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# ripping yarns: science in Asia

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In three previous articles in *New Zealand Science Teacher*[1] I have told a number of stories from the history of science – stories that are intended to illuminate the nature of science itself. Unashamedly to catch the eye, I chose to call them collectively 'ripping yarns', a label that has strong connotations from a bygone age of blissful imperialism. Actually, bubbling through the three new science stories in this article can be found one of the dominant features of the age of imperialism: uneasy race relations. The scientist in the first story, Austrian-American botanist Joseph Rock (1884–1962), who worked in China, has been described as "an egomaniac at best, a racist at worst."[2] Then there is science and technology historian Joseph Needham (1900–1995) who, initially through his research assistant and lover at Cambridge University, Lu Gwei-djen, ultimately came to be described as "the man who loved China"[3] and who, controversially, became an apologist for the newly constituted People's Republic of China. The final story features Indian J.C. Bose (1858–1937), physicist and botanist, who for decades contended heroically with the lofty and patronising attitudes of the British Raj science establishment.

However, each story also has its own particular purpose – to illuminate an important proposition about the nature of science. These propositions feature in the classic catalogue[4] of the features of science (Table 1) that I used in the three earlier articles. Since I wrote those fourteen stories, however, the need to explore the Nature of Science in classrooms, proclaimed in the banner headline across each page of our science curriculum of 2007, has taken on a greater urgency. I address this after I have told these three new stories.

### Rhododendrons, yak butter and brigands

Botanist-explorer Joseph Rock's idea of 'dinner in the field' was more elaborate and less communal than that of most scientists. Wherever he found himself in the great north-south corridor of the China-Tibet borderlands – in a steamy jungle, a forest of fir trees beside a rushing torrent, on a grassy plain beneath snow-clad mountains – Rock's evening expectations would be the same. The clean linen cloth would be spread on the folding table, the bottle of good wine would appear, and his cook (from the Naxi ethnic minority people) would serve, on a gold dinner service, dishes similar to those that Rock recalled from his boyhood in the twilight of the Hapsburg era in Vienna.

Later, after dining alone, and while his party of up to two hundred settled in for the night, Rock would relax his travel-weary body in steamy water in his Abercrombie and Fitch collapsible bathtub. Meanwhile, in the shadows around him, the servants attended to Rock's personal comfort; the porters unloaded the plant presses, cameras, and so on, thus releasing the yaks or mules for feeding and watering by the muleteers; and the mercenaries took up lookout stations, guarding against the ever-present possibility of brigands emerging from the anarchical countryside to attack the expedition.

In the first half of the twentieth century, other botanists, each with their carefully-guarded territory, worked on the resplendent and, at that time, little-known flora of the China-Tibet borderlands. However, Rock's flamboyant expeditions and his colourful personality have become an enduring part of the history of China's south-west. Much of this is due to the enigmatic and eccentric character of this stocky, 1.72m tall, habitually pith-helmeted scientist. It was not just that his temperament was volatile; it was that his personality was deeply contradictory.

Often charming in European company, he was privately perpetually lonely. He was both self-aggrandising and deeply insecure. He was frequently dismissive of Han Chinese culture and surprisingly obtuse about the Tibetan world, but he was nevertheless invariably affectionate, if somewhat patronising, towards the Naxi minority people who inhabit the area of the south-western province of Yunnan where Rock made his base near the town of Lijiang.

After a wearisome time in the remote country of the borderlands, he would long to be rid of China, but once back even in Shanghai (let alone Boston or Vienna) he would be decrying 'civilisation' and longing for the solitude and the grandeur of the China-Tibet borderlands. And all of these erratic foibles spilled over into his science. While his meticulous and pioneering botany was internationally greatly respected, his contributions to ethnography were generally seen by specialists as flawed because of his fascination with the macabre and the sensational. It was impossible to identify where Rock the scientist and Rock the idiosyncratic citizen of the world began and ended. Indeed, his life is a good example of the proposition that ***scientists participate in public affairs both as specialists and as citizens***.

Rock, by a combination of opportunism and bluff, suddenly became a botanist in his early twenties. Born into the lower classes in status-conscious Vienna, he had experienced an impoverished childhood, made more bitter by the contrast with his father's workplace – Franz Rock was a steward in the luxurious home of a wealthy Polish count.

At eighteen years of age, Joseph Rock left Vienna with no academic qualifications but having demonstrated a formidable memory and a gift for languages. (Ultimately, he taught himself eight languages, including Sanskrit; he began learning Chinese in Vienna at the age of thirteen.)

