It’s a privilege to be here today. Doubly so because Professor Jiri Bicak has been a friend and colleague for 40 years – since a time when we were both very young!

There’s one benign change since then. I met Jiri in America. Indeed most scientists of our generation met their counterparts from the rest of Europe in the US – and this was true of those from Western Europe as well as countries the other side of the Iron Curtain. Now there is a vibrant interchange all across Europe – much helped by EU schemes. And in the ‘big sciences’ of particle physics and space science, where economic pressures force all European countriesto cooperate, we have become world-beaters. tAnd this is where academies and learned societies have a role --- and will still more in tomorrow’s world.

But first, a short flashback – to the 17th century. Britain’s academy of sciences, The Royal Society, was founded in 1660. At their regular meetings its Fellows peered through newly-invented microscopes; they heard travellers' tales. They experimented with airpumps, explosions, and poisons. And some meetings were more gruesome. Samuel Pepys recorded in his famous diary a blood transfusion from a sheep to a man - who, amazingly, survived. (Health and safety rules render Royal Society meetings duller these days!)

These men were 'ingenious and curious'. But they were also immersed in the practical agenda of their era - improving navigation, exploring the New World, and rebuilding London after the Great Fire. They were inspired by Francis Bacon - they were, in his phrases, 'merchants of light', but committed also to 'the relief of man's estate'.

And they were ‘international’ right from the start. The Society’s first secretary, Oldenberg, was German, and he founded the first real scientific journal, which had papers from Huygens and other eminent continentals as well as those from Britain itself.

Today's scientists have the same broad motives as these pioneers - the curiosity to probe nature's laws; the delight in ingenious devices; the aim to improve human lives. And their outlook is even more international. But they can't now be polymaths. Research is now professionalised, arcane and technical. There's consequently a communication barrier between scientists and the wider public. -- indeed between different specialisms too. Moreover, scientists are in general too disengaged from politics. That’s why academies that straddle these barriers are more important than ever.

By the way, I'm using the word 'science' in a broad sense to encompass technology and engineering - this is not just to save words, but because they're symbiotically linked. 'Problem solving' motivates us all -whether one is an astronomer probing the remote cosmos, or an engineer facing a down-

to-earth design conundrum. The latter is at least as challenging - a point neatly made by an old cartoon showing two beavers looking up at a hydroelectric dam. One beaver says 'I didn't actually build it, but it's based on my idea'.

Moreover, science isn't just for scientists – it's crucial for an increasing range of careers, but it should impinge on everyone. Today's young people – all of them – will live in a world, ever more dependent on technology, and ever more vulnerable to its failures or misdirection. Society already confronts difficult questions like:

Who should access the 'readout' of our personal genetic code? How will lengthening life-spans affect society? Should we build nuclear power stations - or wind farms - to keep the lights on? Should we plant GM crops? Should the law allow 'designer babies' or cognition enhancing drugs?

Such questions matter to us all: they involve science, but they involve economics, politics and ethics as well – areas where scientists speak as citizens without special expertise. But democratic debates won't rise beyond tabloid slogans unless everyone enough 'feel' for science – and for risk and uncertainty -- to prevent their being bamboozled by propaganda and bad statistics, or over-deferential to experts.

[Scientists routinely bemoan how little the public knows, and grumble about scientific education. But ignorance isn't peculiar to science. It's equally sad if citizens don't know their nation's history, can't speak a second language, and can't find North Korea or Syria on a map -- and many in my country can't. This is an indictment of our schooling in general – I don't think scientists have a special reason to moan. Indeed, I'm gratified and surprised that so many people are interested in dinosaurs, the Hubble Telescope, the Higgs Boson -- all blazingly irrelevant to our day-to-day lives.

And this leads to another reason why science education is important. Scientific insights should be valued for their own sake.

In the 19th century, the ideas of Darwin and the geologists reached a broad public. Today, it's a real intellectual deprivation not to understand our natural environment and the principles that govern the biosphere and climate. And to be blind to the marvellous vision offered by Darwinism and by modern cosmology -- the chain of emergent complexity leading from a 'big bang' to stars, planets, biospheres and human brains able to ponder the wonder and the mystery of it all.

These concepts are highlights of human culture. More than that, science is the one culture that's truly global – protons, proteins and Pythagoras are the same from China to Peru. It should transcend all barriers of nationality. (And,

by the way, it should straddle all faiths too. The scientists who attack mainstream religion, rather than striving for peaceful coexistence with it, damage science, and also weaken the alliance against fundamentalism and fanaticism.).

