical structure turns into something fixed and imprisoning; when people are so keen to uphold their theory that everything else has to be bent to fit it, or it gets turned into a series of stereotypes. People who want quick results will produce them. These results will be predictable but not interesting. I am not a philosopher, I do not deal in abstract ideas. Maybe a philosopher would say: 'well theory is of course what we do, all the time'. But the theories of philosophers (the best ones, at least) are not fixed, there is always a progressive, self-transforming process. Socrates would have told you that.

Question from the audience:
(Nora van Montagu) I am excited by the Prizewinners' discussion concerning curiosity driven research. Curiosity is the driving force for learning, but do our school systems and academic training adequately foster curiosity, in the different fields of natural sciences and the humanities?

Paolo Rossi Monti:
The problem does not lie in 'curiosity' in general. The curiosity of a child is different than scientifically-driven curiosity. In science, curiosity is specific: it roots out the open problems in science. The scientist broods about open questions and about the reasons why they are open, in search of a formula. Newton is a splendid example, concerning the 'open problem'.

Question from the audience:
(Denis Monard) As President of the Swiss Academy of Sciences, my question concerns the perception of science, also in a historical perspective. As knowledge or proofs accumulate, some concepts have to be revised. For example, during the last fifteen or twenty years, support for the validity of Darwin‘s ideas has accumulated, but at the same time, creationism has gained importance. Is there an obvious explanation?

Terence Cave:
As I said earlier, science is always embedded in a culture and the culture shifts in ways that are very difficult for us to predict. Sometimes it is reactive and it sees the world as becoming too materialistic. All of those rather mechanistic explanations upset people in the end, so they come back to something they prefer, even if they have been told over and over again that it is not the truth. I believe that this is the reason why the humanities have to keep providing a context within which other sorts of interpretation of the world are understood, otherwise there will be complex and unpredictable shifts between these two polarities.
In other words, we must not have a duality between the two hemispheres of the brain (I am here speaking metaphorically, of course). The use of the practical or instrumental side only without connecting it to the image making part of the brain, is not the way we should go. We have got to make the brain work as a whole and the only way you can do it is by having universities that embody all these ways of thinking.

Peter Suter:
Do you mean that the humanities must be sort of an essential part of all domains, and that humanists should be also trained in the natural sciences in order to include in their discussions topics like creationism and Darwin? Do you foresee this kind of exchange in the future of universities?

Terence Cave:
My feeling is that the current trend in universities, under pressure from both governments and civil society, is to instrumentalise all subjects, and what we are getting as a result is a purely instrumental view of the university. In order to get their research financed, people in the humanities are asked to say exactly what impact their work will have for the good of society. I think it is very difficult to predict that, and so humanists are being discouraged from pursuing many questions that may later turn out to be highly relevant. And that is very dangerous.

Peter Suter:
Professor Grätzel, you work in a famous technical university here in Switzerland, where the humanities have always co-existed with the sciences. How do you see the humanistic influence on students and on your own research work?

Michael Grätzel:
It is an important advantage for somebody who studies engineering, or another scientific topic, to look into the humanities. It is compulsory for our students to take a certain number of classes in the humanities. Myself, I think that somebody who has a broad education will always be able to get a better position in his professional life than someone who is narrowly focused.
We train students and we want them to do well afterwards. One of my greatest sources of pride is that all my doctoral students have done well, and they have told me: 'Professor, what we really like is that we have a good job, we can raise a family'. These are the fundamental values of life. In the end, I think that it is very important to have that broad basis.

Peter Suter:
Brenda Milner, how do you see the development within psychology of the different branches of clinical psychology and the more humanities oriented psychology?

Brenda Milner:
When I started in Cambridge, Psychology was classed as a moral science. Now it is considered a natural science and within psychology there are today many separations. The American Psychological Association probably has at least fifty branches, many of them predominantly clinical. There is also a very important and serious part of psychology that does not talk about the brain at all, but is interested in mathematical modelling and in computer science. These people are brilliant, but they find that the brain is not useful to them, in their thinking.
I used to call myself, and I am actually, an experimental psychologist. This is what my degree was in Cambridge. My degree at McGill was in 'Physiological Psychology', which would be 'Cognitive Neurosciences' today. I very rarely call myself a Psychologist today because there are branches of Psychology that are so alien to me that I cannot identify with them and they would not identify with me.

Peter Suter:
To conclude our panel, I would like to ask our Prizewinners how their work will be influenced by what they have heard at today's Forum and what impact the Balzan award will have on their research.