Drifting his way to the United States and, out of work in Honolulu, he successfully persuaded the Division of Forestry that he was needed as an herbarium collector. That day he blustered and charmed his way into a successful lifelong career, made possible by his orderly, systematic mind, his prodigious memory, his relentless energy for writing and exploring, his love of natural beauty and solitude, and his willingness to go where few trained botanists had ever penetrated. During his subsequent travels in India, Burma and mainly China over the next thirty years, he shipped more than 80,000 plant specimens back to institutions as prestigious as the Arnold Arboretum at Harvard University, Kew Gardens in London, and the Smithsonian Institution in Washington. He specialised in rhododendrons, had two new species named after him, and his numerous but irregular journeys back to London, Edinburgh, Berlin and Boston kept him well informed, and also enhanced his international prestige. Curiously, however, Rock never actually published any works on the botany of China.

Early in his time in China, Rock's attention was diverted towards another discipline – ethnography. In 1924 Rock, now an American citizen, secured a lucrative contract with *National Geographic Magazine* and over the next ten years "our man in China"[5] became known internationally to millions of readers through the nine articles he wrote. His achievements in this area are uneven. The articles contained stunning photography; amazingly, Rock was taking and developing *in the field* the first colour photographic plates in the 1920s. For example, such photos flamboyantly illustrated Rock's account of the production and display of the sculptured and tinted yak butter deities which formed the backdrop to the festive devil dancing at the Choni lamasery up in Gansu province.[6] However, his frequent claims to be "the first white man" to view aspects of indigenous life, or to explore a snowy peak or a river gorge betray (certainly to our ears today) at best a Eurocentric bias. With readership and funding no doubt in mind, his attention was frequently transfixed by macabre and sensational details; even the titles of his articles spoke of "weird ceremonies", "strange kingdoms", "brigand-infested central China", "holy mountain of the outlaws".[7] And he can be rightly accused of dismissively treating everyday people and customs with a high-mindedness that contrasted with the avid attention he paid the indigenous, so-called, kings and princes of the region. Approaching a settlement, Rock would often require his entourage to carry him into the town in a sedan chair, in order to impress the population, and especially its rulers, of his importance. It is hard to escape the conclusion that his attitude towards people in power was an outcome of the way he forever begrudged his own lowly beginnings in Vienna.

Rock's time in China finally came to an end in 1949 as Mao Zedong's newly constituted People's Republic of China required Westerners to vacate Yunnan province. Worn out by years of travel, by the perpetual threats to his physical safety, and now by indifferent health, Rock fled from his home of twenty-seven years near Lijiang. For the next eleven years he was a perpetual emigrant, always travelling, nowhere at home. He gave up ethnography and returned to his two early interests, botany and languages. Rock died of a heart attack in Honolulu in 1962, just prior to the publishing of the second volume of a monumental and still widely revered dictionary of the language of the Naxi people.

Joseph Rock's story reminds us that scientists are citizens too. Sometimes this becomes apparent when scientists become involved in public action-taking: Nobel Prize winners British crystallographer Dorothy Hodgkin, and New Zealander Maurice Wilkins, of DNA renown, also devoted much of their energies towards international peace and understanding[8]; and many climate scientists "are going out of their way as private citizens to say, 'Wake up! This is not a good thing to be doing.' "[9] And sometimes scientists' lives as private citizens spill over and, unintended, influence their specialist activities in science: there is evidence that the private religious views of scientists as eminent as Sir Isaac Newton and Charles Darwin inevitably affected their professional lives.[10] So, too, did Joseph Rock's private inner world impinge dramatically and erratically on his public work in science.

## Joseph Needham's great labour of love

Cambridge University historian Joseph Needham's long life (1900–1995) is remarkable for one titanic enterprise that he came passionately to embrace: the documenting of China's entire history of science and technology, and its contribution to world civilisation generally. Needham's clearest purpose was to promote cross-cultural understanding; in attacking Western complacency, he aimed to show just how many crucial scientific advances, in fact, originated in China – the invention of printing, gunpowder and the magnetic compass are three of hundreds of examples.

Needham's monumental labour of love comprised 18 hefty

***Table 1: Thirteen propositions about the nature of science (from Rutherford and Ahlgren, 1990), and seventeen stories from science that illuminate the propositions. The stories are either in the present article, or in three earlier editions of New Zealand Science Teacher.***

