POPULAR SCIENCE COMMUNICATION

TALENT WORKSHOP

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Communicating science,
especially physics:

should it be done?

Victor Weisskopf, *Physics in the 20th Century*

"More concerted and systematic effort toward presentation and popularization of science would be helpful in many respects … it would make science a more integral part of our culture today.

Much more could and should be done to bring the fundamental ideas to the intelligent layman. Popularization of science should be one of the prime duties of a scientist."

" … it is beneficial to the scientist to attempt seriously to explain scientific work to a layman or even to a scientist in another field. Usually, if one cannot explain one's work to an outsider, one has not really understood it."

"Communicating" physics

What are the aims?

- to raise awareness of physics
- to encourage appreciation of physics
- to increase understanding of physics

What are the problems?

Mathematics is the natural language of physics

$$E = mc^2$$

$$s = ut + ft^2/2$$

$$\gamma = (1-\beta^2)^{-1/2}$$

If people other than physicists are to gain access to the knowledge base of physics - and also to its excitement and beauty - then physics must be presented not through mathematics but through the normal languages of the written (and spoken) word.

This is the art of communicating physics

Communicating science,

especially physics:

Can it be done?

W.H.Auden, *The Dyer's Hand*

"When I find myself in the company of scientists, I feel like a shabby curate who has strayed by mistake into a drawing-room full of dukes.

The true men of action in our time, those who transform the world, are not the politicians and statesmen, but the scientists. Unfortunately, poetry cannot celebrate them, because their deeds are concerned with things, not persons and are, therefore, speechless."

Richard Feynman, *Feynman Lectures in Physics, vol I*

"Poets say science takes away the beauty of the stars – mere globs of gas atoms. Nothing is 'mere'. I too can see the stars on a desert night, and feel them. But do I see less or more? The vastness of the heavens stretches my imagination … my little eye can catch one-million-year-old light … Far more marvellous is the truth than any artists of the past imagined! Why do the poets of the present not speak of it?"

Communicating science,
especially physics:

from fundamental questions
to everyday life

→ a key message

What is physics?

Why is the sky blue?

How does an aeroplane fly?

What are we made of?

Where did matter originate?

The *Oxford Shorter English Dictionary* says that physics is:

"The branch of science that deals with the nature and properties of matter and energy, in so far as they are not dealt with by chemistry or biology."

Heat, light, sound, electricity, magnetism, gravity, radioactivity: all these are natural phenomena that the physicist seeks to understand.

Radio, television, microchips, lasers: all these are technologies developed from the physicist's curiosity to discover more about how things work.

Why care about physics?

- **It is a science of everyday life.**
- **It is a fundamental science.**
- **It underlies much modern technology and instrumentation.**
- **It is a useful science.**

Medical physics	Artificial Intelligence
Health and safety	Laser technology
Geophysics	Alternative energy
Meteorology	Enviromental physics
Communications	Pollution control ,
Forensic science	Aerospace
Metallurgy	Optics
Hydrology	Defence
Non-destructive testing	Microelectronics

"I know well the impression [my apparatus] made on the average spectator, for I have been occupied in experiments of this kind nearly all my life, notwithstanding the advice, given in perfect good faith, by non-scientific visitors to the laboratory, **to put that aside and spend my time on something <u>useful</u>.** "

From a speech by Sir J.J.Thomson in 1916 on behalf of the Conjoint Board of Scientific Studies, to Lord Crew, Lord President of the Council.

J.J.Thomson discovered the electron in 1897, while investigating the flow of electricity through gases. One hundred years later, this discovery underpins much of the technolgy of the modern age.

Why is communicating physics difficult?

Mathematics is the subject's basic language

$$\gamma = (1-\beta^2)^{-1/2}$$

Common words have specific use

Power

Energy

Force

It deals with the invisible

Forces

Electric charge

Atoms

It defies common sense!

