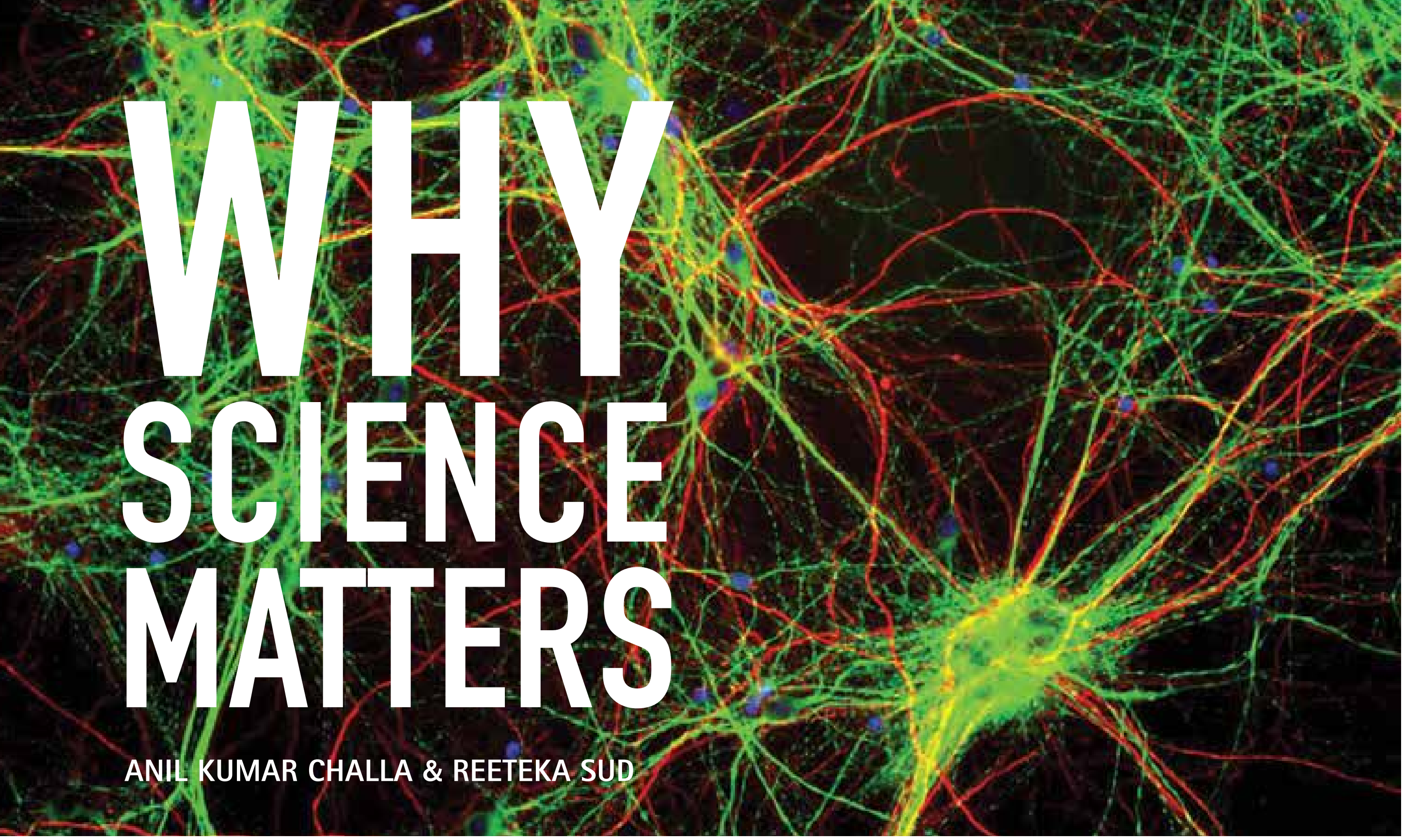

WHY SCIENCE MATTERS

ANIL KUMAR CHALLA & REETEKA SUD

Science is more than a body of knowledge; it is a way of thinking. Our aim, above all else, should be to foster scientific thinking in students. If students seem bewildered about the need to study science, our response to them has to go beyond the cool gadgets and ease of life that scientific advancements have brought us.