Michael Grätzel:
I think that knowledge has value *per se*. We all draw on knowledge, be it from one or other part of the sciences or from the humanities. We should really appreciate our colleagues' work in this latter area, because it will enrich our lives as well.
My doctoral thesis was in an area that nobody other than myself was interested in. It was on mono-nitrogen oxides (Nox), which, as it turned out all of a sudden, when the pollution problem popped up, became very important. All the papers on it – including mine – received a lot of attention. So in the end, the value lies in the knowledge.
The Balzan award will have the impact that the second part will be invested in the improvement of the performance of the Dye Sensitized Solar Cell (DSC)[1].

Terence Cave:
I think it is difficult to imagine ways in which Michael Grätzel's photovoltaic cells could make an impact on my work, except that it always moves me to see how scientists, in one way or another, become interested in, or involved, in aesthetic ideas. But, there are quite deep similarities in the ways we work, despite all the apparent differences. Every time I hear people like Professor Grätzel talk, I am reminded of that and it is very important for me to feel that we have common aims and principles.
There is a much more obvious continuity between the cognitive neuroscience that Brenda Milner does and my research. Her studies come to me via cognitive psychology on the one hand and certain kinds of cognitive linguistics on the other. Philosophy has become more interested in the mind again, partly for the same reason; i.e. the impact of cognitive neuroscience. And in literary studies too we are beginning to talk again about mind and communication, there is a sort of cognitive turn in my subject, while in the sixties and seventies research was all on language itself, and there was nothing about intention or human agents communicating with one another. Everything that Brenda Milner says is relevant to what I do, even though not in a direct, immediate way. As for the connection with Professor Rossi Monti's studies that is of course even clearer, I mentioned it earlier, so I won't elaborate on it here.
With the second part of my Balzan award I will run a research project at the Research Centre of St John's College, Oxford[2] on Literature as an object of knowledge.

[1] s. page 82 description of Michael Grätzel's Balzan research project.
[2] s. page 81 description of Terence Cave's Balzan research project.

Brenda Milner:
Concerning the talks and debates of today, I am sure that they will influence me. I am going to have very rich recollections, episodic memories, of this afternoon.
I feel encouraged that the Balzan General Prize Committee thinks it is worthwhile to explore how the brain's hemispheres work together. It is important that I get good young people to work on the Balzan research project[3] to be financed by the second half of the award. I was talking earlier about how you get an enthusiasm or curiosity, in young people. Undergraduates can get very excited and sometimes I think that what they get excited about is the fact that I am excited. Young people respond to enthusiasm.

Paolo Rossi Monti:
I think that this was a very stimulating meeting. I will remember it as something pleasant and gratifying. Questions on the future are especially important for old men, because they expect to have a future and to be able to continue to study and write.
I am happy that the second half of the Balzan award will be entrusted to the Istituto Nazionale di Studi sul Rinascimento in Florence, and that it will enable me to involve seven young scholars in a research project entitled Cosmology and Physics, Memory and Emotions[4].

Peter Suter:
I would like to again thank the Balzan Prize Committee for having selected such interesting Prizewinners whom I would like to thank for their presentations this afternoon. I will now give the floor to Ambassador Bruno Bottai – who is the President of the International Balzan Foundation 'Prize' – for his closing remarks. Once again on behalf of the Swiss Academies of Arts and Sciences I thank the Balzan Foundation for their work and the very gratifying panel they have offered us today.

[3] s. page 84 description of Brenda Milner's Balzan research project.
[4] s. page 86 description of Paolo Rossi Monti's Balzan research project.

