



Citizens, Science and Science for Citizens

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18th Century: Romantic Poetry, Art and Science Co-mingled

Erasmus Darwin in *The Loves of the Plants* 1789 on ballooning

The calm Philosopher in ether sails,
Views broader stars and breathes in purer gales;
Sees like a map in many a waving line,
Round earth's blue plains her lucid waters shine;
Sees at his feet the forky lightning glow
And hears innocuous thunder roar below.

There's something in a flying Horse,
There's something in a huge Balloon:
But through the Clouds I'll never float
Unitil I have a little Boat
Shaped like the crescent-Moon



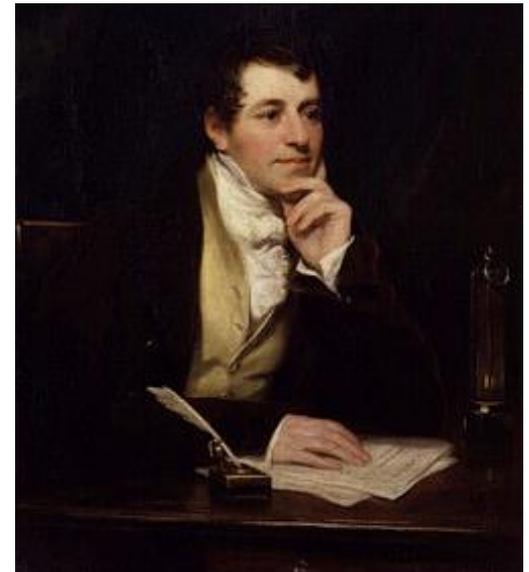
Joseph Wright of Derby: *An Experiment on a Bird in an Air Pump*, 1768

Wordsworth also on Ballooning in *Peter Bell* 1798

Away we go! – and what care we
For treason, tumults and for wars?
We are as calm in our Delight
As is the crescent Moon so bright
Among the Scattered Stars

Revolutionary Science

- Think of 'citizens' and the French Revolution may come to mind.
- Erasmus Darwin's reputation suffered at the end of his life because he spoke in favour of the French Revolution.
- His own poetry was lampooned .
- Likewise, Joseph Priestley, discoverer of oxygen (at least in part) and a dissenting priest, who loudly backed the Revolution was mobbed, his house fired and he eventually was driven out of the UK, living his last years in the US.
- At the start of the 19th century, scientists like Humphry Davy worked hard to eradicate this image of scientist as revolutionary.



Davy and the Royal Institution

- Davy worked hard to make science both accessible and 'safe' so that it had no connections with revolution (as much of the work on gases was perceived to have been, both through Priestley and Lavoisier).
- His talks were, however, designed to be showcases for spectacular science.
- People – men and women – flocked to see him at the new Royal Institution.
- He was popular, idolised by women and made science seem accessible through his public lectures
- But it was around this time that science and 'art' began to part company



Gilray cartoon: Davy, with the bellows, giving a lecture on 'pneumatics'

Huxley- Arnold arguments (1880's)

Thomas H. Huxley 1880

From the time that the first suggestion to introduce physical science into ordinary education was timidly whispered, until now, the advocates of scientific education have met with opposition of two kinds. On the one hand, they have been pooh-poohed by the men of business who pride themselves on being the representatives of practicality; while, on the other hand, they have been excommunicated by the classical scholars, in their capacity of Levites in charge of the ark of culture and monopolists of liberal education.

Matthew Arnold 1883

....and that, while we shall all have to acquaint ourselves with the great results reached by modern science, and to give ourselves as much training in its disciplines as we can conveniently carry, yet the majority of men will always require humane letters; and so much the more, as they have the more and the greater results of science to relate to the need in man for conduct, and to the need in him for beauty.....

There is, therefore, really no question between Professor Huxley and me as to whether knowing the great results of the modern scientific study of nature is not required as a part of our culture, as well as knowing the products of literature and art.

Class, Religion and Culture

- Matthew Arnold, son of Thomas Arnold who turned Rugby School around, thought of culture as
 - *The best which has been thought and said in the world' conducive to 'to make all men live in an atmosphere of sweetness and light'*
- Huxley was essentially an atheist and many others of their time were non-conformists of one type or another and (necessarily) educated outside Oxbridge.
- My distant relative EB Tylor, founder of the discipline of cultural anthropology in the 1870s, was a Quaker and travelled around the world, seeing cultures (as we would use the term) in many different places.
- He introduced the idea that customs and beliefs belonged to culture just as much as literature and philosophy, so changing the emphasis away from the Arnold 'ideal'.
- Furthermore, as another heated debate of the time made clear, with ideas of evolution gaining acceptance, traditional biblical teaching was being overturned.

21st century – Debate continues

Lawrence Summers, 2001 inaugural address as president of Harvard

We live in a society, and dare I say a university, where few would admit — and none would admit proudly — to not having read any plays by Shakespeare. It is all too common and all too acceptable not to know a gene from a chromosome.