Quantum mechanics

Relativity

Communicating science

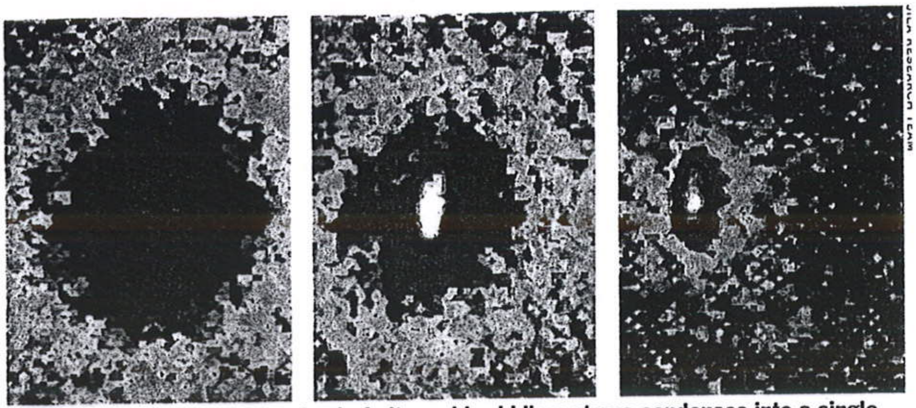
Rule 1:

know your story →

select a key "takehome" idea

→ your "headline"

TIME magazine



"superatom"

SUPERATOM: The core of a cloud of ultra-cold rubidium atoms condenses into a single, dense "particle" (white spot, center), then evaporates (right) in a fraction of a second

■ SCIENCE

Einstein Strikes Again

key messages →

Seventy years after he predicted its existence, a new form of matter is created in a Colorado lab

By MICHAEL D. LEMONICK

FOR THREE DAYS ERIC CORNELL KEPT rechecking his computer, not quite willing to believe what his eyes and his instruments were telling him. There on the screen was a dense knot of *something* that had appeared in a cloud of rubidium atoms. Finally, Cornell had to acknowledge that it could mean only one thing: he and his colleagues had created a new form of matter, predicted by Albert Einstein more than 70 years ago but never before seen on earth. Called a Bose-Einstein condensate, it is a kind of "superatom," in which individual atoms lose their separate identities and merge into a single entity.

key physics

When Cornell and fellow physicists at the JILA laboratory (formerly the Joint Institute for Laboratory Astrophysics) in Boulder, Colorado, announced their achievement in *Science* last week, their colleagues around the world were quick to cheer. "The term Holy Grail seems quite appropriate, given the singular importance of this discovery," wrote Oxford physicist Keith Burnett in a commentary that accompanied the report.

The physicists' excitement comes partly from the intellectual pleasure of seeing an important scientific loose end tied up at last. When Einstein first suggested the idea of BEC back in the 1920s, building on the work of the Indian physicist Satyendra Nath Bose, quantum mechanics was a new and controversial field. Among its stranger assertions—long since confirmed—was that atoms and other elementary particles can also be thought of as waves. The waves are really waves of probability, which describe where an atom is most likely to be at a given moment (Heisenberg's uncertainty principle dictates that you can never say precisely where an atom actually is).

strange but true: wave-particle duality

Einstein argued that as atoms approach absolute zero (-273.15°C), the waves expand and finally overlap; the atoms merge into a single "quantum state." It's extraordinarily difficult to get them to 180 billionths of a degree above absolute zero, though—the point at which the merging occurs. Thus the Boulder group's feat was a technical as well as a scientific one.

Awe: extremes

technical feat

They started by barraging their rubidium atoms with lasers, slowing them to a crawl (heat is really just the motion of atoms and molecules; slowing therefore equals cooling). Then they put the atoms in a magnetic "bottle" that allowed the faster-moving, more energetic atoms to escape; those left behind were cooler. Finally, in a leap of ingenuity that enabled this scientific team to outflank its rivals, the Boulder scientists rotated the magnetic field so that the few cold atoms that were leaking through a weak point in the bottle couldn't find this one escape route.