[It's important that everyone realizes how much scientists still don't know – how patchy our current understanding is. And that commonplace phenomena are often the most perplexing. It may seem odd that astronomers can speak confidently about galaxies billions of lightyears away, whereas the gurus who pronounce on everyday matters like diet and childcare, change their advice from year to year. But it isn't really so odd. What makes things hard to understand isn't how big they are, it's how complex they are. It's harder to forecast the weather than to predict eclipses. An insect, with its layer upon layer of intricate structure, is far more complex than a star. Human beings and their interactions are far more complex still.]

What breakthroughs can we expect? In my own subject of astronomy there's much excitement – for instance, retinues of planets orbiting other stars – discovered by a spacecraft fittingly named after Kepler.

I'll have a chance to say more about this in another talk this afternoon

So much for science as culture. What kind of world will today's young people be living in by mid-century? One of the few things we can predict is that they'll be in a more crowded world. Fifty years ago, world population was below 3 billion. It now exceeds 7 billion.. And by 2050 it's projected to be between 8.5 and 10 billion, the growth being mainly in the developing world, And the world's intellectual and physical capital will shift to Asia -- the end of 400 years of hegemony by Europe and North America.

As well as being more crowded, the world will have a changed climate and that will add to the pressures.

But despite all this, Brian Heap will discuss how 9 billion needn't face starvation. Modern agriculture – low-till, water-conserving, and perhaps involving GM crops – together with better engineering to reduce waste, improve irrigation, and so forth, could sustainably feed that number by mid-century And other advances, especially in healthcare and information technology, offer grounds for hope .

And we can predict something else. There'll be a growing gap between what science allows us to do, and what it's prudent or ethical actually to do. Technology will offer amazing prospects but will opens up new threats and poses new ethical dilemmas.

Our world is getting more interconnected. We depend on elaborate networks: electric power grids, air traffic control, international finance, just-in-time delivery and so forth. Unless these are highly resilient, their manifest benefits could be outweighed by catastrophic (albeit rare) breakdowns cascading through the system. Pandemics could spread at the speed of jet aircraft, causing maximal havoc in the shambolic but burgeoning magacities of the developing world. Social media could spread psychic contagion – rumours and panic – literally at the speed of light.

Malign or foolhardy individuals or small groups have far more power and leverage than in the past. Concern about cyber-attack, by criminals or by hostile nations, is rising sharply. Advances in biotech , likewise, offer huge potential for medicine and agriculture -- but they amplify the risk of bioerror ot bioterror. Recently some researchers who'd shown that it was surprisingly easy to make an influenza virus both virulent and transmissible were pressured to redact some details of their publication. And the US government has stopped finding these so-called 'gain of function' experiments. Even more recently there's been controversy about CRISPR experiments done by Chinese scientists on human embryos. These are just portents foreshadowing the ethical and prudential issues that will face us in future.

And this is something I worry about – we need regulation, and 'responsible innovation'. But can we enforce this -- in the 1970s there were some precedents, but the field is more global – more subject to commercial pressures. So regulations may be as impossible to enforce as the drug laws. And that's scary.

And such concerns may arise not just in biotech but in another fast-advancing technology: robotics and machine intelligence

We're plainly witnessing momentous advances in the power of machines to learn, to communicate, and to interact with us.

Computers don't learn like we do: they use 'brute force' methods. They learn to identify dogs, cats and human faces by 'crunching' through millions of images – not the way a baby learns. They learn to translate from foreign languages by reading multilingual versions of millions of pages of (for example) EU documents (they never get bored!).

There's been exciting advances in what's called generalized machine learning – Deep Mind (the small London company that Google recently bought for 500 million dollars) created a machine that can figure out the rules of all the old Atari games without being told, and then play them better than humans.

Advances in sensors and motor-skills have been slower. Robots are still

clumsy compared to a child in moving pieces on a real chessboard. They can't tie your shoelaces or cut your toenails. But sensor technology, speech recognition, information searches and so forth are advancing apace.

Robots will take over an ever-wider range of jobs – not just manual work (indeed jobs like plumbing and gardening will be among the hardest to automate), but clerical jobs, routine legal work, and medical diagnostics and operations. And the big question is this: Will the robotics be like earlier disruptive technologies – the car, for instance – which created as many jobs as it destroyed? Or is it really different this time?

And what about the use of 'dumb' autonomous robots -- and drones --by the military? Can they be trusted to seek out a targeted individual via facial recogntion, and decide whether to fire their weapon? Who has the moral responsibility then?

