Classroom

In this section of* Resonance,** ***we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. "Classroom" is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.

? Diatomic molecules of the type A-B are polarised such that the more electronegative atom has a negative charge. However carbon monoxide (CO) has a small dipole moment with the negative end at carbon? What could be the reason?

? We are familiar with σ and π bonds in molecules. Can there be a δ (delta) bond? Is there any well characterised example of a compund containing a δ bond? (Hint: This may be treated as a question in inorganic chemistry.)

? In a laser beam, many photons occur with the same direction, frequency and polarisation. Is this an example of Bose-Einstein condensation (BEC)?

? A collection of non-interacting Bose particles exhibit BEC at low temperatures. How is this possible in the absence of interparticle forces? One usually assumes that an ideal gas does not condense.

! On Bunsen Burners, Bacteria and The Bible.

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One of the key concepts of microbiological and biotechnological work is aseptic handling. One may be handling plant or animal tissue cultures, microbial cultures, injectable drugs or the like; it is essential to keep them away from contaminating micro-organisms. Micro-organisms are present in the air, on solid surfaces, on the skin of the worker and they are thrown out along with coughing, sneezing or even breathing by the worker. This makes things tricky. One can sterilize bottles, test tubes and media. How are we to sterilize the air in the working room, or ourselves for that matter? Nonetheless, there are ways of working which reduce the probability of contamination to an acceptable low level. These are called aseptic techniques. Industrial, analytical or research units usually have a device called laminar flow system in which sheets of sterile air are passed over the working area. Laminar flow systems are somewhat expensive; all undergraduate teaching laboratories cannot afford them.

What do the undergraduate laboratories then do? The students are told to take a pair of bunsen burners and keep them burning at a distance of roughly six inches from each other. One is supposed to work within this six inch zone which is comfortably sufficient after some practice.

Three years ago I was explaining this concept to a batch of first year B.Sc students in exactly the same way I had heard it from my teacher some fifteen years ago. "Look, when you light the burners, the air expands and moves away. So if you open the mouth of a test tube in this area, contaminants from the outside air are unlikely to enter the test tube. You can get your work done aseptically".

Batch after batch of students, have accepted these arguments. But that day one particularly adamant boy did not oblige. We argued

Some fifteen years ago my teacher had told me: "Look, when you light the burners, the air expands and moves away. So if you open the mouth of a test tube in this area, contaminants from the outside air are unlikely to enter the test tube. You can thus get your work done aseptically".

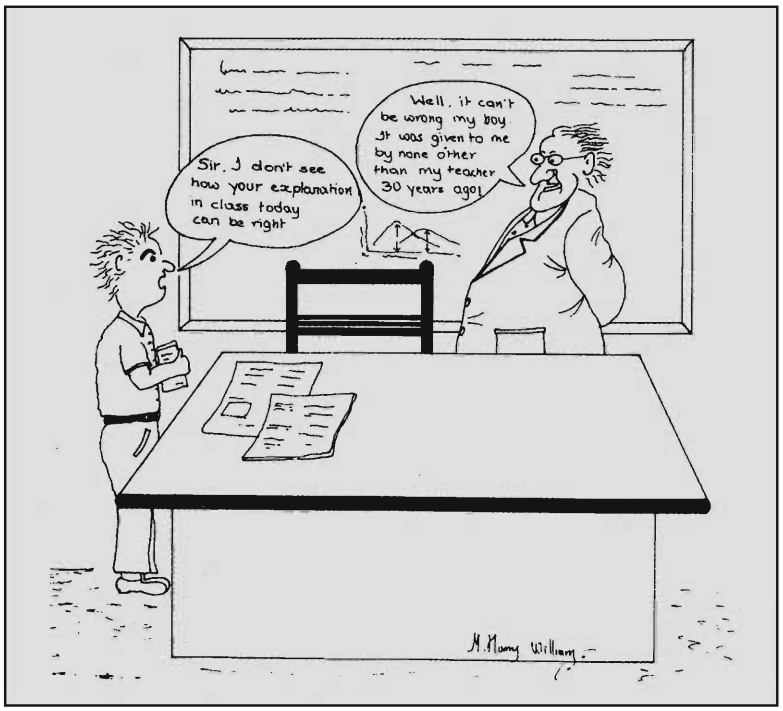
To confirm the aseptic technique which my teacher taught me, my students and I decided to look at the distribution of bacteria themselves in and around the burners.

about the air currents but did not reach a consensus. So we decided to experiment. An easy way, I thought, would be to generate visible aerosols so as to have a visual idea about them. We burnt some paper and took the small charred pieces that drift with the slightest air current. This worked to some extent, but no clear picture emerged. Then we decided to look at the distribution of bacteria themselves in and around the burners. A very simple technique is to expose gels of nutrient media for a defined time in specific locations. If bacteria floating in air come in contact with the gel, they get stuck and start growing because of the nutrients provided. If incubated overnight, they form visible colonies which can be counted. This does not ensure a count of the total number of organisms in a unit volume of air, but gives a relative account of the aerial load of micro-organisms. We did the experiment by exposing nutrient agar plates at various distances and heights from the flames of the bunsen burners and incubated them. The next day I intended to demonstrate that the plates exposed within the six inch aseptic zone carried a few or no bacteria, and as the distance from the burners increased, the number of colonies on the plates increased.