Closing remarks

Bruno Bottai: President of the International Balzan Foundation "Prize".
As Chairman of the International Balzan Foundation 'Prize', I congratulate and thank the 2009 Balzan Prizewinners for their talks. Balzan's Prizewinners are the source of the foundation's prestige, and I congratulate the General Prize Committee and its Chairman Professor Salvatore Veca for the Committee's excellent decisions. The Balzan Foundation's authoritativeness is in fact due to the merit of its Prizewinners, and through their example, to its ability to give life to a virtuous cycle of stimuli to research and to the elaboration of new concepts and experiences in all fields of culture and science.
An agreement of cooperation between the International Balzan Foundation 'Prize' and the Swiss Academies of Arts and Sciences was signed earlier this year. This agreement aims at fostering scientific research. The organization of this Forum is part of the agreement, and I want to acknowledge President Peter Suter, Professor René Dändliker and Dr. Markus Zürcher for today's very productive meeting, and also our Councillor and Vicepresident of the Accademia Nazionale dei Lincei, Professor Quadrio Curzio, who is the initiator of this agreement.
Let me remark that the International Balzan Foundation is both an Italian and a Swiss institution. The „Prize"'s headquarters are in fact in Milan. Exactly half a century ago, Angela Lina Balzan decided to honour the memory of her father and further his principles by using his considerable estate in a project for the promotion of knowledge and culture. Thus, an exemplary tradition of impartial patronage began, with solid foundations in the personal vicissitudes of a young man from Badia Polesine, a small town near Rovigo (Northern Italy), who later became an renowned resident of Milan. That young man was Angela Lina's father, Eugenio Balzan, who had worked in the first decades of the twentieth century to make *Corriere della Sera* the most modern, authoritative and widely circulated Italian newspaper. In those years, he was a leading figure in Milan's cultural milieu, which was brilliant and unrivalled on a national level at the time, especially in the field of publishing.
We feel that in these past fifty years, the International Balzan Foundation has created a personal and distinguished image for itself in the realm of philantropic work, by jointly recognising the most excellent minds and the very essence of knowledge.
In order to maintain this solid tradition, the International Balzan Foundation can count on a strong guarantor: the shrewd, functional administration of the estate by the

„Fund“ Foundation in Zurich, with former Vice-Chancellor and Spokesman for the Swiss Confederation Achille Casanova as Chairman.
I thank you all for your participation in this Interdisciplinary Forum of the 2009 Balzan Prizewinners at the Nationalfonds in Berne and hope to welcome you next year in Rome, at the Interdisciplinary Forum of the 2010 Balzan Prizewinners.

The 2009 Prizewinners' Research Projects

The Balzan Interdisciplinary Seminar:
Literature as an Object of Knowledge

Terence Cave, Professor emeritus of French Literature and Fellow of St John's College in Oxford, was awarded the 2009 Balzan Prize for Literature since 1500 *for his outstanding contributions to a new understanding of Renaissance literature and of the influence of Aristotelian poetics in modern European literature.*

He will use the second half of his Balzan Prize to explore the value of literature as an object of knowledge, and more specifically, the cognitive value of literature in relation to other kinds of discourse. The word "seminar" is used in the title to indicate the heuristic nature of the project: the core of the work will lie in discussions designed to foster a sharper awareness of the issues that are at stake and to explore new directions in the understanding of literature.
The research project will be run at the Research Centre of St John's College, Oxford. The programme will establish a core team of individuals who are committed to the long term. These will in turn seek to involve others working in relevant interdisciplinary fields for attendance at workshops, discussion groups and a major methodological colloquium, under the general guidance of Terence Cave, who will act as Director. The project will comprise a Senior Advisory Panel, two post-doctoral Balzan Research Fellowships, four short-term Balzan Research Lectureships, and a number of discussion groups. There will also be a programme of individual visits and exchanges of researchers.
There will be two principal sub-themes: (i) Historical approaches to literature as an object, vehicle and instrument of knowledge (with particular reference to the early modern period); (ii) Cognitive approaches to literature.
Individual research programmes will be respected, but will also be used as test-cases or illustrations of the broader interdisciplinary issues raised by the project.

Improving the Performance of the Dye Sensitized Solar Cell (DSC)

Michael Grätzel, Professor at the Ecole Polytechnique de Lausanne, where he directs the Laboratory of Photonics and Interfaces, was awarded the 2009 Balzan Prize for the Science of New Materials *for his many contributions to the Science of New Materials, and in particular for his invention and development of a new type of photovoltaic solar cell, the Dye Sensitized Cell, commonly known as the Grätzel Cell.*

The overall goal of his Balzan research project is to improve the performance of the Grätzel Cell. An increase in the overall efficiency of this kind of photovoltaic cell from its present 12.3 to nearly 15 percent is predicted, which would strongly contribute to making the Grätzel Cell a widely used method for electricity production from sunlight.
With the second half of the 2009 Balzan Prize for the Science of New Materials, the Laboratory of Photonics and Interfaces at the Ecole Polytechnique de Lausanne (ETH), directed by Michael Grätzel, will acquire an Atomic Layer Deposition System for the Laboratory and hire Dr. Aswani Yella as a postdoctoral fellow for two years. Aswani Yella is a PhD student who has just finished her thesis with Professor Tausch Tremel in Mainz, Germany. The remaining sum will support visits of students and researchers from Italian universities within a framework of collaboration on the research project. Adopting an experimental approach to the design of the Grätzel Cell, the Balzan research project will focus its attention on the interface that separates the materials used in the device for transporting the negative charge carriers (electrons) and positive charge carriers (called holes). The electron transporting material is constituted by a network of very small titanium dioxide (TiO_2) particles whose size is in the nanometer range (a nanometer is one million times smaller than a milimeter) while the hole transporting medium is either an electrolyte or a solid p-type semiconductor. These electric charges are generated by dye molecules that are anchored as a monomolecular layer at the surface of the nanocrystalline TiO_2 film. Following excitation by sunlight, the dye molecules inject electrons in the TiO_2 particles and holes in the electrolyte or solid p-type conductor. In order to reach high conversion efficiencies with the solar cell it is very important to collect these photo-generated charge carriers as electric current before they recombine. In order to achieve this goal, the charge carrier collection has to be significantly faster than their recombination. Contrary to conventional photovoltaic devices where electrons and holes are generated – and recombine – in