Evan Harris 2010

There is a perception that science is different from other cultural or intellectual pursuits. Unlike sport, art or music, it's harder for anyone to 'have a go' at science.

Michael Gove

People in this country have had enough of experts.

This last remark was explicitly directed at economists but sends shudders through academic corridors as, of course, does 'post-truth' Trump.

Lack of Creativity?

Recall Carlyle: The Progress of Science...is to destroy wonder, and in its stead substitute Mensuration and Numeration.

Or more recently, **Goldworthy Lowes Dickinson**, historian and fellow of Kings College, Cambridge

‘When science arrives, it expels literature’ (1931).

The novelist **Lucy Ellman** (2010):

The purpose of artists is to ask the right questions, even if we don’t find the answers, whereas the aim of science is to prove some dumb point.

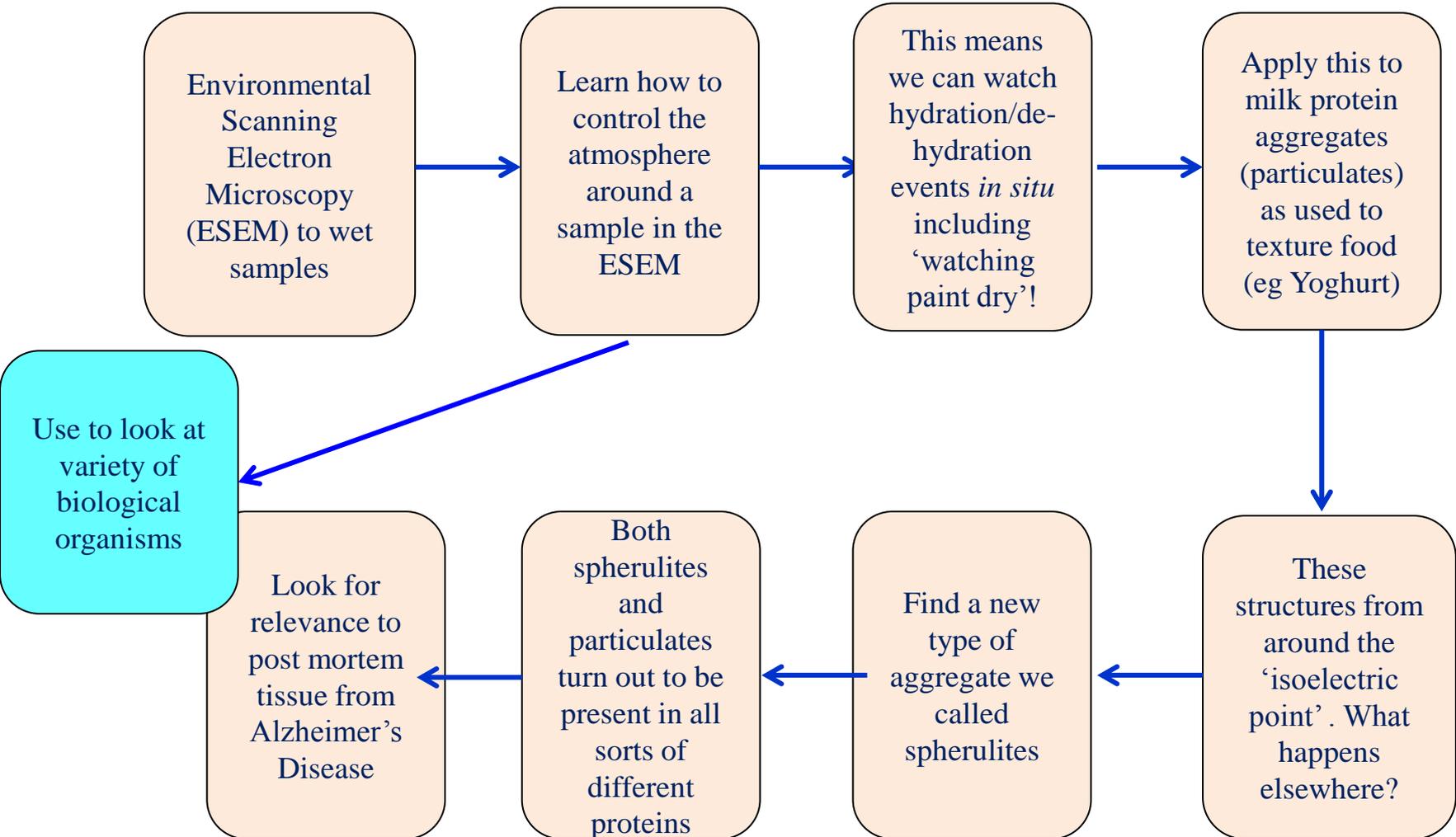
These embody the idea that science has no creativity – a view I would utterly reject.