| Propositions about the Nature of Science | Stories from Science (and sources in NZST) |
|---|---|
| **The Scientific World View**<br>• The world is understandable<br>• Science ideas are subject to change<br>• Science knowledge is durable<br>• Science cannot provide complete answers to all questions | 'All knowledge is my province'-Frances Bacon's big claim (#113)<br>The spirals of life (#106)<br>Joseph Needham's great labour of love (#124)<br>'A plant is an animal standing on its head' (#113)<br>Harold Wellman-honest to a fault (#113) |
| **Scientific Enquiry**<br>• Science demands evidence<br>• Science is a blend of logic and imagination<br>• Science explains and predicts<br>• Scientists try to identify and avoid bias<br>• Science is not authoritarian | The case of the midwife toad (#113)<br>Why the Kaingaroa forest isn't grassland (#101)<br>What transpires in heartless vegetables? (#106)<br>Radio waves and brain waves (#124)<br>The shameful case of sex in plants (#106)<br>Knowing ourselves-bias in anthropology (#113)<br>Joan Wiffen, dinosaur woman (#101) |
| **The Scientific Enterprise**<br>• Science is a complex social activity<br>• Science is organized into content disciplines and is conducted in various institutions<br>• There are generally accepted ethical principles in the conduct of science<br>• Scientists participate in public affairs both as specialists and as citizens | Maize, mysticism and jumping genes (#113)<br>Facial eczema day at Ruakura (#106)<br>Andreas Reischek-the collector (#101)<br>Romanov DNA-from Siberia to sainthood (#106)<br>Rhododenrons, yak butter and brigands (#124) |

tomes when he died, and it is proposed that his appointees will conclude a 25-volume programme. With some disagreement, these volumes are revered as a supremely important contribution to humankind. Needham's story, one of passionate single-mindedness, rigorous scholarship, and political activism, tells us much about the proposition that ***science ideas are subject to change***.

Yes, we can all think of instances where the great ideas in science are successively replaced (for example, Newtonian physics by Einsteinium physics), but Needham's story brings another meaning to this proposition about the nature of science – that our constructions of science history themselves are subject to change by hindsight.

Historians of science are quite often drawn from the ranks of scientists themselves,[11] and so it was with Needham. After an intellectually stimulating but solitary boyhood in London, he embarked on courses at Cambridge University that led him into biochemistry and then embryology.[12] By 1935 he was working with the famous C.H. Waddington on one of the greatest scientific puzzles of the time: the identity of the 'organizer' responsible for inducing embryological differentiation. Needham's private interests were many – this tall, rangy, bespectacled, tousle-haired man, with a wicked grin and a piercing gaze, was also a nudist, a morris dancer, an accordion player and a chain-smoking churchgoer with a strong bent for philosophy and exploring the origins of cultures.

But Needham's world was to take a new direction late one summer day in 1937, when Lu Gwei-djen knocked softly and unexpectedly on his office door. A talented biochemist herself, who was fleeing from the Japanese invasion of China, the 33-year-old was offering to work with Needham and his biochemist wife of 13 years, Dorothy. Soon, fascinated by the forms and mysteries of Chinese characters, Needham was begging Gwei-djen to teach him the language. In little time, Needham's systematic and wide-ranging foray into Mandarin was causing him to fall in love, not only with the language, but also with China itself. And, inevitably, he found his admiration growing rapidly for the people who, over the last 3,000 years, had made this language their cultural continuum.

Needham's newfound love of China was no passing phase, and World War II provided an opportunity to pursue this passion – he was seen as the ideal person to fulfil the role of Director of the Sino-British Science Co-operation Office, in Chongqing.[13] So it came about that Needham's plane touched down in June 1943, in what is today the world's largest city, but what was then a place of war-ravaged chaos. Located in west-central China, Chongqing had been bombed more than 200 times in the previous three years, as the invading Japanese sought to destroy the city to which Chiang Kai-shek had moved his Nationalist government from Nanjing,[14] far to the east.

Needham set about his task with vigour – rebuilding scientific life in China by boosting morale and providing equipment and, more politically, waving the flag for Britain and establishing relations with the Chinese communists. By the end of the war he had carried out eleven expeditions (four of them major) and had covered 30,000 miles; he had visited nearly 300 scientific institutions and he had delivered thousands of tons of equipment.

But during his time in China, Needham also had a personal agenda. In 1942 in New York, he had confided a sudden idea to Gwei-djen: why not, one day, write a book that would explain to the Western world just how profound and enormous was China's contribution to science? His mission in China was an ideal chance to pursue that thought and, typically systematic, he had collected thousands of documents for this purpose by the time the War was over.

One very early, massively difficult expedition typifies his goal. In August 1943, Needham and a party set out from Chongqing in a converted Chevrolet ambulance for the far northern province of Gansu. Needham's objective was to visit Cave 17, one of the 400 man-made Mogao Grottos near the far western town of Dunhuang on the famous dry and dusty Silk Road. It was here in 1907, that an immense ancient Chinese library had been discovered, including a printed scroll that was now recognised as the oldest dated printed book in history. It is the 'Diamond Sutra', printed in AD 868. In other words, printers had been at work in China six centuries before either Gutenburg or Caxton set their own first books in type in Europe. As Needham's biographer Simon Winchester puts it,[15] "If any one thing in all creation gave the lie to the Western notion that China was a backward country, this was it".