That's a near-term concern. But, looking further ahead,
how can we ensure that ever more sophisticated computers remain docile 'idiots savant' and don't 'go rogue'? If they could infiltrate the internet – and the internet of things – they could manipulate the rest of the world.

Experts disagree on how long it will take before machines achieve general-purpose human level intelligence. Some say 25 years. Others say 'never'. The median guess in a recent survey was about 50 years

Some of those with the strongest credentials in AI think the field already needs guidelines – just as biotech does.

Finally, a few thoughts about the obligations of scientists (and engineers) when their investigations have potential social, economic and ethical impacts that concern all citizens.

It's important to keep 'clear water' between science and policy. Risk assessment should be separate from risk management. Scientists should present policy options based on a consensus of expert opinion; but if they engage in advocacy they should recognise that on the economic, social and ethical aspects of any policy they speak as citizens and not as experts – and will have a variety of views. The decisions should be made democratically. Sometimes this has happened, and constructively too. In the UK, a dialogue with parliamentarians led, despite divergent ethical stances, to a generally-admired legal framework on embryos and stem cells -- a contrast to what

happened in the US. But we've had failures too: the GM crop debate was left too late -- to a time when opinion was already polarised between eco-campaigners on the one side and commercial interests on the other.
Scientists have a special responsibility to engage – though they should accept that on the economic, social and ethical aspects of any policy they speak as citizens and not as experts.

There were fine examplars among the atomic scientists who developed the first nuclear weapons during World War II. Fate had assigned them a pivotal role in history. Many of them --- men such as Jo Rotblat, Hans Bethe, and Rudolf Peierls -- returned with relief to peacetime academic pursuits. But the ivory tower wasn't, for them, a sanctuary. They continued not just as academics but as engaged citizens --- promoting efforts to control the power they had helped unleash.

Scientists have a special responsibility to engage. You would be a poor parent if you didn't care what happened to your children in adulthood, even though you may have little control over them. Likewise, scientists shouldn't be indifferent to the fruits of their ideas – their creations. They should try to foster benign spin-offs – commercial or otherwise. They should resist, so far as they can, dubious or threatening applications of their work.

A special obligation lies on those in academia, and on those who are self-employed entrepreneurs – these groups have more freedom to engage in public debate than employees of government or industry.

Nations may need to merge more sovereignty in new organizations along the lines of IAEA, WHO, etc.

The biggest challenge, of course, is that most of the important issues facing the world are global and long term. We need to act internationally (for instance, whether or not a pandemic gets global grip may hinge, for instance, on how quickly a Vietnamese poultry farmer can report any strange sickness.) And many of them – energy and climate change, for instance, involve multi-decade timescales – plainly far outside the 'comfort zone' of most politicians. For instance, in the long-run maybe all Europe could depend on solar energy, but this would require a continent wide DC grid. A huge infratructure project but no bigger than the construction of European railways in the 19th century.
In contrast, politicians look to their own voters – and the next election. Stockholders expect a pay-off in the short run. We downplay what's happening even now in far-away countries. – even the moral imperative to improve the lot of today's 'bottom billion'. And we discount too heavily the problems we'll leave for new generations.

["Space-ship Earth" is hurtling through the void. Its passengers are anxious and fractious. Their life-support system is vulnerable to disruption and break-downs. But there is too little planning, too little horizon-scanning. Without a broader perspective – without realizing that we're all on this crowded world together – governments won't properly prioritise projects that are long-term in a political perspectives, even if a mere instant in the history of our planet.

Unlike our 17th century forebears who I cited at the beginning of this talk, we know a great deal about our world – and indeed about what lies beyond. Technologies that our ancestors couldn't have conceived enrich our lives and our understanding. Many phenomena still make us fearful, but the advance of science spares us from irrational dread. We know that we are stewards of a precious 'pale blue dot' in a vast cosmos – a planet with a future measured in billions of years, whose fate depends on humanity's collective actions. ]

We need a change in priorities and perspective -- and soon – if we are to navigate the challenges of the 21st century: to share the benefits of globalization, to prioritise clean energy, and sustainable agriculture; and to handle the Promethian challenge posed by ever more powerful technology.

We'll need the idealistic and effective efforts of natural scientists, environmentalists, social scientists and humanists. They must be guided by the insights that science will offer, but inspired by values that science itself can't provide.

And I give the last word to a great scientist – the biologist Peter Medawar:

"The bells that toll for mankind are ..... like the bells of Alpine cattle. They are attached to our own necks, and it must be our fault if they do not make a tuneful and melodious sound."