Peter Medawar (1968) expressed his rejection of the idea thus:

All ideas of scientific understanding, at every level, begin with a speculative adventure, an imaginative preconception *of what might be true* – a preconception that always, and necessarily, goes a little way (sometimes a long way) beyond anything which we have logical or factual authority to believe in.

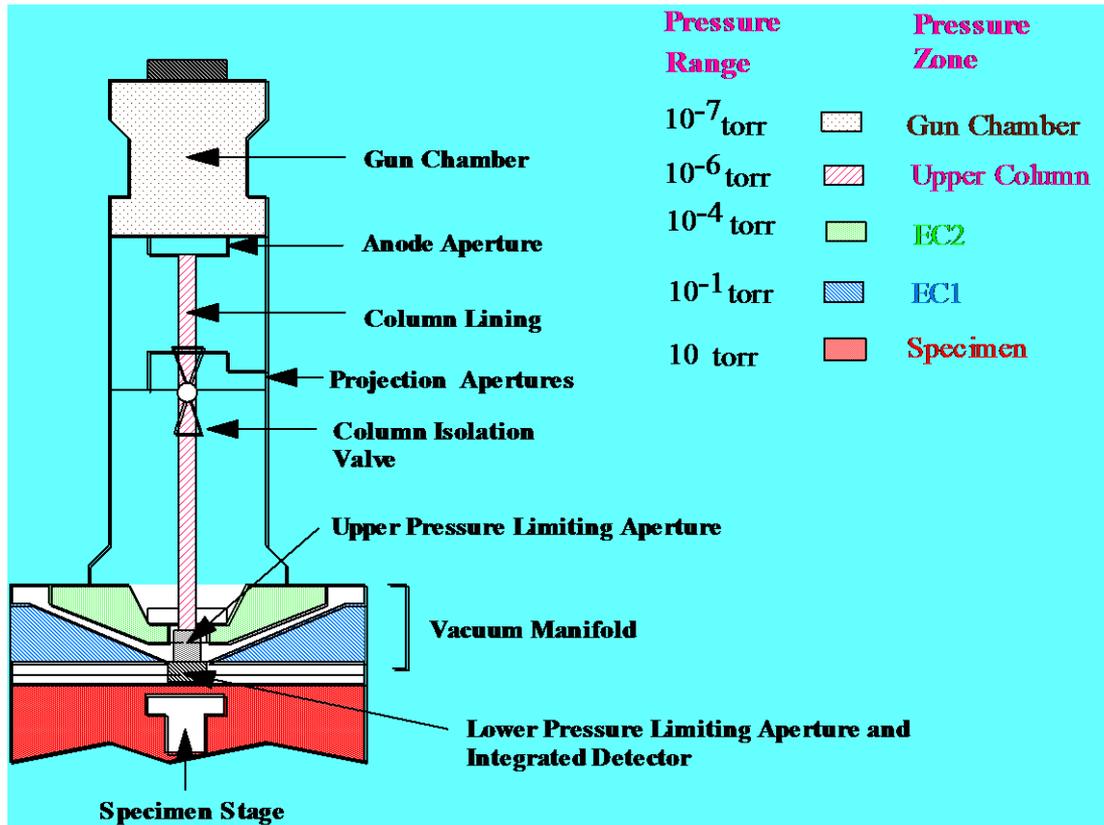
I would say further, at every stage of experimentation, one is constantly recreating how one will proceed in the light of what one has learnt already.

Electron Microscopy, Yoghurt, Alzheimer's Disease and Leaves



ESEM

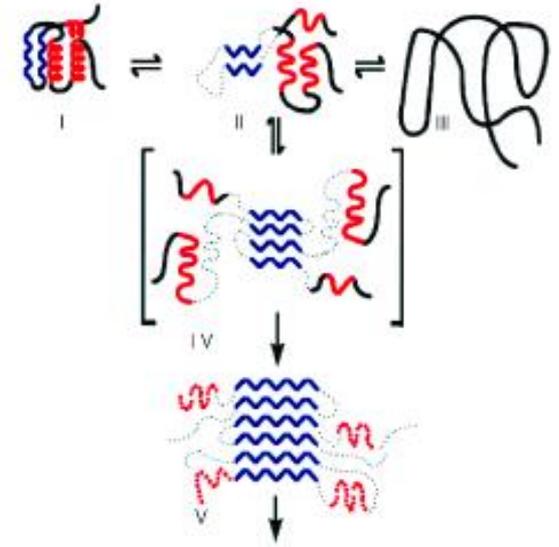
(Environmental Scanning Electron Microscopy)



- Electron microscopes can operate with higher resolution than standard light microscopes.
- Normally they operate under high vacuum.
- In ESEM, a system of differential pumping means wet samples can be maintained hydrated.
- So is ideal for studying hydrated systems without changing the structure.
- (Additionally, insulators do not need to be coated to prevent image degradation due to coating.)