Returning to Europe, Needham was called on to assist in the setting up of the United Nations Educational, Scientific and Cultural Organization – it is said[16] that "he was famously instrumental in putting the S in UNESCO" – but by 1948 it was time for his book to be born. Installed back in room K-I at Cambridge University (a room he occupied for six decades), Needham began writing *Science and Civilisation in China*.

Once started each day, he would work non-stop until long after dark, typing everything himself. The task was massive, and its completion ever-receding. Volume I appeared in 1954. By the time he died in 1995 there were 18 volumes; and by 2008 the faithful inheritors of the task had completed 24 volumes, comprising 15,000 pages and three million words.[17] It covers everything from the evolution of the most theoretical of mental models in astronomy and the nature of materials, across to things as pragmatic as the invention of the toothbrush (9th century AD) and toilet paper (AD 589). Beginning with what today would be called the pure sciences, it ranges into engineering, papermaking, ceramics, navigation, mining, metallurgy, architecture and painting. It ventures into areas where the very titles may to us seem "lost in translation": 'glyphomancy', 'ataraxy' and 'scapulamancy and milfoil lots'.

*Science and Civilisation in China* has had its critics, both in terms of its scholarship and its politics. Sometimes Needham has been accused of mistranslation; ambiguous writings in the ancient Chinese manuscripts, it is suggested, have been massaged into exaggerated claims for innovation in China. Other criticisms have been made about deep-seated assumptions: is 'science' universal, as Needham suggests, and can comparisons be meaningfully made, at all, between Eastern and Western science? Needham has been accused of being politically naïve – he lent his voice to calls for an international investigation into communist accusations that American forces were using biological weapons in the Korean War, and he was consequently denounced in the British press as a traitor and a stooge.[18] This has spilled over into hostility towards the Marxist framework he adopted in *Science and Civilisation in China*.

Needham's final years were marked by huge worldwide acclaim which, however, did nothing to distract him from the task. When Dorothy died, in 1987, he was briefly married to Lu Gwei-djen, whom he once tenderly described as "the explainer, the antithesis, the manifestation, the assurance of a link no separation can break."[19] Continuing to write to the end, Needham passed away in March 1995.

The notion of "re-writing history" is interesting. If someone tells you that you are "re-writing history", it is usually not a compliment. Instead, it is often an accusation that you are trying to persuade people (probably for your own dubious purposes) that past events took a different course from what is generally accepted. But, actually, there is a sense in which *all* history is perpetually and properly being re-written; the events of the past are forever being re-interpreted, not only as new evidence comes to hand, but also in the light of the set of ideas and theories which we hold precious today. In Russia, they sum this up with the pithy saying, "Russian history is unpredictable". So it also is with the history of science.

To expand the point made at the beginning of this story: science ideas *are* undoubtedly subject to change; many people can cite science theories that have been discarded and replaced – for example, in astronomy (the crystalline spheres of the ancient Greeks), in chemistry (phlogisten), in physics (the optical ether), in biology (spontaneous generation) and in Earth science (catastrophist geology).[20] However, the Joseph Needham story also tells us that science ideas are frequently perceived to change because *our account* of them changes, by hindsight.

### Radio waves and brain waves

In a lecture room in the huge old colonial-style Town Hall in Calcutta,[21] the 'City of Palaces', a large audience had gathered that day in 1895[22] and all eyes were on the short, portly, dapper figure of the Bengali scientist Jagadis Chunder Bose (pronounced 'Berzah') as he made the final meticulous preparations for the demonstration. At the appointed time there was no failure; to the crowd's wonderment and delight, at the flick of a finger, Bose activated the transmitter and caused the mysterious invisible waves to apparently hurtle right through the body of the chairman, Lieutenant-Governor Sir William Mckenzie, through three solid walls, and to activate a receiver 75 feet away in an adjacent room. In the words of Bose's 1920 biographer, Patrick Geddes, "the receiver … which curiously anticipated the antenna of modern wireless … at this distance still had energy enough to make a contact, which set a bell ringing, discharged a pistol and exploded a miniature mine."[23]

Radio waves had now been demonstrated in public in Asia. But this was no cheap trick turned on, circus-style, for mass entertainment; nor was it an all-or-nothing experiment designed to prove, one way or the other, whether radio waves existed. It was simply a sober demonstration of Bose's hard-won powers of logic and imagination. J.C. Bose[24] (1858–1937), often described as India's first modern scientist, was not a man to leave anything to chance, and his habitually authoritative exterior that day, as he drew his audience into advances at the very frontier of science, revealed how utterly confident he was in what he was doing.