The modern usage of the word 'science' refers to a systematic study of the natural world in its many facets. Perhaps the best example of this can be seen in the San, hunting tribes indigenous to South Africa. Their hunt for an animal starts with an observation (pug marks in sand, etc), a hypothesis is formulated (direction the animal went), a course of action is decided (the equivalent of research methods), and pursued till conflicting evidence is found (overlapping pug marks) – at which point an alternate hypothesis is formed. Even though the San are miles away (literally and metaphorically) from the schooling you and I see in the "civilized world", we can see their actions follow the same thread as any scientific investigation: observation → hypothesis → experimental methods (to test the hypothesis) → record results → analyse results (whether they support or contradict the hypothesis) → in case of contradictory results, develop alternate hypothesis and follow-up accordingly.

How does this process lead to progress in science? The history of scientific pursuit somewhat resembles the ancient parable of six blind men describing an elephant[1]. Each one is trying to figure out what an elephant is, by touching one part of it. In so doing, one of the men likens the elephant to a fan (by touching its ear), another to a pole (its legs), a third to a rope (its tail), and so on. Similarly, different scientists, in different countries or even in different eras, pursuing differing questions have followed essentially this same process, and continue to do so. Through this process, a body of knowledge is generated over time. The progression from first observations is hardly ever linear, unlike what textbooks will have you believe (and this is where confining ourselves to science textbooks can be misleading!).

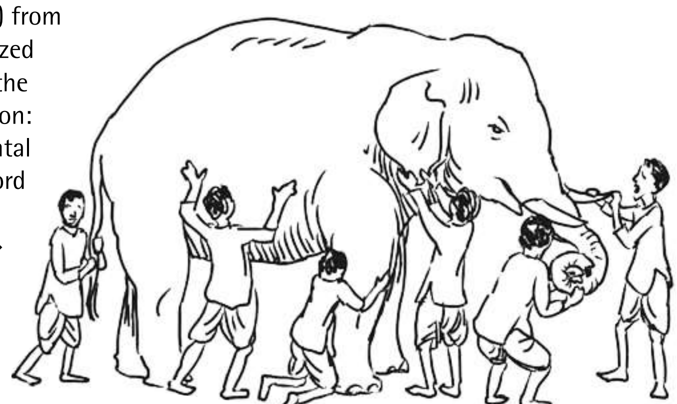

Fig. 1. The six blind men and the elephant.

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Fact or myth:

Does the cold weather make you catch a cold?

The virus that causes common cold infects the mucus lining the insides of the nose. In the 60s, scientists found that the virus multiplies much faster at cooler temperatures. But why this is so wasn't known until 2015, when a team of Japanese scientists reported that this is not because the virus adapts better but because our immune system falters at cooler temperatures. Why our immune system falters at lower temperatures remains an open question.

Should you take antibiotics when you have a cold?

Antibiotics (anti = against; bios = life), also called anti-bacterials, only work against bacteria. Common cold is caused by a virus, and antibiotics cannot destroy viruses[2].

Why should we care about this iterative nature of science? When students are quizzed on their understanding of topics in the Biology curriculum, the Cell Theory for instance, they can recite the core principles of the Theory, but are unaware that it is the culmination of more than 300 years of research (refer 'The wacky history of Cell Theory' at http://ed.ted.com/lessons/the-wacky-history-of-cell-theory), with contributions from scientists in many branches of science (Botany, Zoology, Physics, Chemistry and Maths). A failure in understanding the nature of the scientific process can have many consequences on the way students perceive the practice of science – ranging from general distrust to the outright denouncement of scientists. Distrust of scientists by the general public raises its head frequently enough, on a variety of issues – from climate change and genetically modified crops to vaccination in children. In every one of these cases, hearing opposing sides of the same issue can be (and often is) misinterpreted as a "lack of knowledge" among experts. Our contention in this article is that this distrust is linked to the lifelong learning of science as a "compilation of facts", with no effort devoted to how these facts, as we know them, come to be. Interpretation of new knowledge is frequently debated before being accepted by the scientific community. If we only think of science as being a list of answers (or facts), then open questions can be unsettling, as has been the case with climate change. Is the current crisis of global warming natural? Or are humans causing it? Which of these is true?