the same semiconductor solid, in the Grätzel Cell their recombination has to take place across the interface that separates the electron transporting material from the hole transporting material. This offers the opportunity to retard the charge carrier recombination by judicious engineering of this interface.
The Balzan research project will explore several new strategies to retard the interfacial charge carrier recombination rate. The dye molecule itself is a molecular insulator and hence should impair on its own the electron-hole recombination. However the molecular dye layer formed by adsorption on the TiO_2 nano-particles is usually disordered, leaving part of the surface exposed to the electrolyte or hole conductor. Hence research will be conducted to improve the self-assembly of the dye molecules in order to form more compact films at the surface. Thus, Grätzel's research group shall modify the chemical structure of the dye molecules to endow them with long alkyl chains enhancing their lateral attraction. This is expected to increase the packing of dye molecules retarding the unwanted interfacial recombination of negative and positive charge carriers. They will also attempt to use additives in the electrolyte that will promote the formation of dense monolayers of dye molecules. Finally the atom layer deposition (ALD) system acquired with the second half of the Balzan Prize will provide a powerful tool to modify the titanium oxide surface by depositing a very thin overlayer of a semiconducting oxide in a contiguous and conformal manner. The goal here is to eliminate defects such as oxygen vacancies that are present at the nanocrystal surface. These defects, called electronic surface states, are known to accelerate the interfacial electron-hole recombination. Judicious engineering of the interface will retard the interfacial charge carrier recombination increasing the open circuit voltage and cell efficiency.

Hemispheric Interaction in Cognitive Processes

Brenda Milner, Dorothy Killam Professor of Psychology at the Montreal Neurological Institute and Professor at the Department of Neurology and Neurosurgery of McGill University, was awarded the 2009 Balzan Prize for Cognitive Neurosciences *for her pioneering studies of the role of the hippocampus in the formation of memory and her identification of different kinds of memory system.*

She will devote the second part of the 2009 Balzan Prize for Cognitive Neurosciences to recruit several post-doctoral fellows from well-established neuroimaging labs. The young researchers will work under her supervision at the Montreal Neurological Institute at McGill University, using functional imaging to explore the issue of hemispheric interaction in cognitive processes, first in healthy volunteers, and possibly later in selected neurosurgical patients. A recent study from Marcus Raichle's lab (1), Washington University in St. Louis School of Medicine, uses functional magnetic resonance imaging to explore changes in resting interhemispheric connectivity after complete section of the corpus callosum in a 6-year old child, thus suggesting a powerful methodological approach.

Brenda Milner's intends to begin her research project with a "brainstorming" session in Montreal, which will be focused on the development of the appropriate experimental paradigms and involve researchers including Marcus Raichle.

Since the early stages of her career, Brenda Milner has worked on delineating the differing and complementary specializations of the left and right cerebral hemispheres of the human brain (2). In particular, in the domain of memory, she has used special tasks with patients undergoing unilateral temporal-lobe removals for the relief of epilepsy to demonstrate material-specific deficits that vary with the side of the lesion.

These laterality effects were even more striking in the case of Sperry's patients tested after cerebral commissurotomy. However, in working with the commissurotomized patients, and comparing their results with those of a matched group of patients in Montreal with intact commissures, it became evident to Brenda Milner and others that each hemisphere acting alone was severely handicapped on memory tasks (3). This excited her interest in further exploring how the two hemispheres work together, both in health and disease. Subsequently, functional imaging studies have shown, for example: increasing bilaterality of involvement in normal healthy subjects as they grow older (4); and increasing involvement of the right hemisphere, as verbal tasks become more demanding. The aim of the research project funded with the second part of her Balzan Prize is to gain a better understanding of the significance of such "recruitment".

