NEWSLETTER

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Contents

Beginning Bit

Hello all.

Welcome to the latest edition of the Fusion newsletter. For those of you new to the society, some previous editions are on the website (https://oufusion.org/).

There are two academic articles, by Laura Pickard and Alexia Beale, along with reports on the visit to Lord Rayleigh's labs at Terling Place and last year's Fusion weekend in Bristol.

Fusion members Gurbir Singh and Agata Winiarska represented the society at FUSE – and Gurbir has written about the event.

We hope you enjoy reading the newsletter and taxing your brains with the crossword and the usual 'what is it, and what is it for' article.

Dwyn Padfield.

Visit to the Natural History Museum:

places still available!

Fusion is organising an informal visit for members to the Natural History Museum in London on **Saturday 24th February**. This will include a tour/talk at 1415 on their exhibition on 'Women in Science – Space' – one of whom is the OU's own Monica Grady!

There are lots of exhibits on meteors and scientific subjects, as well as photographs and info on non-scientific but interesting subjects – eg photos of when some of the galleries were commandeered to provide training for the British Secret Service during WWII.

Tickets have to be, and are, booked and are limited. Only 8 are available and booked for the tour, but we have 10 general admission tickets for the museum for 1200, when we will meet - so it is essential that anyone interested **contact us ASAP**. Note that all of these tickets are free.

It has been suggested that we get together for a meal in a local hostelry after the visit, which would be good!!

Please contact Dwyn on **fusionevents@live.com** to book a place, and for more information.

Terling Place Visit

Terling Place, near Chelmsford, is the family home of the Rayleigh Family. It is also the location of the labs of John William Strutt, the 3rd Lord Rayleigh, a physicist who worked in many areas including optics, acoustics and electricity. He won many awards, the most notable of which was the 1904 Nobel Physics Prize for the discovery of argon.

In June, three Fusion members were able to join the IOP Retired Physicists Group for a visit to Terling Place. We met for lunch in a local pub beforehand, so we were able to meet each other and the IOP attenders.

The visit started with a talk by the present Lord Rayleigh on the history of the family and house. We then had a tour of part of the house, which included a small lab where we saw the balance and weights which are believed to have been used in the discovery of argon. There was also a cabinet showing many of Lord Rayleigh's awards – including his Nobel medal. This, for me, was one of the highlights – I doubt that I will see another Nobel medal! A large quantity of manuscripts and documents are being sorted and archived in another room of the house.

Left to right: Clive Blanche, Dwyn Padfield and Gurbir Singh

Then to the main reason for our visit – the tour of the labs. These have been preserved in their original state – dust included! There were obviously no health and safety rules in those days, as illustrated by, among other things, unguarded mechanical equipment and bare electric cables hanging from the ceiling. One of the many items on display is the original, sealed ampoule of argon.

I would like to thank the organisers who made the visit possible – Lord Rayleigh, Hugh Deighton of the IOP Retired Members Group and Ted Davies of Cambridge University.

Dwyn Padfield

Introducing Bradley Allsop…

the IOP Student Engagement Officer

Bradley Allsop was appointed to the post of Student Engagement Officer at the Institute of Physics in April 2023. Previously he took a PhD in social sciences at the University of Lincoln, studying political engagement in young people, and worked at the student union at the University of Suffolk.

The Student Engagement Officer liaises with physics students across the UK and Ireland, both directly and through the IOP's Student Community Panel, which is made up of 13 regional representatives. Bradley sees his remit as ensuring that physics students have the best possible start to their career. He is keen to support physics societies and campus ambassadors, and make opportunities for students to get involved in their community. He sees his role as that of an enabler – responding to the wishes of student members rather than directing activities "from the top" – and is also keen to reach out to students who aren't yet IOP members.

The Student Engagement Officer's responsibilities include involvement in FUSE, the annual event for university physics societies, which is held at a different university each year; and also in IAPS, the International Association of Physics Students (https://iaps.info), and the PLANCKS competition (Physics League Across Numerous Countries for Kick-ass Students)

If you would like to get more involved or have ideas for how the IoP could help you, please drop a line to Fusion or add on the Facebook group.

Jim Grozier

FUSE 2023

November 24-25 2023

University of Birmingham

This year's Forum of University Societies Event (FUSE) was held between the 24th and 25th November and hosted by the University of Birmingham Poynting Physical Society and the University of Birmingham Astronomical Society, supported by the Institute of Physics. In a pretty crammed program, 45+ attenders from 16 Physics, Astronomy, Maths societies and a single Nuclear and Particle Physics society, met to learn about “Running big events on campus, “Embedding Equality, Diversity and Inclusion in your society”, and the University of Manchester Physics group spoke about “Running great outreach events”.

The theme for both days was about learning about and from each other. First one group of 8 societies laid out their stall (many were really well prepared as they would be for a public outreach activity) and showcased their offerings. The second group interacted as spectators. After lunch the two groups swapped. This was an opportunity not only to get to know the groups and individuals but also to share good practices in organising, marketing, fundraising and strategies for public engagement. Perhaps the most tangible outcome was sharing details of each other's events and thus increasing mutual attendances.

Agata Winiarska and I represented OU Fusion. We highlighted a particularly OU unique USP that our members are located across the UK. Apart from organising the OU stall, Agata came prepared with hard copies of papers and newsletters published by OU Fusion. She had also prepared a powerpoint presentation to share images of previous activities. We reminded everyone of the growing OU Fusion Facebook page as an initial point of contact.

FUSE 2023 participants

The Friday night was scheduled for stargazing from the roof using the UoB telescopes. Unlike my many experiences of being clouded out whilst observing the night sky in Manchester, Birmingham offered a surprisingly clear night. We all enjoyed the telescopic views of the Moon, Jupiter and Saturn which was a low in the sky.