Schooled in East Bengal (now Bangladesh), and having obtained his BA in Calcutta, Bose had travelled to England, where he first studied medicine in London, and was then awarded a scholarship to Christ's College, Cambridge University, where he took up physics. Bose immersed himself in James Clerk Maxwell's epic theorising about electromagnetic waves of various lengths, and also in the practical demonstration of their existence by Heinrich Herz. Bose's teachers included Lord Rayleigh and James Dewar, and his work – both theoretical and practical, especially his capacity to devise the most sensitive and robust of instruments – was later to win high praise from the great Lord Kelvin. But the decades following Bose's return to India in 1885 would show that there was even more to Bose's life in science than being at the world forefront of the invention of radio.

Later, Bose would turn to plant physiology and achieve distinction there; and, in the stultifying context of science in British colonial India, his grappling with an attempt to define, create and amplify a uniquely 'Indian' science was a brave, if initially doomed, enterprise. In an utterly astonishing way, Bose infused three careers – physicist, botanist and activist in the culture of science – with the notion that ***science is a blend of logic and imagination***.

Mention radio waves and, of course, the name of Guglielmo Marconi, the Italian scientist-engineer and businessman comes to mind. The research of Bose and Marconi has interesting parallels. During the 1890s, both were strenuously seeking to reduce the wave length of radio waves to a matter of millimetres (needed for effective transmission), and both were labouring to perfect a 'coherer', that is, a radio wave receiver.[25]

Around the time of Bose's demonstration in the Calcutta Town Hall, Marconi was gradually extending the range of his transmission, first over about a mile on his father's estate in Italy in the autumn of 1895, then in England across a distance of nine miles on the Salisbury Plain in 1896, and then, most dramatically, across the Atlantic Ocean, a distance of 1800 miles on December 12th 1901. But there were also important differences: Marconi had no academic qualifications in physics, Bose did; Marconi usually never lacked supportive working facilities and funding for his projects, Bose often did; Marconi had a great eye for global marketing, Bose's ultimate concern, as we shall see, was for the fortunes of science itself in Colonial India; Marconi was quick to patent his discoveries, Bose never did. And although both were acclaimed for their work, somehow Marconi received very much the major share – along with Karl Braun, he was awarded the Nobel Prize in Physics in 1909. Bose was nominated for a Nobel by his friend, the Bengali poet Rabindranath Tagore, but missed out, although he did receive a share of honours from the Western science establishment: he was knighted by the British government in 1916, and he was elected a Fellow of the Royal Society of London in 1928.

However, by the time these awards were made, Bose had dramatically switched his attention from heartland physics to heartland botany and, even wider, to the relationships between the living and the nonliving worlds. His capacity to monitor tiny electrical currents was the connecting factor in this stunning leap of the imagination, but there were also deep-seated philosophical reasons for his switch. Bose's work in physics had been entirely within the framework of mainstream or Western science[26] but now, around the year 1901, his research clearly began to show the influences of certain aspects of the Indian philosophical tradition, notably the doctrine of 'monism' – the notion that reality is in some sense one, that is, unchanging or indivisible or undifferentiated.

His views culminated in the publication of *Response in the Living and Nonliving* in 1902. The book's main theoretical importance was the propounding of the so-called Bosian thesis, namely that there is no discontinuity between the living and the nonliving. His strongest claim, that "inorganic matter possessed a specific property, electrical responsiveness, that was the fundamental property of life itself",[27] was in any literal sense, not one that the course of biological science has since sustained. However, in a number of more general ways (for example, ecological systems' thinking) Bose's insistence on the fundamental inter-relatedness of the living and nonliving worlds is not so controversial today.

Plant physiology emerged as the main thrust of Bose's research in his later years. Using instruments like his 'Crescograph', which was said to be able to record plant growth as small as 1/100,000 inch per second[28], Bose made contributions to studies in what we would call chronobiology, translocation, photosynthesis, and plant growth and responsiveness. Bose's plant physiology was in many ways the opposite of his physics; it was "eccentric, idiosyncratic, overwhelmingly prolific, surprising …" and "… it drew a mix of intense admiration and intense dislike among scientists in the West in a way his physics never did."[29]

The lack of acceptance was due to such things as the absence of any research tradition in which the work could be placed (no one else was measuring electrical responses across plant tissues, and it fell in a gap between physicists and physiologists); some regarded it as a work of philosophical rather than scientific interest; and, very significantly, the work was based on Bose's idiosyncratic