Does any of this have any practical use? Perhaps. Beams of BEC atoms might be used to inscribe exquisitely small circuits onto the ultra-compact electronic chips. The atoms might also be put to work in ultra-precise atomic clocks. So far, the list of applications is not very long. But, says Oxford's Burnett, "it's like the beginnings of laser technology. It's a solution in search of a problem." Given the thousands of ways lasers are used today, that sounds pretty promising.—***Reported by J. Madeleine Nash/Chicago***

Practical uses? perhaps

THE GUARDIAN 14 MAY 1998

Science and technology

The mother of all sums

Is Nature simply a mathematical whim? **Tim Radford** reports on a model answer

SCIENTISTS are using mathematics to predict what the world's biggest machine is likely to find as it probes the first moments of the Universe. Ben Allanach of the Rutherford Appleton Laboratory in Oxfordshire and his colleague Steve Abel of Cern, the European centre for particle physics research at Geneva, have been playing with the parameters of the "Big Bang" to propose the masses of some 20 particles that ought to have existed within the first second of time, if standard theories are correct.

The oddity is that they have used something with no physical existence — mathematics — to give shape to things that could exist only for small fractions of a second.

Here is the problem: the large electron positron (LEP) collider at Cern whizzes matter and antimatter round a vast underground tunnel at almost the speed of light, and then stages a head-on collision. At any time, there are roughly a thousand billion bits of matter in the machine, hitting each other at a million times a second.

In the intense energies of collision, there should be echoes of conditions in the very early Universe. But there is a bewildering firework display to be studied every millionth of a second and, somewhere in the exquisite pattern of pyrotechnics, there could be the so-far undiscovered particles — ghosts that take shape only in the most extreme energies — that physicists need to find to confirm whether their theories of creation make sense in the first place.

The hunt for these precursors of modern matter will accelerate in the next two or three years. The catch is that in order to find them, the experimenters have to know roughly what they are looking for. The mystery is that mathematics can tell them. Allanach and Abel took the logic of the standard interpretation and began "twiddling" the knobs: they played with the parameters of the field, mass and energy, in the unusual conditions of the birth of a Universe to arrive at a series of limits.

It's amazing that we can describe physical reality so simply

"What we are doing is making their job easier. It could be that we are wrong, and that things are more complicated. But they have got something solid to shoot at," says Allanach. "It's amazing that we can describe physical reality. The theories we make are so simple. You'd expect them to be massive and really complicated with thousands and thousands of knobs. But in the end it does turn out to be very simple."

Einstein once observed that the most incomprehensible thing about the Universe was that it was comprehensible. Mathematicians too, are sometimes astonished by the way the world seems always to have conformed to the equations they have lately devised.

Allanach adds: "There is a suspicion that maybe all we are doing is finding a mathematical description for what reality is, rather than something more fundamental — discovering the mathematics that is already in Nature. There is a subtle difference between the two, and some overlap as well. But I find it hard to believe that we are only cobbling together from description.

"These very simple theories have worked so well, and been tested so thoroughly, that I would go out on a limb and say that we are discovering that there is some fundamental meaning in mathematics that it can describe all this stuff so well."

SCIENTISTS are using mathematics to predict what the world's biggest machine is likely to find as it probes the first moments of the Universe. Ben Allanach of the Rutherford Appleton Laboratory in Oxfordshire and his colleague Steve Abel of Cern, the European centre for particle physics research at Geneva, have been playing with the parameters of the "Big Bang" to propose the masses of some 20 particles that ought to have existed within the first second of time, if standard theories are correct.

The oddity is that they have used something with no physical existence — mathematics — to give shape to things that could exist only for small fractions of a second.