Bradley Allsop, IoP's Student Engagement Officer was the key organiser and my primary contact. Like me, this was his first FUSE event and he provided all the steering necessary to ensure everyone understood what was happening, where and when. Before I left I suggested to Bradley that since all the societies are showcasing their offerings, perhaps an element of "open to the public" could be introduced in future FUSE events. It may help to attract more members or the publicity could increase engagement and event attendances.

Gurbir Singh

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FUSION EVENT 2023

Fusion held an event at Bristol university, the weekend of 9th and 10th September.

On the Saturday we had five talks. Michael Banks spoke about 'The Physics of Babies' a subject on which he has written a book. Fusion's Secretary, Greg Vaughan, has worked as a scientist in government for 25 years, and gave us a history of, and opportunities for, scientists in government.

The talk by Craig McNiele, secretary of the South West branch of the IOP, was titled 'Using supercomputers to search for the breakdown of the standard model of particle physics', an outline of his research at the University of Plymouth. He also gave us an overview of the work of the IOP in this region.

Alexia Beale, IAPS archivist and PhD student, and Dominic Wearne, JIAPS editor, spoke about IAPS and Plancks, while Alexia ended the day with a talk about her research – 'Colloidal gelation inside porous structures imaged using x-ray computerised tomography.'

The day also included the AGM. Saturday evening and Sunday were given over to social events – a meal Saturday evening, and visits on Sunday to the Clifton Observatory Museum, camera obscura and giant's cave. The event finished with a tour of the Clifton Suspension bridge, and a talk on its history.

Dwyn Padfield

Some of the participants on the tour of the Suspension Bridge

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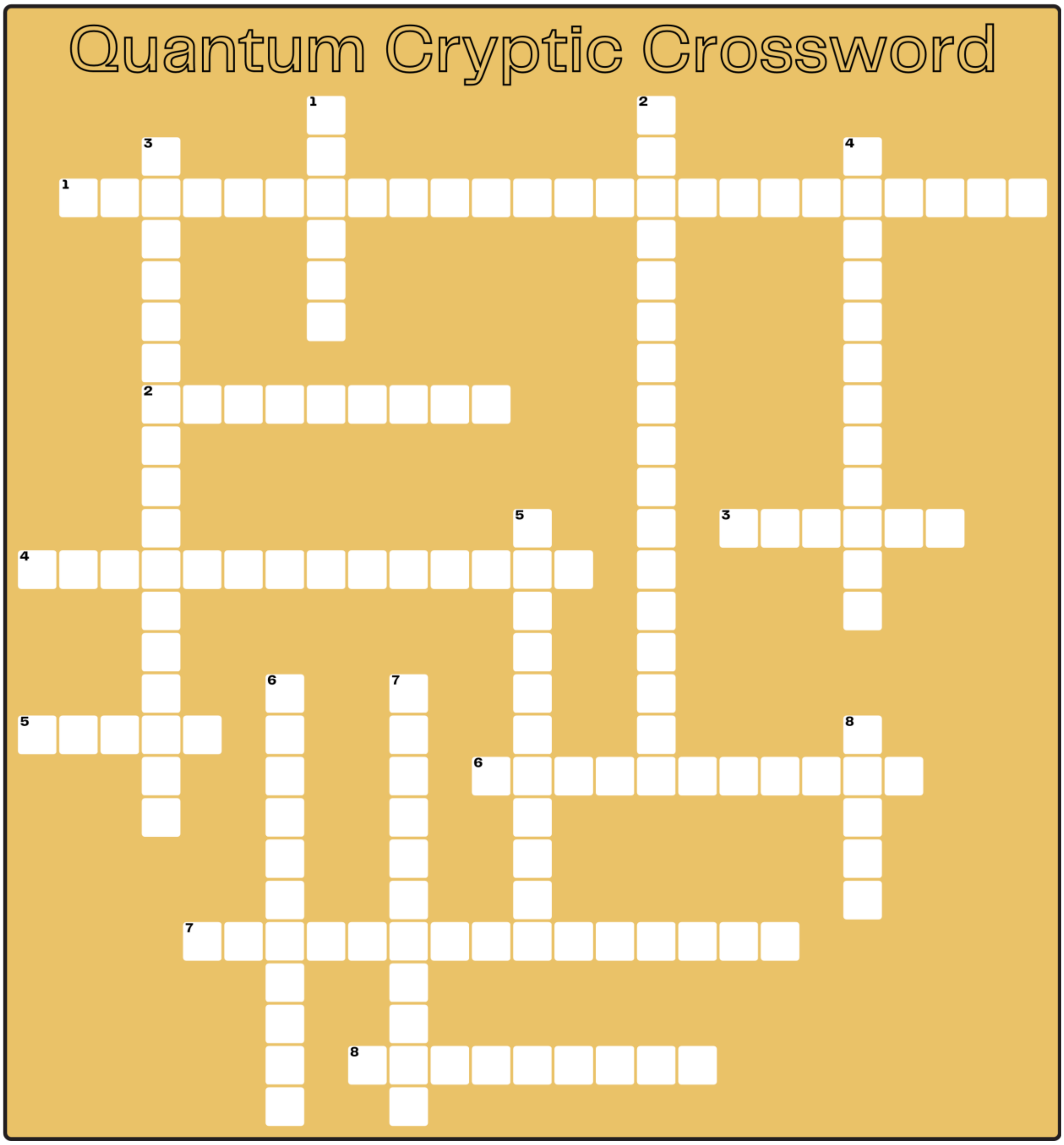
Write for the Newsletter!