***Table 2: Connections between seventeen stories from science published in four editions of* New Zealand Science Teacher *and the 'Understanding about science' statements in* The New Zealand Curriculum. *Key connecting words are in italics. The curriculum statements are treated cumulatively rather than sequentially replacing. The five stories with a New Zealand context are asterisked.***

| Science curriculum statements: Understanding about science | Stories from science | Connections |
|---|---|---|
| **LEVEL ONE AND TWO**<br>• Appreciate that scientists ask questions about our world that lead to investigations and that open-mindedness is important because there may be more than one explanation. | - 'All knowledge is my province' – Francis Bacon's big claim (#113)<br>- Knowing ourselves – bias in anthropology (#113)<br>- Rhododendrons, yak butter and brigands (#124)<br>- The spirals of life (#106) | - His 'scientific method' was supposedly a way of responding to whatever questions were asked.<br>- Open-mindedness has been difficult because our approaches have been dominated by current values in society.<br>- Joseph Rock's open-mindedness was clouded by his temperament and the expectations of his reading audience.<br>- More than one explanation (nucleic acids versus nucleoproteins) competed in the DNA story. |
| **LEVEL THREE AND FOUR**<br>• Appreciate that science is a way of explaining the world and that science knowledge changes over time.<br>• Identify ways in which scientists work together and provide evidence to support their ideas. | - The shameful case of sex in plants (#106)<br>- Joseph Needham's great labour of love (#124)<br>- Maize, mysticism and jumping genes (#113)<br>- Facial eczema day at Ruakura* (#106)<br>- Joan Wiffen, dinosaur woman* (#101) | - Applying models for plant sexual life cycles allows us to explain and predict botanical mysteries.<br>- He rewrote the changes over time that have occurred in Chinese science and hence changed Western perceptions.<br>- Barbara McClintock and other geneticists worked together respectfully but from very different assumptions.<br>- Toxicologists, soil scientists, botanists and mycologists worked together.<br>- The scientific community initially worked together with her very unevenly. |
| **LEVEL FIVE AND SIX**<br>• Understanding that scientists' investigations are informed by current scientific theories and aim to collect evidence that will be interpreted through processes of logical argument. | - 'A plant is an animal standing on its head' (#113)<br>- Why the Kaingaroa forest isn't grassland* (#101)<br>- What transpires in heartless vegetables? (#106)<br>- Radio waves and brain waves (#124) | - Aristotle's erroneous idea that plants get their food from the ground guided current scientific theory for 2000 years.<br>- The cobalt-'bush sickness' link was discovered by dogged logic and inspired interpretation of evidence.<br>- The fruitless search for plant/animal analogies was contradicted by logical interpretation of Hales's experiments.<br>- J. C. Bose's extraordinary powers of logic and imaginative interpretation were applied to physics, botany and living/nonliving relationships. |
| **LEVEL SEVEN AND EIGHT**<br>• Understand that scientists have an obligation to connect their new ideas to current and historical scientific knowledge and to present their findings for peer review and debate. | - Harold Wellman – honest to a fault* (#113)<br>- The case of the midwife toad (#113)<br>- Andreas Reischek – the collector* (#101)<br>- Romanov DNA – from Siberia to sainthood (#106) | - He connected his new ideas about the South Island's alpine fault to a then-minority theory: plate tectonics.<br>- Lamarckian Paul Kammerer's difficulties in submitting to peer review culminated in his suicide.<br>- His activities would spark huge peer debate today, on conservation grounds.<br>- The atmosphere of fear and suspicion in the final Soviet years retarded processes of peer review and open debate in the use of DNA fingerprinting. |

ideas about what constitutes the 'sign of life'. In a sense, this was a tussle between Bose's powers of logic and his imagination. As one commentator puts it, "On the one hand, he was an experimentalist and instrument designer par excellence; on the other, his monistic metaphysics exceeded what his data could deliver."[30]

Bose's third career, as an activist in the culture of science, developed relentlessly as his life went on. When, as a young man, Bose was advancing into science in Calcutta in the late nineteenth century he had found himself in a profoundly discouraging environment. Western science had been very slow to establish itself in India over the previous three hundred years, and the prevailing view of the British colonial administration was that Indians were incapable of engaging in fundamental scientific research and that, instead, they should concentrate on applied technology.[31] This assumption impacted on Bose when – now impressively qualified from Cambridge University – he arrived back in Calcutta in 1885. He was offered a post at India's best-known college, Presidency College in Calcutta, as a junior professor of physics but only if, being Indian, he agreed to receive two-thirds of the regular salary. Bose famously protested by foregoing his pay and by relentlessly appealing to the authorities. Three years later he achieved pay parity.[32]