• using maths to probe very early Universe

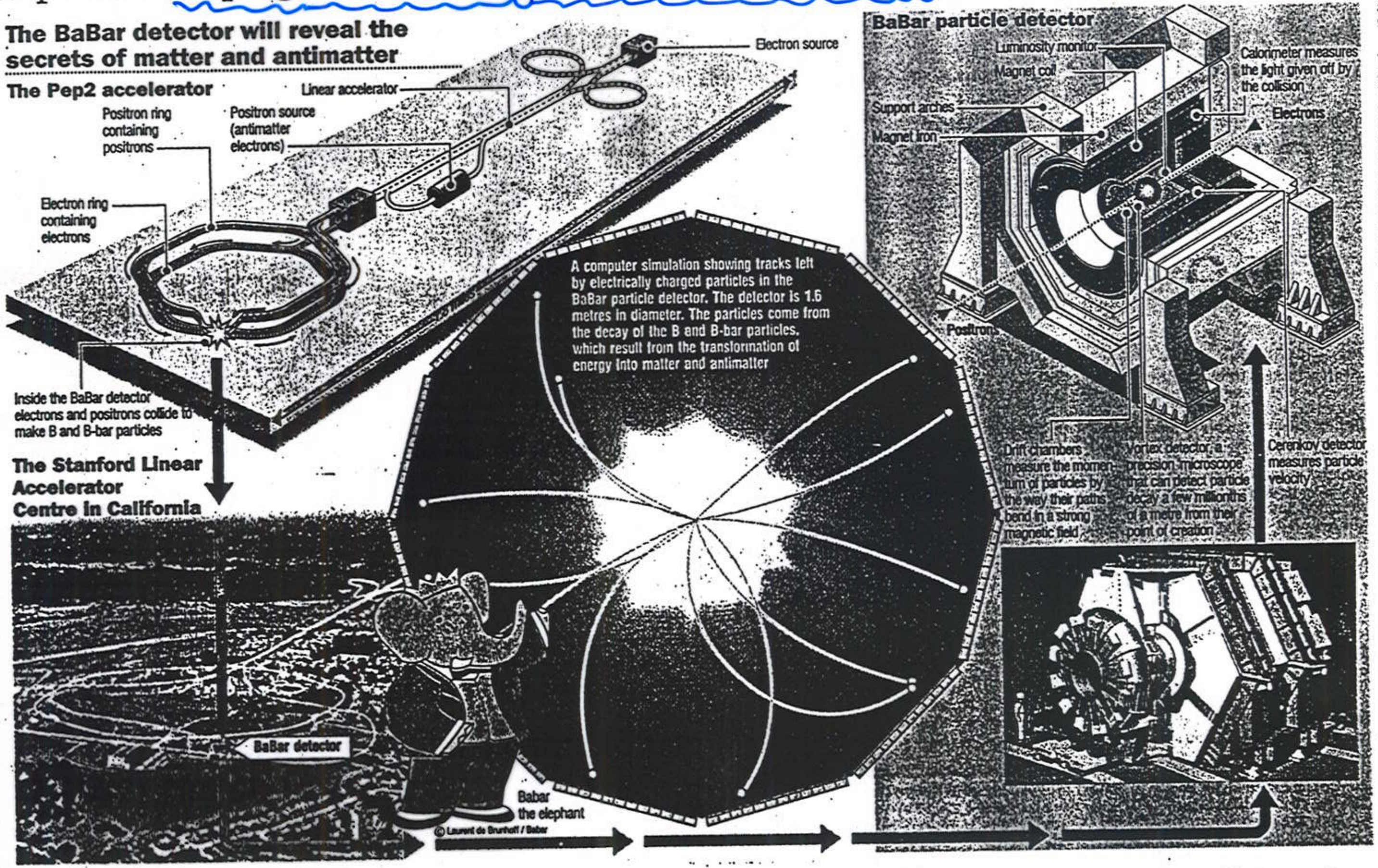
BaBar →

The Daily Telegraph

19 May 1999

A storybook elephant is helping British scientists to explain the universe. Science Editor **Roger Highfield** reports

We shouldn't even exist



ON THE other side of the planet, a 500-strong team is struggling to launch a £186 million experiment to tackle a question that has bothered physicists for years: what is the matter with the universe?