Invitations are invited from ANY Fusion member (or associates or friends of members) who would like to contribute an original (previously unpublished) article, quiz, puzzle etc to the next Fusion Newsletter. Any theme remotely related to the interests of the Society would be welcome. Please consult the editor if you are unsure about a topic.

For enquiries and submissions email the editor, Nigel Patterson, on FusionSocietyOU@gmail.com.

All authors of published contributions will receive a free FUSION sweatshirt!



Clues

Across

1. Translating from a European city gives no meaning if unwatched. (10, 14)
2. Let’s bleat for a chiming parliament. (4, 5)
3. It’s me in the festivity; am I odd? (6)
4. Swift movement of a web browser is strongly binding. (14)
5. Waiting for part of the information. (5)
6. Eel’s Uni. gave worth once more. (11)
7. Enclosed fish change position system. (7, 8)
8. Juvenile ovine’s working patterns. (4, 5)

Down

1. Dropping a wooden bar perhaps? (6)
2. An estimation of the naissance results in a break-up. (4, 13)
3. Dating site for yoyos and planets. (9, 8)
4. The purpose of a hand gesture. (4, 8)
5. Standing in a quiet line like a clanger. (11)
6. A recluse's hometown. (11)
7. The eponymous one's weapons and boats sing of absolute vigour. (11)
8. I'm referring back to the energy change. (5)

Solutions will appear in the next issue of the *Newsletter*. (With thanks to Alexia Beale)

The Invisible Scientists

The study of the history of physics is often a neglected element of science education, with teachers focusing on scientific content. Sparked by curiosity to learn current students' experiences and perceptions, I asked my peers, international physics students who are studying physics at university (at bachelor's, master's, or doctorate level), whether they have learnt anything about the history of physics in their undergraduate course. I collected over twenty responses from students, with each student at a different institution spanning four continents [1]. The majority of students responded that the historical context of the concepts they studied at university was only mentioned briefly, usually just by a reference to the figurehead for that discovery (featuring the all-too-predictable examples of Einstein, Bohr and Feynman), with perhaps the occasional addition of the dates and profile picture of the scientist. Students often receive an isolated, factual picture of the most well-known physicists, whilst the majority of scientists remain invisible.

What was particularly striking was the phrasing of the students who replied in the negative to my inquiry. Their responses included the following phrases: "Not really no, I wish I'd learnt more!", "Sadly not" and "No unfortunately I did not". These responses demonstrate that there is a greater need for the implementation of the history of physics within the university course structure, with students wanting to learn more about this topic.

The students highlighted in their responses that the inclusion of historical anecdotes within lectures is dependent on the individual lecturer, with some lecturers omitting the historical background completely and others providing more detail by including stories related to the one 'figurehead' physicist. The students also displayed an awareness of the time constraints of the lecturer. Providing a historical background is usually a supplement to the main focus of the lectures, with limited time available to provide an introduction to the rich variety of history surrounding the scientific context. How should the lecturer choose which elements of history to include? How can they provide an overview of such a broad topic in restricted time?

In this essay, I would like to explore the concept of the invisible role-players in the history of science and the importance of their inclusion in the teaching of the history of physics. A significant proportion of 'scientists' (whether credited as such or not) belong to this group, with only a small number mentioned in the core content of degree programmes. I will provide an overview of a few examples of groups which have typically been underrepresented throughout the history of science, before providing suggestions for their inclusion in science education.

Looking Beyond the Figureheads

When researching deeper into the history of physics, we discover that there are always more people behind the figurehead, from the involvement of their academic research team to the vital role played by the laboratory technicians, with assistance sometimes even being provided by family members of the scientists. For example, during the declining years of J. Plateau, his family used to assist him by reading aloud scientific publications and writing at his dictation [2]. The contribution of the students of the scientist has also often remained unrecognised.

I will briefly provide one example of an academic setting where the presence of talented teams of physicists was conducive to the multitude of notable scientific effects studied. The Cavendish Laboratory was a leading school of physics in the early nineteen hundreds [3]. The community offered by the research groups and the inevitable discussions between the physicists added to the quality of the scientific research. C. T. R. Wilson's invention of the cloud chamber, W. Richardson's experimental study and development of the theory of thermionic emission, and Chadwick's discovery of the neutron are just some of the significant results of work carried out at the Cavendish [3]. Although the lead scientist for each discovery is justified with receiving the credit for these discoveries, the role of the research team in providing suggestions and contributions to the direction of their work should not be omitted when providing the historical background.

'Invisible Technicians'

In his work *'The Invisible Technician'*, Shapin explored the role of laboratory assistants and their significance in the development of science (see Figure 2) [4]. He provided the example of the social structure of Boyle's laboratory in seventeenth-century England, highlighting that although these assistants were completing tasks which were essential for the running of the laboratory, they remained anonymous and invisible to the public view. These technicians were ignored by the managers of their workplace and absent from published literature. Referred to as 'operators', 'assistants' or even 'servants', the laboratory technicians were under orders from the manager of the laboratory. Their existence was chiefly mentioned when the experiments were not proceeding as expected, with the comments preserved in written records directed towards the demonstration of their incompetence.

Shapin's paper, published in 1989, sparked an interest in the role of technicians and their contribution to science, which had been previously passed over by historians [5, 6]. In 2008, *'Notes and Records'* (the Royal Society Journal of the History of Science) published an issue which was dedicated to the role of technicians [5], and further research studies have been designed to investigate the role of technicians within a range of scientific disciplines [7].

As is expected, in general the greater the 'invisibility' of the scientist, or in this case, their 'assistant', the fewer the historical records [4]. This provides a challenge for science educators and historians if they wish to provide an accurate picture of the role played by these assistants.