This incident cannot help but have propelled Bose's thinking along a pattern common in the development of science in European-colonised countries: from the initial sciences which accompany early colonial penetration (zoology, geology, geography), to a science which draws on established European practices and institutions, and then to a third stage – a somewhat independent science tradition, invented by scientists who are natives of, and culturally tied to, the colonised country. [33]

Bose's mind clearly began taking into account how, as one of his biographers puts it, "for centuries the Indian imagination had used nondualist thought to impose order on diversities, contradictions and oppositions, and a unified worldview on a fragmented society."[34] As we have seen, this awareness spilled over into the underpinnings of Bose's own research. However, Bose's imagination also caused him to question the very structure of organised science in India, and in 1917 he inaugurated an advanced research centre in Calcutta: the Bose Institute. Its purpose, according to Bose's dedication speech, was to defy the excessive specialisation in modern science and to capitalise on India's unique strengths: "Through her habit of mind (India) is peculiarly fitted to realise the idea of unity, and to see in the phenomenal world an orderly universe."[35]

If Bose's imagination had taken a leap which was difficult for some Western scientists to accommodate at that time, assessments now are more forgiving; for example, "Today, when biophysics is a generally recognised discipline and comparative physiology rests on a more scientific basis, the idea that animal and plant tissues exhibit similar responses seems less controversial and may even be taken as foreshadowing Norbert Wiener's cybernetics."[36] These days, there is a widespread acceptance that Eurocentric views of science and technology have "primarily de-developed the vast majority of the peoples who were supposed to benefit from such science and technology transfers."[37] A final thought: it is important that the developers of school science curricula do not perpetuate the myth that science is an exclusively Western, post-Renaissance activity.[38]

## Stories and the *NZ Curriculum*

Table 2 shows how the seventeen stories in four issues of *New Zealand Science Teacher* illuminate the thirteen propositions about the nature of science suggested by Rutherford and Ahlgren. Now – and not forgetting that all the stories actually comprise many rich cross-currents and issues about how science works – I have identified from each story one dominant aspect which aligns with key words in the 'Understanding about science' statements in *The New Zealand Curriculum* (see Table 2). I would stress that I have interpreted the statements cumulatively, that is, I assume that each contains a wealth of meaning that can be explored in greater and greater depth across each successive level of schooling. The stories are therefore to be selected and used in whatever way is most productive, appropriate and purposeful. Even better, they might inspire storytelling and story writing in others.[39] Overall, it is my hope that they will humanize, de-mythologise and enliven our science teaching.

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## Footnotes

1 Barker, M. (2002). *Ripping yarns – science stories with a point*, 101, 31-36; Barker, M. (2004). *Spirals, shame and sainthood – more ripping yarns from science*, 106, 6-14. Barker, M. (2006). *Ripping yarns – a pedagogy for learning about the nature of science*, 113, 27-37.

2 Mayhew, B., & Huhti, T. (1998). *Lonely planet: South-west China,* p. 378. Hawthorne, Aust: Lonely Planet Publishing.

3 Winchester (2008). See below, has been published under this alternative title in the United States.

4 Rutherford, J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

5 Edwards, M. (1997). Our man in China. *National Geographic Magazine*, *191*(1), 62-81.

6 Rock, J. (1928). Life among the lamas of Choni: Describing the mystery plays and butter festival in the monastery of an almost unknown Tibetan principality in Kansu province. *National Geographic Magazine*, 54, 569-619.

7 National Geographic Magazine 1924, #46, 473-499; 1925, #47, 447-491; 1925, #48, 331-347; 1931, #60, 1-65.

8 Ferry, D. (1998). *Dorothy Hodgkin: A life*. London: Granta. Wilkins, M. (2003). *The third man of the double helix: The autobiography of Maurice Wilkins*. Oxford: Oxford University Press.

9 Kolbert, E. (2006). *Field notes from a catastrophe – man, nature and climate change,* p. 131. New York: Bloomsbury.

10 Manuel, F. E. (1974). *The religion of Isaac Newton*. Oxford: Clarendon Press. Quammen, D. (2006). *The reluctant Mr. Darwin*. New York: Norton.

11 The philosopher Thomas Kuhn is an obvious example.

12 Many of these biographical details are sourced from Simon Winchester's (2008) superbly readable account.

13 Formerly Chungking.

14 Formerly Nanking.

15 Winchester (2008), p. 102.

16 Hessenbruch (1999), p. 868.

17 Winchester (2008), p. 9. It is published by Cambridge University Press.

18 Blue (2004).

19 Needham (1969), frontispiece.

20 French, S. (2007). *Science: key concepts in philosophy,* p. 95. London: Continuum.

21 That is, modern-day Kolkata.

22 Accounts differ as to the exact date. This is a sensitive point for those who would claim that Bose's initial transmission preceded Marconi's.