Heat Set Gel Structures in β lactoglobulin

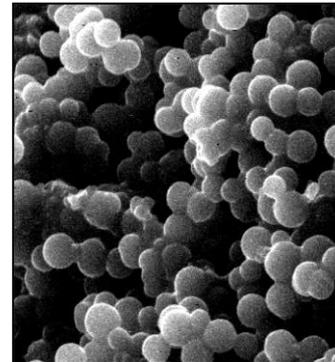
- Beta-lactoglobulin forms gels on heating to temperatures above 60°C.
- The protein loses its native structure with heat, and becomes an unfolded chain.
- The gelation is widely used by the food industry
- The type of gel formed broadly depends on the charge per molecule, controlled by pH.



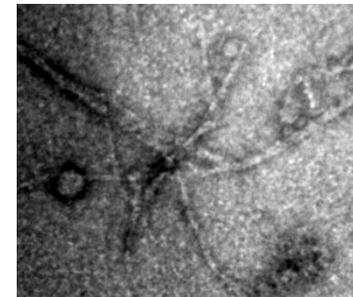
Structure



Fine Stranded



Particulate



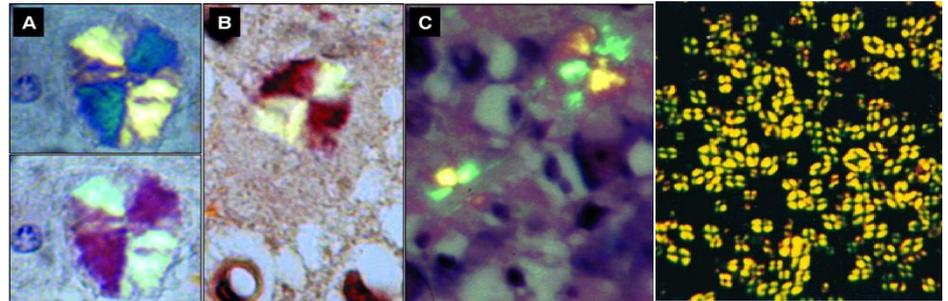
Fine Stranded

Amyloid Fibrils and Higher Order Aggregation

- Amyloid fibrils have been much studied, although it is thought that the toxicity of misfolded proteins occurs before even the fibrils form. It does not mean that the fibrils themselves represent the end of the story.
- We have studied higher order assemblies, found, both *in vivo* and *in vitro*. which we have termed spherulites by their similarity to structures observed in semi-crystalline synthetic polymers



Insulin spherulites viewed under crossed polarisers.

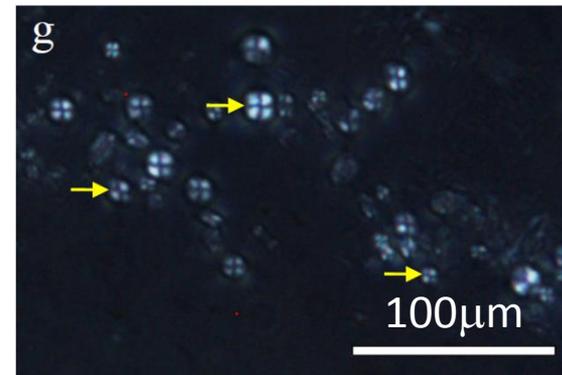
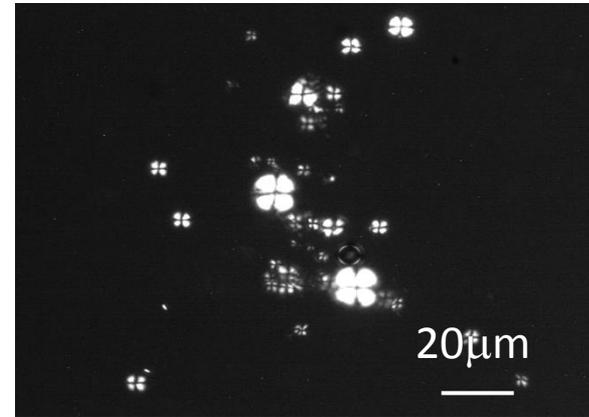


A: A β Alzheimer's plaque; **B&C** Prion plaques in mice; both stained with Congo Red; **D:** κ 4 light-chain variable domains amyloid fibrils stained with Congo Red

Pictures from: A-C Manuelidis et al., *Science*, **277**, 94-98 (1997); D Raffen et al., *Prot. Science* **8**, 509-517 (1999)

A beta – the Toxic Component in Alzheimer's Disease

- We can see spherulites in solutions of the key segment of APP (amyloid precursor protein).
- They are also seen in hippocampal samples from patients who have died from Alzheimers.
- Plaques may exist as spherulites, and as a way of sequestering misfolded protein.
- As I frequently tell journalists, this does not mean I am about to cure Alzheimer's.