Whilst most of Boyle's assistants remained anonymous, a few, notably D. Papin and R. Hooke (see Figure 2), have been named in historical records [9]. Hooke's time as an assistant in Boyle's laboratory is often omitted when he is introduced in science education[1]. Throughout his career, Hooke's masters assumed the right to identify whether Hooke had performed a competent experiment, and when he eventually published successful results, the *Journal-Book* once referred to his investigation as the experiment 'he said he had made', illustrating that the credibility of the work completed by an 'assistant' was often questioned. Hooke was rarely mentioned when Boyle entertained visitors to his laboratory and did not the receive the public recognition that Boyle did [8].

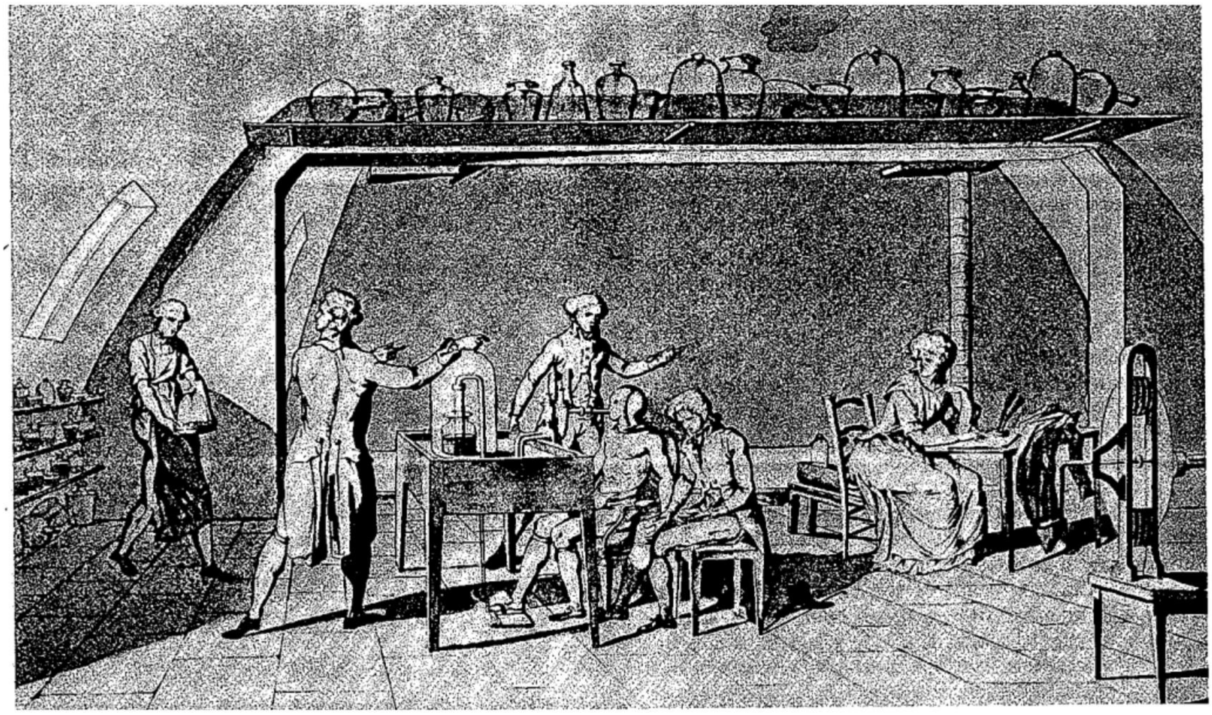


Figure 1: Scene of the late eighteenth century chemical laboratory of A. L. Lavoisier with a lab technician carrying an instrument on the far left. (From [4].)

Papin is most notably remembered for his invention of an early pressure cooker [4]. He started his career as an assistant to Huygens, working on the air-pump [9]. He published his results in a book, *Experi´ences du Vuide*, and communicated them in a series of five papers to the Royal Society. Papin was offered employment by Boyle and moved to the UK to continue his experiments on the air-pump under Boyle's direction. During his time in Boyle's service, Papin did not feature as an author in scientific papers and was largely invisible to public view[2] [4]. In *The Invisible Technician*, Shapin says that Papin 'did Boyle's

[1] I asked a sample of international physics students and although all of them had heard of Hooke, none of them could recollect any mention of his time as an assistant to Boyle [1] .
[2] None of the sample of international physics students had heard of Papin [1] .

experiments and wrote Boyle's text'. Boyle trusted his assistant to design and conduct experiments. Unusually, Boyle once even admitted (speaking of the interpretive work completed by Papin) that "some few of these inferences owe themselves more to my assistant than to me" [4].

William Kay was Rutherford's Laboratory Steward in the early 1900s [10]. His recollections of working in Rutherford's Manchester physics laboratory have been recorded through the transcript of an interview with Samuel Devons (a physics professor at Manchester). This interview provides an overview of Kay's day-to-day life and details the work completed by the Laboratory Steward. The following quotation from the interview illustrates the extent of the role of the assistants in Rutherford's laboratory practice:

> [Interviewer] "Did Rutherford actually make any apparatus himself?"
>
> [Kay] "No, no, no, no. We used to, I used to set up nearly all his apparatus. You know, when he did his work, you know, oftener than not, he used to tell me and we did a rough experiment" [10]

Figure 2: Notable assistants who were employed by R. Boyle: R. Hooke, left and D. Papin, right (From Wikipedia [14]).