To be more specific, they want to know why there is enough matter to build planets, stars, galaxies and much more besides. As an example, each reader of this article consists of around 50 billion billion billion protons. But, according to the standard picture of physics, we should not exist at all.

Physicists calculate that equal quantities of matter and "antimatter" were created in the Big Bang some 15 billion years ago. When matter and antimatter met, as anyone who watches *Star Trek* knows, they should have disappeared to form pure energy. This process of annihilation did occur, because today's universe is awash with this energy — called the cosmic microwave background radiation. But why has all the antimatter disappeared and yet huge amounts of matter remain around us and within us?

To find out why matter has an edge over antimatter, scientists from 10 British institutions, backed by the Particle Physics and Astronomy Research Council, are toiling night and day to prepare a new experiment at the Stanford Linear Accelerator Centre, Slac, in California.

The origins of the experiment date back to 1928, when the British physicist Paul Dirac predicted that antimatter can exist. Each particle has a corresponding antiparticle which is equal in mass but opposite in other respects, such as charge. That is why they annihilate each other if they come into contact, for instance when antimatter is made artificially in an accelerator.

Then the physicist Andrei Sakharov speculated three decades ago that a preference for matter must have arisen a fraction of a second after the Big Bang. To create our lop-sided universe there needed to be only a tiny imbalance, with as little as one extra particle of matter surviving out of every billion created in the primordial inferno.

To investigate whether antimatter really does behave differently from matter, 10 countries have joined forces at Slac to use "BaBar", a 1,200 ton detector that gets its name from the storybook elephant and the B particles (matter) and B-bar particles (antimatter) it will study. B-bar is normally written by physicists as a letter B with a bar on top.

By using BaBar "we hope to see the tiny differences in behaviour between matter and antimatter which will explain the huge imbalance in the Universe," said Prof Ken Peach of the Rutherford Appleton Laboratory, Oxfordshire.

"Until today we haven't been able to create enough particles to see this effect, or had detectors able to record sufficient detail," he said. "BaBar offers us a fantastic opportunity to take a huge step forward in our understanding of our Universe."

To supply BaBar with the swarm of particles, the team upgraded an existing particle accelerator. The result, Pep II, creates millions of Bs and B-bars by making electrons collide with their antimatter counterparts, positrons.

Because the particles exist for only one thousand-billionth of a second, BaBar is fantastically complex, consisting of detectors arranged in layers around its axis. More than 50 Britons were involved in its development, contributing £8 million worth of British components, said Prof Michael Green of Royal Holloway College, London. For BaBar's "calorimeter", for example, Hilger Crystals in Margate made 1,000 detectors, brick-sized caesium iodide crystals that give off green flashes when particles hit them.

To test BaBar, the team recorded the rain of cosmic rays that constantly bombard the Earth. Impacts were seen as trails of energy in its tracking chamber and calorimeter.

Then came the tricky part: marrying BaBar to the Pep II accelerator. Last week, these efforts came to a head, not least because Prof Green and his colleagues want to beat a rival "B factory" being made ready at the High Energy Accelerator Research Organisation near Tokyo.

"The first days with a new accelerator are like taming a wild beast," commented Dr Adrian McKemey, a Slac visiting professor from Brunel University in London.

"The levels of radiation are quite severe," he said. "The detector we've built is like a high-performance sports car. We all feel very proud and protective, but we're about to beat the living daylights out of it by taking it off road."

The first tests, using a beam of electrons, took place last Tuesday. "BaBar's control room was buzzing with physicists anxiously making checks to monitor the readiness of their detectors, and fussing over software to read out the signals from the electronics," said Dr John Fry, a Slac visiting professor from Liverpool University.