Spherulites observed in section of Alzheimer's hippocampal tissue [Exley et al J Alz Disease 2010](#)

Real Time Imaging in the ESEM

- Leaves are pretty resistant to the electron beam whereas organisms such as bacteria and mammalian cells are much less so: we have spent a long time trying to study viability after imaging.
- But for leaves, this means dynamic experiments can be carried out.
- By changing the vapour pressure of water in the chamber around the leaf (from *Tradescantia andersonia*), it is possible to force the stomata to open and shut (they close as the relative humidity is decreased).
- BBC clip <C:\Athene\general talks\BAS 2015\How to Grow a Planet - 1. Life from Light.mp4>
- This is one way of making sure one's science gets into the public domain.

Science in the Everyday World

Why Every Citizen Should Care

- Climate change (and Climategate)
- Renewable energy sources including biofuels and wind farms
- Nuclear power
- Cancer – kill or cure
- Breast and prostate cancer screening
- GM crops
- MMR and cervical cancer vaccinations
- Legalisation of drugs
- Mobile phone use and masts
- Nanoparticles (eg in sunscreen and deodorised socks)
- Obesity and diet
- Food additives and organic foods.....the list goes on (and on)

Effective democracy requires the electorate being able to assess science-related issues based on understanding

How Should Scientists Communicate their Science?

- There has been a progression over the years as it has become clear that the public need to engage rather than just be talked down to as if they were simple-minded.
- PUS – Public understanding of science
- PAS – Public awareness of science
- PES – Public engagement with science

- But what does engagement mean?
- Is it just about attending science festivals and ‘listening’ or is it a more active process?

Trust

William Clifford 1872 to the BA

- ‘Such distrust or dislike of science, then, as is to be found among us, is due to circumstances which are rapidly disappearing. In the good times come from imperfect training. In the bad times come from the fact that the public does not know as much of science as a

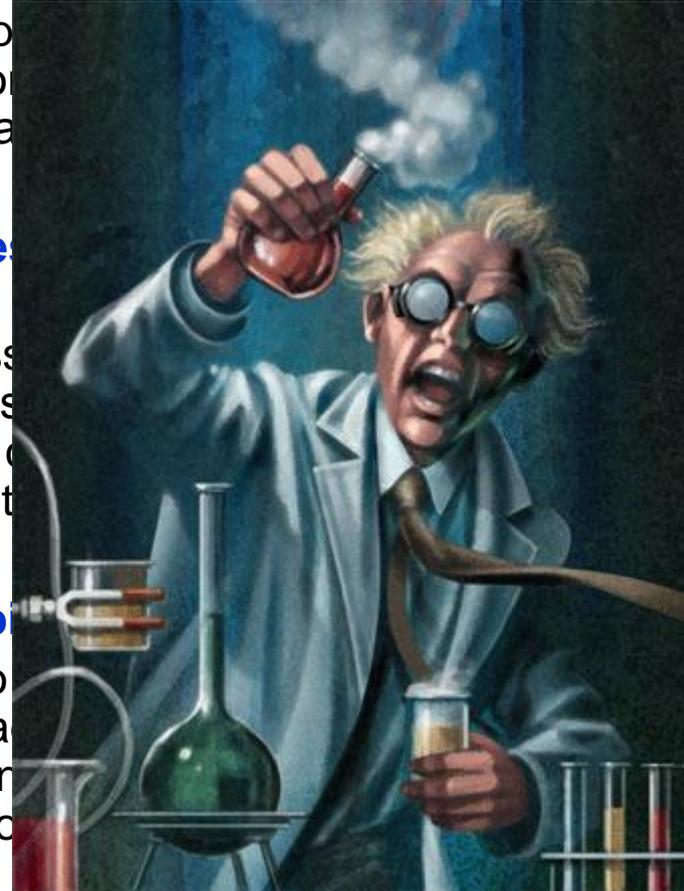
Gerald Warner Telegraph correspondence with scientific advisors:

- ‘white-coated prima donnas and narcissists who have had cranks and crackpots of science and angelical creatures who dissect as to



- ‘The one who wants to persuade us that there is a conspiracy to control us. tax and control us.

Peter Sellers as Dr Strangelove



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- **William Cavendish at the Devonshire Commission reporting in 1875**

‘In a science dominated world, such a low level of scientific understanding among our parliamentarians is a problem’.

- **Julian Huppert 2010**

‘....really important for all MPs to have some exposure, because some of them will not have studied any science since they were 15 and it's important to understand how to engage with it. You would then have a lot of MPs who were able to understand the information they were being presented with.’

‘They have a set of beliefs and they will argue that regardless of the science.’

And on the banning of mephedrone

‘What we saw was a policy based on media reports, rather than based on evidence’

- **Andrew Maynard 2011 (Director University of Michigan Risk Science Center)**

We need a whole new generation of leaders, leaders who are cross-trained in governance, who understand risk literacy, who can communicate complex problems in simple ways, who truly believe in democracy, and who are willing to engage with their constituents in a way that ups the conversation. So people know what the hell they're voting for.

Science in a Post-truth World?