Kay also assisted Rutherford in his teaching, helping him to deliver lectures to students. In the interview, he also elaborated on this aspect to his work:

> "I think I used to do all the diagrams, I used to do all the lectures, and I used to do all the bills and all the clerical work." [10]

One of Rutherford's students provided an insight to the delivery of these lectures:

> "It almost seemed at times that the course of the lectures was determined, not by any preconceived plan of Rutherford, but by Kay's taste in lecture demonstrations", [10]

adding that "sometimes [...] Rutherford would [...] appeal to Kay for information about the experiment he was demonstrating". The role of a Laboratory Steward here is seen to surpass the passive figure of a manual laborer. Kay played a significant part in the workings of the Manchester laboratory. His role, along with that of the multitude of forgotten laboratory assistants, should be acknowledged in the teaching of the history of physics [1].

In this section, we have considered a few examples of 'invisible technicians' and their contribution of the development of science. The role played by these laboratory assistants was vital in ensuring the completion of successful experiments. It is arguable that the work performed by the assistants was on a par with, if not of greater value than, that of their employer. However, their contribution to science during their time as a laboratory assistant remains unrecognised. When providing the background to historical experiments, we should ensure that the role of laboratory assistants is not forgotten and that the contributions by assistants such as Hooke, Papin and Kay are acknowledged.

Unrecognised Female Physicists

There are many notable examples of female physicists who have made a significant contribution to their field without receiving public recognition. In recent years, the visibility of the role played by previously unrecognised female scientists has increased. For the purpose of this essay, I will briefly mention two female scientists who faced obstacles due to their gender: Ida Noddack and Lise Meitner. The reader will most likely be aware of other examples, all of which are worthy candidates to be included in teaching of the history of physics.

Ida Noddack is now renowned for anticipating the possibility of nuclear fission nine years prior to its discovery in addition to her discovery of rhenium with her 'co-worker' and husband Walter Noddack [12]. Noddack faced opposition from leading scientists, including Otto Hahn, when she proposed a contradiction to Fermi's explanation of the products of the collision between heavy elements and neutrons. Lise Meitner was the first woman to become a professor of physics in Germany, however her work on nuclear fission was not fully recognised [11]. The Nobel Prize in Chemistry was awarded solely to her collaborator, Otto Hahn. Both Meitner and Noddack faced challenges due to their gender and their work did not receive full recognition. When discussing the historical context, it is important to address the challenges faced by female scientists and present how they overcame these, continuing to make significant contributions to science.

Making the Invisible Visible

Scientists have always built on one another's work, drawing inspiration from the scientists who came before them and from their colleagues. There is a need during the teaching of undergraduate degree programmes to provide examples of the collaboration required to complete experimental work and to highlight the contributions supplied by the supporting 'assistants', rather than providing isolated examples featuring a single 'figurehead' scientist.

How can we integrate stories of the significance of these less visible role-players into science education at university? One of the respondents to the inquiry mentioned in the introduction to this essay offered a

[1] Of the sample of physics students I asked, half had not heard of William Kay; the other half recognised the name, but could not remember who he was. All of them will have heard of Rutherford during their undergraduate degree [1].

suggestion from their personal experience: they had a lecturer who 'used to dedicate five minutes every lecture to talk about underrepresented scientists' [1]. The practical plan of devoting a set amount of lecture time to the inclusion of historical background to the scientific context, with a focus on the 'invisible' scientists, provides a solution.

Another student offered their perspective of one lecturer who included anecdotes in their lectures: 'he has some great little stories. Probably makes him one of the most interesting lecturers' [1]. Even the dedication of a small proportion of lecture time to providing anecdotes has a noticeable effect on student engagement. In addition to introducing students to the wide historical context of the theory studied during their degree, the inclusion of 'stories' within teaching is a useful tool to increase awareness and understanding [13].

To conclude, there is a need to provide a historical background to the scientific content studied at university level. Science educators should consider integrating anecdotes and historical context into their lectures, providing a focus on the under-represented groups. Instead of giving isolated examples of 'figurehead' scientists, lecturers should include references to the academic research team behind the 'figurehead', increasing the visibility of 'invisible scientists'.

Alexia Beale (Department of Physics, University of Surrey, UK)

References

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https://en.wikipedia.org/wiki/Denis_Papin (Accessed on 30th September 2023)

A physicist engineers bio-inspired composites

Dr Laura Rhian Pickard is a Senior Research Associate at Bristol Composites Institute, University of Bristol.

Following my degree in physics with astrophysics, I embarked on research into gravitational waves. The subject still fascinates me, but I found the day to day reality, largely coding, didn't suit me. I needed something more practical, where I could do hands on research and see the results getting out into the world and making a difference. While trying to decide what to do, I met a Professor of composites manufacturing at a conference, who mentioned an EngD project that needed someone with a physics background. It sounded exciting – a lab in a brand new, state of the art facility, novel research that would push the boundaries of knowledge while being directly applicable in industry, and a chance to make a growing manufacturing industry more energy efficient. I jumped at the opportunity and now consider myself both a physicist and a composites engineer.

I imagine most readers have heard of carbon fibre composites, and many will be aware of alternatives like glass, aramid and natural fibres. The fibre reinforcement is embedded in a polymer resin and the combination shaped into the required configuration and processed under heat and pressure. The resin either undergoes a chemical reaction (thermoset) or melts and solidifies at very high temperature (thermoplastic). My EngD research demonstrated use of active process control to minimise the energy used during this process. I also developed a new way of tracking defects using in-situ CT scanning, allowing us to better understand defects which occur during manufacture and hence avoid them – and so avoid wasting materials, effort and energy going into parts which end up being scrapped.

Making a composite part. Reproduced from [1].