Science is more than a body of knowledge; it is a way of thinking. Our aim, above all else, should be to foster scientific thinking in students. Folklore and anecdotes can make their way as "immutable facts" instead of testable ideas into students' lives. Time spent in the science classroom ought to give them tools to critically analyse the stories they hear. They ought to question "common wisdom" in things like "cold weather makes you catch a cold", or "the human body is designed for a vegetarian lifestyle". Science classrooms should give them the tools for doing so, along with skills of critical analysis.

The history of science is also replete with examples pointing to the limits of our knowledge and underscoring how factual knowledge in science is subject to the tools available at a given point. An interesting case from the history of neuroscience offers an excellent example of how improvements in tools lead to an enhancement of knowledge. Italian scientist Camillo Golgi has

Fig. 2. Cajal and Golgi. (A) Santiago Ramón y Cajal in the library of the "Laboratorio de Investigaciones Biológicas" (ca. 1930). In the left-upper part there is a picture of the Helmholtz gold medal, one of the more renowned prizes and one of which he was especially proud. Cajal was very popular in his country as can be seen by the use of his portrait on a 50 pesetas bill (paper currency, bottom-left). (B) Picture of a microscope, some colorants and some histological tools used by Camillo Golgi, conserved in the Museum of Pavia University, Italy (upper-left). Golgi also was a very popular scientist in his own country. This can be seen by the commemorative stamp produced by the University of Pavia tocelebrate the centenary of the discovery of his impregnation method, the "reazione nera" (bottom-left).

Credits: Juan A. De Carlos, José Borrell from the article - A historical reflection of the contributions of Cajal and Golgi to the foundations of neuroscience. Brain Research Reviews 55 (2007) 8-16.
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made innumerable contributions to the development of Biology, including a technique to visualise brain tissue that he was the first to develop in 1873. Although the postulates of the Cell Theory were widely known (since 1838-39), no one realized that it applies to cells of the nervous system too. An alternative explanation, called reticular theory, was gaining ground instead. According to this theory, the nervous system was formed from continuous fibres that formed an intricate network. Golgi's method allowed him to visualize nerve cells in their entirety. But seeing highly branched membranes, he too concluded that the reticular theory held merit (we know these branched parts as dendrites today). It wasn't until later that a Spanish scientist by the name of Santiago Ramon y Cajal made significant improvements in Golgi's method. Consequently, the anatomic features of nerve cells, and their organization in different parts of the brain, became distinctly clear to him. He first published his results in 1888, supporting "neuron theory", which stated that brain tissue was made up of distinct cells, like every other tissue in the body; and was no exception to the Cell Theory as the proponents of reticular theory (including Golgi himself) thought. In spite of their interpretations being polar opposites of each other, both Golgi and Cajal laid the foundations of neuroscience, and were jointly awarded the Nobel Prize in Medicine in 1906.

By incorporating stories of *how* discoveries are made[3], students also become familiar with the broader context into which the syllabus fits. What better way of stimulating their curiosity than by stories of key discoveries coming from [a scientist] following their curiosity! This strategy offers the added advantage of hooking student attention, since our brains relate to stories much better than they do to facts read from books.

Another way of exposing students to the process of science is by organising visits to research laboratories. Students are not only able to look at the practice of science but can also interact with scientists— ask them questions about what they do, why, why this particular problem, and the like. The point isn't to get all of them to grow into future scientists, but to help them develop into scientifically literate citizens of the future. Science education can enhance students' perception of themselves, their immediate surroundings, their communities and ecosystems, and the planet at large.

Thus science can help students when they confront real-life questions – is genetically-modified food safe for us? Should Indians be worried about contracting infection from drug-resistant bacteria? Is climate change man-made or does it happen in the natural course of earth's history?

The clarity of our perception depends on the quality of tools at our disposal. As young minds engage with life and learn about how things work around them, it makes sense to have effective tools. The question is – are we giving today's students the best tools to help them deal with challenges of tomorrow? Science is critical in enabling human perception through continuously improving and evolving tools. And that is why science matters.

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Further readings:

1. Wikipedia contributors. "Blind men and an elephant." Wikipedia, The Free Encyclopedia. Web. 4 Nov 2016. URL: https://en.wikipedia.org/wiki/Blind_men_and_an_elephant.
2. Dworkin, B. 2003. Why antibiotics don't kill viruses. Web. 4 November 2016. URL: http://www.drbarrydworkin.com/articles/medicine/infectious-disease-articles/microbiology-101-why-antibiotics-dont-kill-viruses/
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