- If the public are willing to swallow statements without evidence to back them up;
- If politicians are able to make promises based on nothing and not held to account;
- If international movement is restricted-

What Then?

Scientists (the 'liberal elite') must listen but not bend their principles. They must continue to argue the facts and not be derailed by false arguments or destructive methodologies (such as 'Gish gallop'). We must have confidence the spirit of the Enlightenment will return!

Scientists Communicating

- Science may be about facts but conclusions may not be black and white.
- We have to be able to convey complexity
- We must be able to understand where people are coming from
- And that politicians are going to factor in far more than evidence in reaching conclusions about their actions.

The screenshot shows a Guardian article page. At the top, the Guardian logo is visible with the tagline 'website of the year'. Below the logo is a navigation bar with links for UK, world, politics, sport, football, opinion, culture, business, lifestyle, fashion, environment, tech, and travel. The article is categorized under 'Science' and 'Notes & Theories'. The main headline is 'A crisis of trust is looming between scientists and society - it's time to talk' by Helen Czerski. A sub-headline reads: 'It's vital to improve public trust in science and expertise. But science is increasingly complex, and getting harder to explain. Things need to change'. The article features a photograph of a chalkboard filled with complex mathematical equations. Below the photo, the text begins with 'Self-scrutiny is hard, but a crisis is looming and we scientists need to get out the mirror. A casual observer, viewing the landscape of science, sees a place of lofty achievements: soaring towers built on our understanding of genetics, the effortless sophistication of modern electronics, and astonishing fountains of knowledge on every topic imaginable. But all this rests on the foundations that connect science to society, and this is where the problem lurks. On the surface, science is more democratic than ever - a rapidly increasing generation of all scientific papers are freely available online, universities are...' To the right of the article is a 'Most popular' section with several news items, including 'Donald Trump defends Muslim-countries travel ban amid protests: our country needs strong borders - live', 'Roger Federer beats Rafael Nadal to win Australian Open men's final - as it happened', 'Federal judge stays deportations under Trump Muslim country travel ban', 'Roger Federer beats Rafael Nadal in thrilling Australian Open final', and 'White House defends Trump Holocaust statement that didn't mention Jews'. At the bottom of the page, a Windows taskbar is visible with icons for Internet Explorer, Photoshop, File Explorer, Mail, Word, VLC, and a printer icon.

Many Issues Beyond Science Involved

- Scientists may think evidence and hard fact is all that matters.
- But people have other beliefs which get factored in which might include:
 - Religion and faith
 - Different views on intergenerational justice
 - Economic valuations and assumptions
 - Freedom for the individual versus the good of the state
 - Our acceptance of risk/ psychological factors
- Policy makers, implicitly or explicitly, may bring these additional factors into play and ignore, or at least appear to ignore, the science.
- It would be helpful if policy makers made more obvious the basis on which their decisions are based, rather than asking for scientific advice and then appearing to ignore it.
- But do scientists understand ‘framing’ in the way that social scientists mean it?
- If they did, would that help the debate?

Speaking Out and Speaking With: Responsibilities of Scientists

- Scientists cannot and should not assume public (tax-payers') funding as a right.
- But nor should the idea of blue skies research be ruled out, since so much innovation stems from this.
- This will be important as the new Industrial Strategy Research Fund gets underway.
- We should be willing to engage, in all kinds of ways, with the public
 - Science (and more general) Culture Festivals
 - Outreach in Schools
 - Writing blogs, in print media
- We should also be willing to engage with policy-makers, but avoid special pleading.
- But not all scientists are comfortable with this and engage with this
- And the public also does not always trust scientists or wish to engage

Learning How to Engage

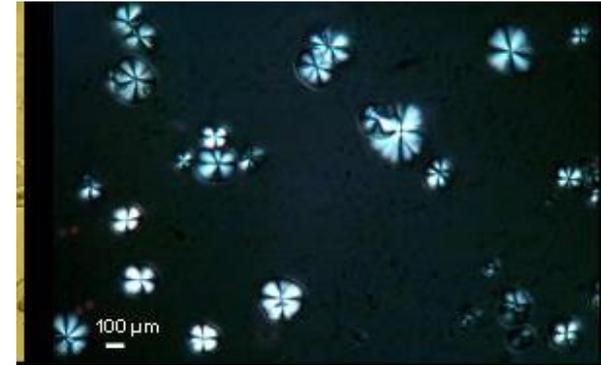
- Many years ago I led a team awarded a large grant to work on colloids.
- What are these?
- At their simplest they can be thought of as small particles, sub-micron, dispersed in another medium.
- Paint is a common example, as is mud, detergent and many other common products.
- The particles have a large surface area and a crucial aspect of their use is to make sure they don't clump.
- When writing a press release I naively used lumpy custard as an analogy.
- This was a bad mistake leading to headlines such as

CAMBRIDGE BOFFINS AWARDED £3M TO STUDY LUMPY CUSTARD!