Layers of material are built up into the shape required for the part, with the fibres oriented in different directions in each layer, optimised to deal with the forces the composite part will encounter in service. Under tension, the strength of the fibres – particularly carbon, aligned along the tensile direction – means a very lightweight part can perform far better than a metallic equivalent. This allows for lightweight aircraft, rail carriages, cars, bikes and ships, which require less fuel (or battery charge) than their metallic brethren. Composites are also vital for renewable energy generation through wind turbines, often made of glass fibre composite, sometimes with a carbon fibre leading edge on each blade. Other uses include civil engineering (there is a composite bridge not far from my house), sports equipment, medical prosthetics, hydrogen storage tanks – another area of sustainability research – and many more.

I'd like to share with you some cutting edge research being carried out today. For the past few years I have been part of a team working on NextCOMP: Next Generation Fibre Reinforced Composites [2]. Traditional fibre-reinforced composites perform very well under tension, leaving performance under compression as a limiting factor for many applications. Until now, this compressive performance has been far lower than tensile performance, NextCOMP aims to change that. We do this by taking inspiration from nature.

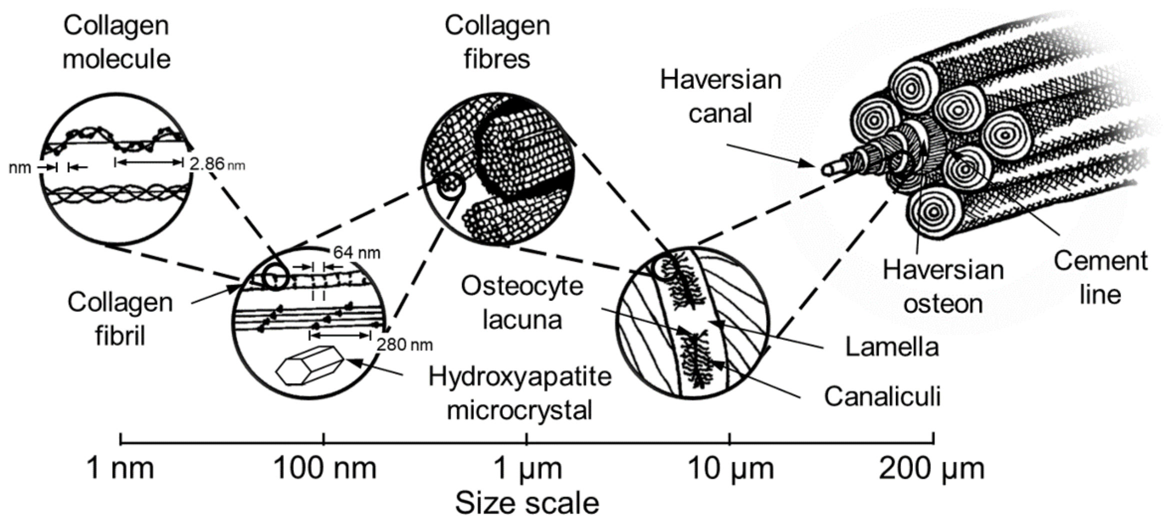


Illustration of hierarchical structure of bone. Adapted from [3].

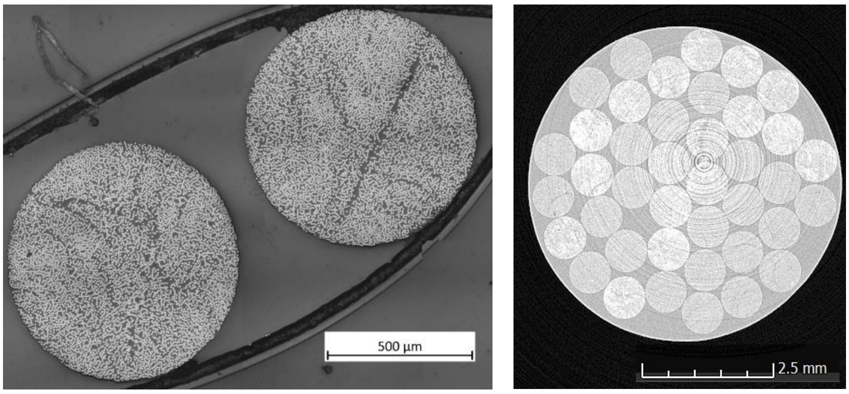
Natural composites, such as bamboo, bone, etc, have a hierarchical structure [4]. In bone, collagen molecules build up into fibrils. Fibrils then build up into fibres, and so on in similar fashion up the length scales until you reach the whole bone. Cortical bone is stronger in compression than in tension [5]. At each of these length scales there can be features which control the way the composite behaves under compression [6]. This is seen in a wide variety of living things, for example equine hooves have stiff tubules which act as reinforcements when the hoof is compressed under the animal's weight [7] and oat stems build hierarchically upwards from the molecules of the cell wall [8].

So how can we apply this to advanced composites? At the smaller length scale, our team are creating novel fibres [9] and resins [10]. At the next scale up, my colleagues have developed new approaches in traditional ply based systems [11] which use nature-inspired combinations of hard and soft materials to stop cracks propagating. My work looks at another option – moving away from the usual approach of layering plies, and instead use pultruded rods as an element with which to build composite structures.

The pultruded rods are themselves composites– consisting of highly aligned fibres surrounded by a resin matrix, usually a thermoset. They are made by pulling fibres under tension through a resin bath then a heated die, which cures the resin and gives the rod a regular, well controlled cross section.