"Although the first electrons into Pep II had not been promised until after midnight, 30 excited men and women were redoubling their efforts throughout the evening to make sure that BaBar was ready," he said.

In the first trials, the electrons only came one third the way round Pep II, smashing into a block of steel 35 metres from BaBar. It would take some days before physicists would attempt to steer them through BaBar and around the ring, and perhaps two weeks before counter-rotating beams of electrons and positrons would collide inside BaBar, when the experiment would start routinely.

In the small hours of last Wednesday, BaBar and Pep II control rooms discussed safety protocols to ensure that the bursts of radiation expected from the electrons crashing into the steel would not blind any of BaBar's detectors. Then the electron beam struck.

All that was active in BaBar was its calorimeter, along with a detector for Cerenkov radiation (given off when particles outstrip light, which travels more slowly through the detector). "There were gasps as monitors showed the hit patterns in the calorimeter and Cerenkov detector: both lit up like Christmas trees as the debris from the stopped electrons ploughed into them," said Dr Fry.

"The data acquisition system was not designed to handle such vast amounts of data from the Cerenkov detector, however, and couldn't cope," he said. Experts were dragged out of bed to stem the data deluge. "All thoughts of champagne were forgotten as everyone got stuck into solving their problems. By 6am data was being recorded from all bar one detector."

THE British team was now in high spirits. "How can it work so well?" laughed Dr Jordan Nash of Imperial College, who designed the calorimeter with Dr Fry.

When the day shift arrived at 8am last Wednesday, no one expressed any surprise at the momentous events of the previous night. "Recording data, analysing and displaying it, were now routine — happily for BaBar," said Dr Fry. By the end of that day, electrons were were being steered through BaBar.

"Now all we need is to hit the antimatter beam coming the other way," said Dr McKemey. "When the beams collide, we'll see a very unusual recreation of 'Beauty' particles — that died out about 10 thousand million years ago ... we are all just waiting for the unique signature to find beauty in this beast." The first collisions are expected today.

The race to operate BaBar is urged on by more than just the chance to be the first to get a clearer picture of the birth of matter in our Universe. With luck, these experiments will also endanger the Standard Model, the theoretical edifice used by physicists to describe nature's fundamental forces and particles. The Standard Model falls woefully short of explaining the Universe's preponderance of matter, predicting around a million million times fewer protons than we see today. Whoever can show why could win a Nobel prize.

Communicating science

Rule 2:

Know your audience

Who might want to know about physics
- and where might they find out?

Specialists - other scientists, educators, students, who will read:

- specialist magazines (eg *Physics Today*)
- general science magazines (eg *Nature*, *Scientific American*)

Decision makers - politicians, media controllers, opinion formers, people in business and commerce, who will find out about physics from:

- technical and business magazines (eg *Computer Weekly*)
- newspapers, general magazines
- TV and radio

The general public - includes voters, tax payers and young people, who might find out about physics from:

- newspapers, general magazines
- TV and radio

These categories involve readers with a wide range of sophistication

To communicate effectively we must reach them all

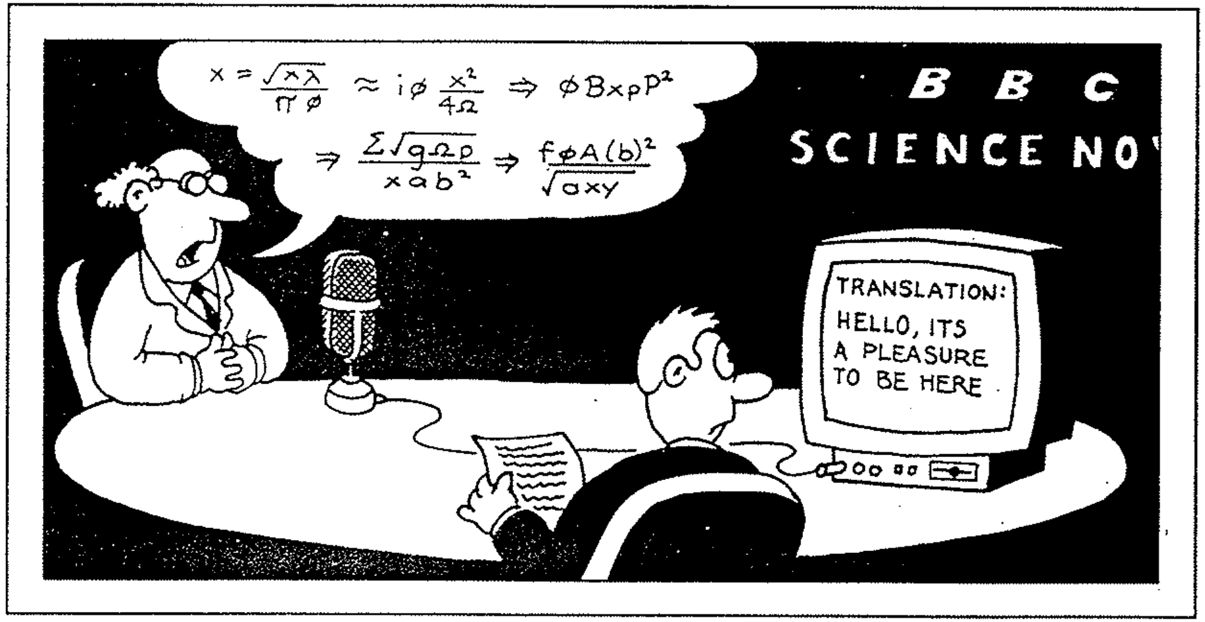
“I have written for one who is willing to puzzle through some detailed arguments, but who is not at home in either mathematics or physics. ... I picture the reader as a smart old attorney who does not speak *my* language, but who expects nonetheless to hear some convincing arguments before he makes up his mind.”

Steven Weinberg in the introduction to “The First Three Minutes”

Communicating Science

Rule 3:

Avoid jargon at all costs


BBC
SCIENCE NO
TRANSLATION:
HELLO, ITS A PLEASURE TO BE HERE

Victor Weisskopf, *Physics in the 20th Century*

"A lucid and impressive presentation of some aspect of modern science is worth more than a piece of so-called original research of the type found in many Ph.D. theses, and it may require more maturity and inventiveness."

CAVEAT !

Many "popular" expositions of science achieve apparent simplicity only by describing something different, something considerably distorted from what they claim to be describing. Respect for our subject did not permit us to do this. Through many hours of discussion, we have tried to achieve maximum clarity and simplicity without compromise by distortion of the truth.

RICHARD FEYNMAN

"QED"

What makes for good communication?

Know your story

- what is your aim? what are you trying to convey?
- organise a structure with beginning, middle and end