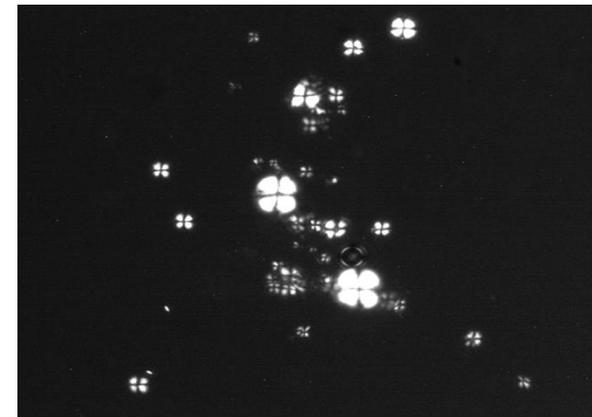
appearing on p3 of The Star – not a good place to be

Proteins, Alzheimer's Disease and Accuracy

- Since then I have had media training....
- As I said, I study protein aggregation and note the appearance of structures *in vitro* similar to those seen in the brains of Alzheimer's patients.
- I try to be careful about how I describe this, but....
- Over the years the media has got sloppy about reporting what I do:
- **Guardian 2009 (based on interview)**
 - “Recently, she has turned her attention to the way protein molecules stick together, which could help reveal what causes Alzheimer's disease.”
- **Guardian 2011 (based on nothing)**
 - “Donald researches unconventional areas for a physicist – such as revolutionary treatments for Alzheimer's”
- **Publicity for talk at Hay Philosophy Festival 2011**
 - “Revolutionary”



Spherulites in the milk protein beta lactoglobulin



Spherulites observed in section of Alzheimer's hippocampal tissue

Role of Citizens

- I do not subscribe to Snow's view that it is a failure if people do not know the 2nd law of Thermodynamics.
- I do think it matters that individuals understand enough to be able to make decisions and to know how to sift the information put out in the media.
- As an aside, I would like to see Ben Goldacre's Bad Science (or equivalent) as required reading in Media Studies GCSE.
- Since science sits so centrally in our lives, it behoves everyone to understand some basic principles.
- It isn't sufficient to say
 'Oh I was never any good at science at school' and then believe every critical story out there.

Who Should Do Science?

What about Science Education?

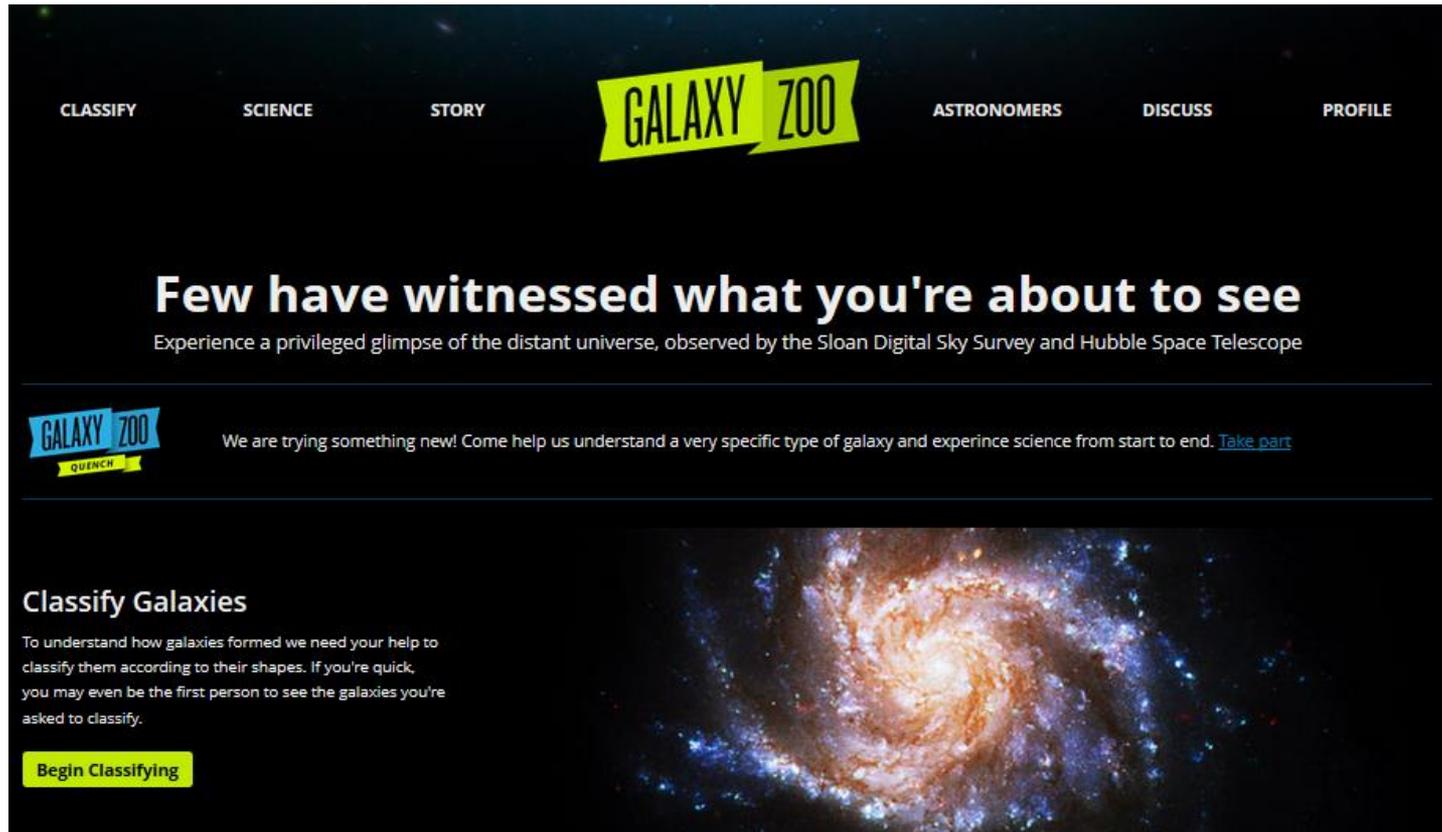
- *'All citizens need the skills and knowledge to be able to make informed decisions about how society handles these issues.'*
Royal Society Report: Vision for Science and Maths Education 2014.
- But does the way our society work make this easy for everyone?