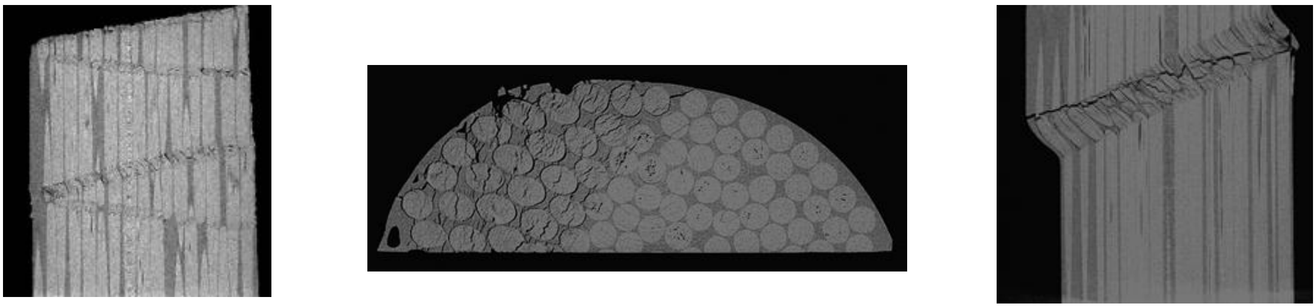
These rods are then used as elements to build larger structures, following the hierarchical approach. Fibres and resin build up into rods. Rods and another resin build up into larger parts, for example a cylindrical strut. These struts might then be used to make a truss, geodesic dome or similar structure. Other geometries can also be made, using a variety of different approaches.

Pultruded carbon fibre- epoxy rods



Hierarchical composite concept. Left: Cross-section of two pultruded rods inside sample clip taken using Zeiss microscope 20x lens, mosaic image with z-stacking. Right: Cross-section of cylindrical strut rod based composite, slice from X-ray Computed Tomography reconstruction of strut taken using Nikon XTH-320. Reproduced from [12].

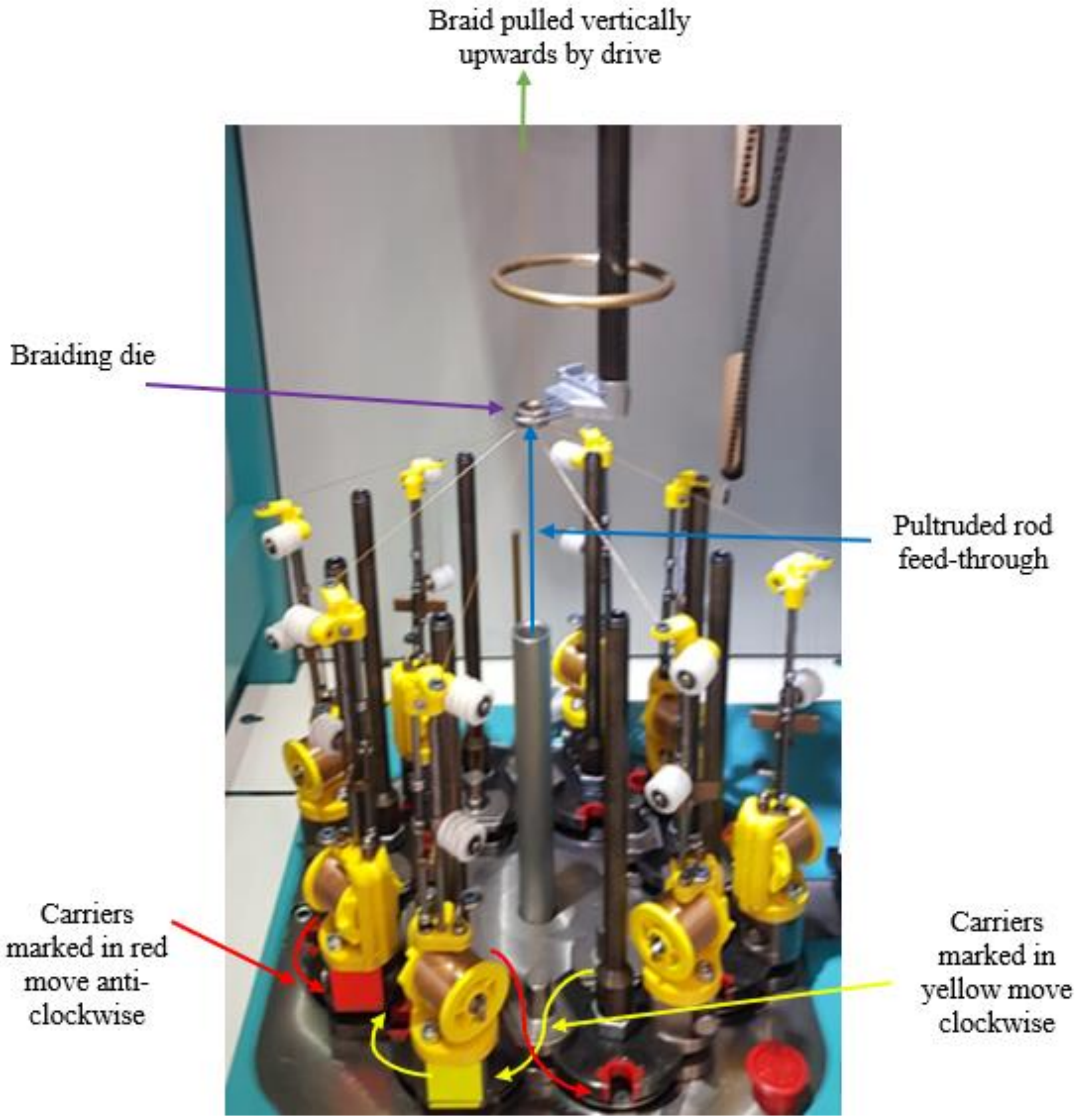
When composites are tested to failure under compression, microcracks form in the resin matrix and we see tiny splits between the fibres and matrix. The fibres bend, and ultimately break. As the fibres bend this applies forces to their surroundings, making fibres next to them bend, which results in a band of failures propagating across the sample – a kink band.