Know your audience

- do not patronise or condescend

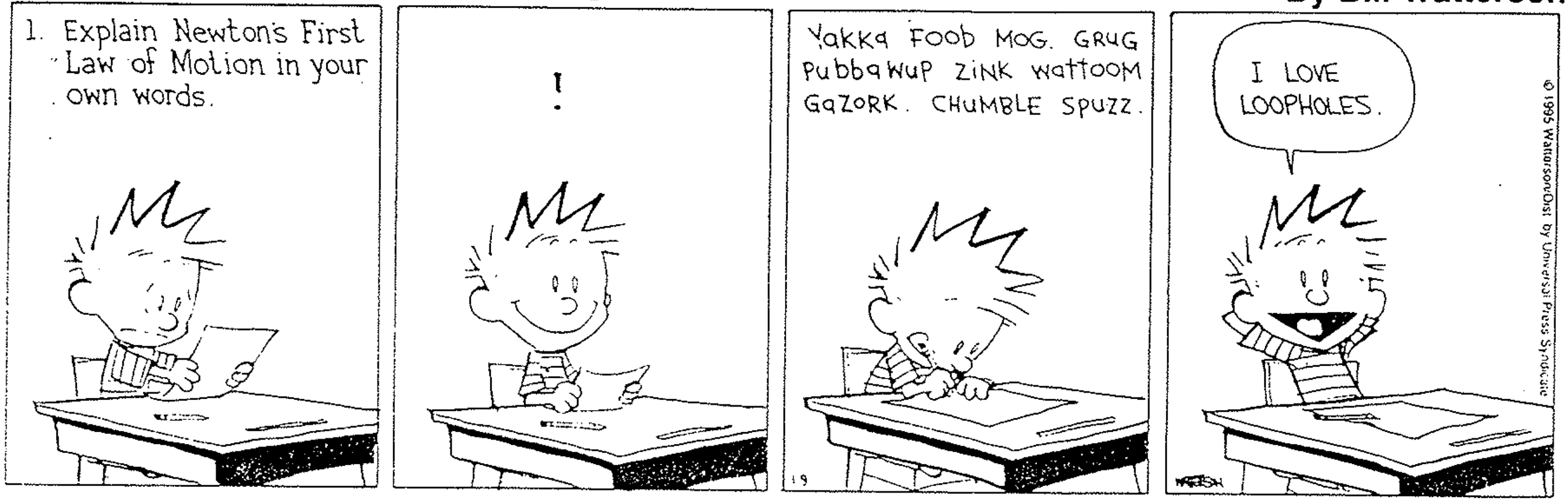
Avoid jargon at all costs

- this tests what you understand!

Use plenty of "signposts"

- remind the reader of unfamiliar concepts

THE BEST OF CALVIN AND HOBBES **By Bill Watterson**



Communicating science

Rule 4:

Use plenty of signposts

You are taking people on an incredible journey!

Finally, the universe was filled with light. This does not have to be treated separately from the particles—the quantum theory tells us that light consists of particles of zero mass and zero electrical charge known as photons. (Each time an atom in the filament of a light bulb changes from a state of higher energy to one of lower energy, one photon is emitted. There are so many photons coming out of a light bulb that they seem to blend together in a continuous stream of light, but a photoelectric cell can count individual photons, one by one.) Every photon carries a definite amount of energy and momentum depending on the wavelength of the light. To describe the light that filled the early universe, we can say that the number and the average energy of the photons was about the same as for electrons or positrons or neutrinos.

Chapter I, p6 (not listed in the index!)

It will be very helpful here if we now give up the classical picture of radiation in terms of electromagnetic waves that we have been using up to this point, and adopt instead the more modern "quantum" view that radiation consists of particles, known as *photons*. An ordinary light wave contains a huge number of photons traveling along together, but if we were to measure the energy carried by the train of waves very precisely, we would find that it is always some multiple of a definite quantity, which we identify as the energy of a single photon.

Chapter III, p53

During the radiation-dominated era there was not only the same enormous number of photons per nuclear particle that exists now, but the energy of the individual photons was sufficiently high so that most of the energy of the universe was in the form of radiation, not mass. (Recall that photons are the massless particles, or "quanta," of which light, according to the quantum theory, is composed.)

Chapter IV, p78

Steven Weinberg, "The first three minutes"

Communicating science:

is it worth it?

It occurs to me that, by attempting to gaze into an exotic, opposite universe of antimatter, I have at least sharpened my mental image of this workaday world. I may still have only a little learning. But if Frank Close is right, and we are all but a tenth of the way along the path of knowledge, then where's the shame in that? In the face of such a journey, the cultural gulf that separates scientists from non-scientists shrinks into relative insignificance. We are all beginners together.

David Newnham
"The meaning of antimatter"
The Guardian Weekend, 20.4.96

"Great triumphs of science are also true advances of the human spirit"

Dudley Moore on "The Muppet Show"

"The effort to understand the Universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy"

Steven Weinberg in "The First Three Minutes"