Barbie the Engineer!

Citizen Science

- Involving a mass public in science is nothing new.
 - For example, in the second half of the 19th century, amateur botanists from around the world would supply Kew (Joseph Hooker) with specimens to help understand species and geographical dispersion.
- Now there are some spectacular citizen science projects.



The screenshot shows the Galaxy Zoo website interface. At the top, there is a navigation bar with the following links: CLASSIFY, SCIENCE, STORY, GALAXY ZOO (in a yellow banner), ASTRONOMERS, DISCUSS, and PROFILE. Below the navigation bar, a large headline reads "Few have witnessed what you're about to see" with a sub-headline "Experience a privileged glimpse of the distant universe, observed by the Sloan Digital Sky Survey and Hubble Space Telescope". Below this, there is a section for the "Galaxy Zoo Quench" project, featuring a small logo and the text "We are trying something new! Come help us understand a very specific type of galaxy and experience science from start to end. [Take part](#)". The main content area is titled "Classify Galaxies" and includes the text: "To understand how galaxies formed we need your help to classify them according to their shapes. If you're quick, you may even be the first person to see the galaxies you're asked to classify." A yellow button labeled "Begin Classifying" is positioned at the bottom left of this section. The background of the page features a large, detailed image of a spiral galaxy.

Whole Range of Projects in Natural History

The screenshot shows the RSPB website interface. On the left, the RSPB logo is accompanied by the tagline 'giving nature a home'. The main header features the 'big garden BIRDWATCH' logo. Below this, a navigation menu includes 'Home', 'Identify newts & survey hints', 'Report your newts', 'Links', and 'Results'. A prominent banner for 'The Great Easter Newt Hunt' features a cartoon boy with a magnifying glass over a newt. Below the banner, a call to action reads 'Join the Great Easter Newt Hunt Help us conserve Britain's newts!'. A sidebar on the left contains sections for 'Why?' (Why are we counting birds?), 'How?' (All you need to know about taking part), 'Garden visitors' (The birds to look out for), 'Family fun' (The Birdwatch), and 'Results 2013' (What we found).

This screenshot displays the 'big butterfly count' website. The main heading is 'big butterfly count' in a large, green, bubbly font, with the dates '20th July - 11th August' underneath. A photograph of a butterfly is visible on the right side. A central call to action says 'Help us take nature's pulse by joining the big butterfly count. [Find out more about this project](#)'. Below this, there is a prominent orange button that says 'Log my sightings (until end of August)'. At the bottom, three smaller images are shown: an identification chart for butterflies, a woman wearing a hat and holding a notebook, and a butterfly perched on a purple flower.

Science Museum Projects

- Science news gallery [Antenna](#) – more rapid updates than any other gallery of its kind.
- Engages visitors with new science and technology and let's them explore the social and ethical issues.



- [Who am I?](#) gallery Live Science Residencies 4x year
- Example: 3D pictures of faces taken by doctors from Great Ormond Street Hospital to investigate the structure of different faces.
- Each was added to a database to help them improve treatment for future patients.



Conclusions

- Scientists need to work harder at understanding where the public are coming from, the broader context of their hopes and fears.
- But we need not to be apologetic for what we do, its relevance, its creativity and its underlying importance.
- We cannot stay stuck in silos.
- In the current political climate more than ever we need to speak up about facts, evidence and expertise without losing sight of those people for whom the relevance of these factors is not obvious.
- Education as ever sits centrally at all those arguments.