Samples from [13]*, CT scanned by L R Pickard using Nikon XTH-320. The centre and right images show a strut with a single, large kink band, as expected from a compressive failure. The image on the left has multiple smaller kink bands. This strut was overwound with Kevlar™, and required significantly more force before the failure occurred.*

We want to delay formation of these kink bands – so that the composite can withstand greater force before failing. This is where adding features to control behaviour under compression comes in.

We know from earlier work [13] that adding a tensioned Kevlar™ overwind around a strut as a whole improves its performance under compression, and compression after impact. The tight overwind suppresses the formation of the kink band. For our hierarchical approach, we want to apply the same principle at the rod level. We overbraid each individual rod, using a microbraider.



Herzog 1/16/80 circular maypole microbraider at half capacity, showing diamond interlace braiding setup with 8 yarn 273 dtex high modulus PBO. Reproduced from [12]

For rods of 0.7-0.8mm diameter we overbraid using 8 very small tows of fibre, with a simple diamond interlace pattern, and the shortest lay length we can achieve with our microbraider – around 1-2mm depending on the material.

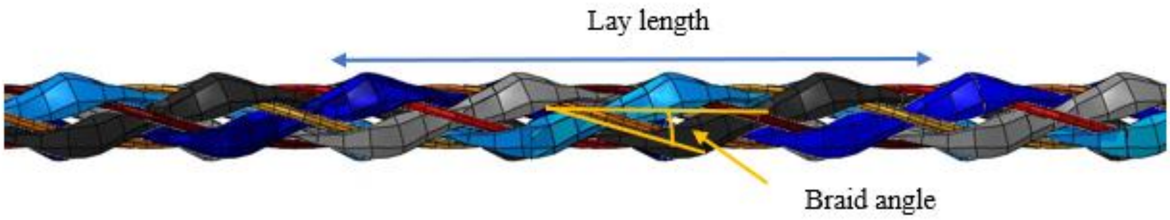
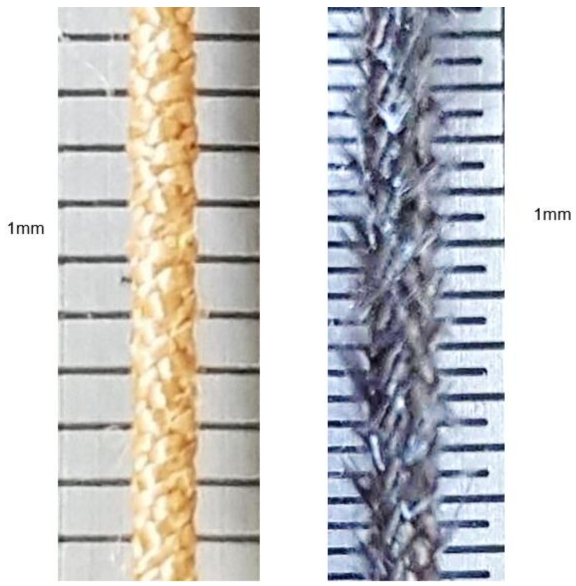


Diagram illustrating lay length of a braid, created using method from [14]*. Lay length is the distance travelled along the length of the braid while one tow makes a single revolution all the way around, 360°.*

Braids of aramid fibre (e.g. Kevlar™ or Twaron™) or Zylon™ (poly(p-phenylene-2,6-benzobisoxazole) aka PBO), conform well to the rod geometry and grip it tightly.

When we overbraid with carbon, the effect is rather different. Carbon fibre is far more brittle than aramids or PBO. So at short lay length some of the fibres within the tows break, creating a fuzzy overbraid. These fuzzy fibres extend out into the matrix surrounding the rod, increasing the contact region between matrix and fibre and hence providing more shear support. Work is ongoing to identify the optimum combination of tight gripping fibres and fuzzy fibres for the best possible performance under compression. These overbraided rods are then used to make struts, and the struts themselves can also be overwound, demonstrating the hierarchical approach.



0.8mm diameter pultruded rods overbraided with Zylon™ (left) and carbon (right). Reproduced from [15]

There are many use cases where natural materials can be used, such as fibres of flax, basalt or jute, and biologically derived resins. Basalt also forms a 'fuzzy' overbraid, but the broken fibres are longer and less dense than we see with carbon. For some applications, the material properties of these natural systems are not sufficient, and carbon is needed.

Research is ongoing to improve the sustainability of composites themselves – including my work on efficiency in manufacturing, minimising energy use and material waste. There is a lot of work going into recycling composites and moving to natural materials where appropriate. We are looking into integrating recycled carbon fibre into some of our hierarchical composites. Composite parts which last longer in service need replacing less frequently, so improving performance – including under compression – can help with this. While vital for a net zero world, making the composites themselves truly sustainable is a big challenge that is being actively tackled.

Like all research, this project has some unexpected and interesting applications. After moving to composites engineering I did not expect to encounter much particle physics again – but I have recently introduced fuzzy carbon overbraids to CERN! Helping the CERN team tackle composites challenges for experiments in the Large Hadron Collider feels like coming full circle, using both my physics and engineering knowledge. Watch out for our paper, and much more to come from this new approach to composites.

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What is it and what is it for?

What is it and what is it for? (see page 23)

ANSWER: This apparatus was used in physics teaching, to demonstrate expansion in metals. The brass sphere just fits through the brass ring at room temperature. However, if the sphere is heated it expands and will not fit through until it has lost some heat (causing it to contract slightly) while at the same time the ring absorbs some of the heat, causing it to expand. The ball then falls through after being watched for a short time.