23 Quoted in Habib and Raina (2007), p. 314.

24 This is how he is usually referred to.

25 Bose's innovative coherer comprised a tube containing iron in the form of fine wire spiral springs with a layer of mercury between; radiation caused the system to switch to a conducting state, detected by a very sensitive galvanometer in the circuit.

26 Habib and Raina (2007), p. 328.

27 Ibid. p. 335.

28 http://www.vigyanprasar.gov.in/scientists/JCBOSE.htm, 07.04.09

29 Habib and Raina (2007), p. 345

30 Ibid, p. 338.

31 Ibid, p. 139

32 Kumar (2006), p. 218.

33 Habib and Raina (2007), p. 326.

33 Nandy (1995), p. 62.

35 Ibid, p. 60.

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# CoRes and PaP-eRs

**CoRes and PaP-eRs can be used as tools for promoting the pedagogical content knowledge (PCK) of novice (and not so novice) science teachers, writes *Anne Hume*, School of Education, University of Waikato.**

## Introduction

There has been increasing discussion around *pedagogical content knowledge* (PCK) as a useful idea for promoting teacher learning. PCK was first introduced by the America writer Lee Shulman (1987) in recognition of the very specialized professional knowledge expert teachers in particular subjects possess, e.g. the knowledge that an expert science teacher has that sets him/her apart from any scientist expert in that field. Shulman credited these expert teachers with the ability to carry out teaching as a complex and challenging activity that required ongoing and informed decision making in response to individual student's learning needs, rather than just the simple transmission of information from teacher to students. He maintained that they possess a special blend of science content knowledge and pedagogical knowledge for teaching particular science topics to particular groups of students, which is built up over time and experience and which he termed PCK. PCK is topic specific, unique to each science teacher, and can only be gained through teaching practice. However, it is a very difficult form of knowledge to describe and exemplify because experienced teachers very rarely discuss or share it with fellow teachers – often because there are few opportunities in busy professional lives to do this, and also because of its fluid nature, constantly changing and evolving as classroom circumstances dictate. Thus PCK tends to remain hidden as tacit rather than explicit knowledge.

Since Shulman first introduced this notion of PCK, other writers have begun to explore, debate, and expand upon its nature. Magnusson et al., (1999) identified five components of a science teacher's PCK that there is some agreement on in the science education field. These components include his/her:

- orientations towards science teaching (the teacher's knowledge of science and the nature of science, and beliefs about science and how to teach it)
- knowledge of curriculum (what concepts and skills to teach and when to teach)
- knowledge of assessment (what to assess, why and how);
- knowledge of students' understanding of science (including their prior knowledge and misconceptions and potential misconceptions)
- knowledge of instructional strategies (proven appropriate and effective).

The specific PCKs that teachers will need to develop during their teaching careers require a great deal of professional learning. Classroom teaching experience is essential for building this knowledge; but imagine the value to novice science teachers of having access to such knowledge that already exists! Not to mention those teachers already in the profession who lack expertise in particular science content areas, such as the physics specialist who is asked to teach biology in junior science programmes. Until recently there have been few concrete examples that are applicable to science teaching.

## Developing PCK exemplars

About six years ago a group of science education researchers at Monash University, began investigating if they could 'capture' the PCK of some expert science teachers for use in initial teacher education. Loughran et al. (2004, 2006) identified a number of expert science teachers in their local area, and invited them to participate in a research project to see if their aim of capturing expert PCK was feasible. To help the teachers recognize and depict components of their PCK, Loughran et al. created strategies known as Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs).

The CoRes are templates which attempt to portray collective overviews of expert teachers' PCK related to the teaching of a particular science topic and are accompanied by PaP-eRs, which are narratives about how specific aspects of the topic aligned to the CoRe have been taught by the expert teachers – each CoRe has a set of related PaP-eRs (see Figure 1 over page).

## Use of CoRes and PaP-eRs in science teacher education

The CoRes and PaP-eRs developed by the expert science teachers in the Loughran et al. study are presented in the 2006 publication *Understanding and developing science teachers' pedagogical content knowledge* by J. Loughran, A. Berry and P. Mullhall.

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36 Susskind (1980), p. 325.
37 Harding, S. 1998). Is science multicultural? Postcolonialisms, feminisms and epistemologies. Bloomington: Indiana University Press, p. 7
38 Hodson, D. (1998). Science fiction: The continuing misrepresentation of science in the school curriculum. *Curriculum Studies*, 6(2), 191-216.
39 See *New Zealand Science Teacher*, #113, p. 27.

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