References

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Cosmology and Physics, Memory and Emotions Research on the History of Science

Paolo Rossi Monti, Professor emeritus at the University of Florence, was awarded the 2009 Balzan Prize for The History of Science *for his major contributions to the study of the intellectual foundations of science from the Renaissance to the Enlightenment.*

He has set aside half of the Balzan Prize for research that will involve seven young scholars who, after writing brilliant theses, have shown their ability to work well and with continuity thanks to fellowships awarded by Italian academic institutions. Paolo Rossi Monti, who will personally follow their research, has contacted each of the young people and their professors, convincing them that, by offering them the possibility of prolonging the period of their research, they will be able to make significant contributions to Italian and international culture.

Paolo Rossi Monti will be joined by Michele Ciliberto, corresponding member of the Accademia dei Lincei and regular Professor of Modern Philosophy at the Scuola Normale Superiore di Pisa, in following the research on cosmology and physics, while Bernardino Fantini, Director of the Institut d'Histoire de la Médecine et de la Santé at the University of Geneva, will follow the research on the subject of memory and emotions. We estimate that the Balzan research project will conclude in 2011, with a conference to be held at the Accademia Nazionale dei Lincei, which will also serve as the place to monitor the projects and let "external" scholars offer an opinion on work completed. The administration of the fund will be entrusted to the Istituto Nazionale di Studi sul Rinascimento, with headquarters in Florence.

The subject *cosmology and physics in the sixteenth and seventeenth centuries* will be investigated in greater depth with the following pre-established themes: Olivia Catanorchi (*Cosmology and Medicine in the High and Late Renaissance*) will study the interrelations between astronomy, cosmology and medicine, and she will dedicate special attention to the work of Cornelio Gemma, who was known by Campanella and Kepler. The research of Francesca Dell'Omodarme (*Aspects of Aristotelian Physics in the Paduan Lessons of Pietro Pomponazzi)* intends to study Pomponazzi's comments and observations on the argumentation on physics and cosmology in Aristotle's works. Marco Matteoli (*On the Mathematical Foundation of Giordano Bruno's Natural Atomism)* intends to translate the *Articuli centum et sexaginta adversus mathematicos et philosophos* for the first time into Italian (including an extensive introduction and analytical commentary), starting with an in-depth study on Bruno's writings dedicated

to mathematics and geometry. Chiara Petrolini (*Science, Philosophy and Politics in the Venice of Paolo Sarpi)* plans to study the intense intellectual exchange between Venice and England at the beginning of the seventeenth century, and in particular, the physiognomy of the so-called *Sarpi's circle.* This theme of research will be related to the cultural background of *De la Pirotechnia* by Vannuccio Biringuccio. The research of Natacha Fabbri (*The Moon in Fabula, Istoria and Utopia)* intends to identify the main sources (pre-Galileo) defining the Moon as *another Earth* (Proclus, Macrobius, Simplicius, Plutarch) and to delineate the ways it was articulated by Bruno, Patrizi, Kepler and Wilkins.

Resarding *memory* and *emotions*, the following research projects will be dealt with in greater depth, with pre-established themes: Matteo Borri's (*Arts of Memory in the Age of the Neurosciences*) will be an investigation of the historical developments of experimental research and on the theoretical contributions to the theme of memory and neurobiology, as well as techniques for increasing mnemonic power, and maintaining mnemonic functions in the presence of pathologies, thus highlighting the connections between these techniques and the *artes reminiscendi* that enjoyed widespread popularity in Europe between the fifteenth and eighteenth centuries. Another young scholar, Yamina Oudai Celso is investigating the background of Freud's Theory of Emotions (*Psychiatry, Anthropology, and Scientific Psychology from Descartes to the French Enlightenment: Textual Heritage and Theoretical Influx on Freud's Theory of Emotions*).

Figure 1: *The 2009 Prizewinners. From the left: Michael Grätzel, Paolo Rossi Monti, Brenda Milner and Terence Cave.*

Figure 2: *René Dändliker, President of the Swiss Academy of Engineering Sciences, opening the second part of the Forum.*

Figure 3: *Alberto Quadrio Curzio, Member of the Balzan Foundation "Prize" Board, posing a question.*

Figure 4: *Peter Suter, President of the Swiss Academies of Arts and Sciences, in discussion with Brenda Milner and Paolo Rossi Monti.*

Figure 5: *Brenda Milner answering a question (second row, left: Ruth Dreifuss, former Head of the Federal Department of Home Affairs).*

Fig. 2

Fig. 3

Fig. 4

Fig. 5