To my surprise it didn't work! The plates exposed within the aseptic zone had nearly the same number of colonies as those exposed a couple of feet away. Why was this so? Something must be seriously wrong. It made me think harder of all possible ways in which the experiment could have gone wrong. I carefully redesigned the experiment. The time of exposure was more rigidly standardised. Randomization was introduced to get rid of possible biases such as distance from wash basin, distance from the experimenter and so on. With the help of fifteen students, we exposed thirty pairs of plates within and outside the aseptic zone, this time with the hope of getting a 'correct' result.

We were expecting to demonstrate that within the six inch aseptic zone there would be few or no bacteria. To our great surprise, this didn't happen.

We took the counts the next day. To my disappointment the counts hardly differed. I tried all possible statistical jugglery that I knew, to try and show at least marginal statistical significance, so that I could somehow push the argument and save my face. But



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We redesigned the experiment more carefully, introduced randomization to eliminate biases, but the bacterial count within and outside the aseptic zone hardly differed!

all parametric and non-parametric methods failed to show a significant difference.

Then I suddenly felt "why should I try to save my face?" So far I had accepted an argument because my teachers said so. It is not necessarily correct. Now that the experimental findings went against what I was taught, should I believe my teachers or should I have more faith in my experimental results? Certainly, I should trust my own findings, in the true spirit of science. It took a little time for me to become determined enough to declare in the class that the lesson that we had learnt from our teachers was certainly wrong.

On the basis of our experimental findings, I had to conclude that the lesson which my teachers taught me was certainly wrong.

I then decided to carry out a deeper investigation into the origin of this concept. I discovered that no textbook clearly advises us to work within the space of two burners. There is no authentic report that quantitatively studies the microbial load of the so-called aseptic zone. Most of all, the aseptic zone concept seems to be

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restricted to only a few universities, where it is propagated by vertical transmission. I say so because my teachers said so, who in turn took it from their teachers, the origin being uncertain. I talked to a large number of microbiology teachers and their reactions were surprising. The most common reaction was "May be, if you say, it could be so." ("but", reading between the lines, "we will continue teaching the same.") Another common reaction was, "working between the burners may be ineffective, but what can we do if we can't afford laminar flow systems?". (This is like trying to light an electric bulb with a match box and saying: what else can we do if there is no power?). One teacher said, "Oh, as it is, we have to teach a lot of rubbish. What difference does it make?" I wish at least one teacher had repeated the experiment and checked it himself. Out of all the students who participated in the experiment, only a handful really believed in their own experimental results and were ready to defend it. Others took a very diplomatic stand — they declared that if their examiner believed in an aseptic zone, it was real. If he didn't, it wasn't.

There are many generalizable lessons arising out of this story. It reflects our style of science teaching in general. We teach science as if we were teaching the Bible, the Bhagavad Gita or the Koran. Every word in those texts is sacred and unchallenged. If you happen to observe something which contradicts what you are supposed to teach, then your observation must be wrong. The textbooks and the teachers are the supreme authorities. So whatever the textbook says is correct and whatever the teacher says is final. So well-trained are our students in this tradition that before they peep into the microscope, they know what they are supposed to observe and they observe and draw it, even if a mischievous teacher like me puts a blank slide under the lens. As a student goes to the higher classes, his natural instincts are killed and he becomes a blind follower.

Our college students are so well-trained to believe that the teacher's word is final that before they peep into the microscope, they know what they are supposed to observe and they observe and draw it — even if a mischievous teacher like me puts a blank slide!

One might have a different experience in high school. With just a little encouragement, the students explore things on their own, observe more honestly and interpret more independently. Let me

relate, for comparison, a school experience. There is an experiment in textbooks about measuring the percentage of oxygen in air. What the textbook prescribes is this: take a bowl with a little water, light a candle at the centre and then place an inverted glass over it. Soon the flame gets extinguished and water will rise in the glass to occupy about 20% of its volume. This proves that oxygen occupies 20% of the volume of air. I remember the experiment as well as the figure in my textbook, decades back. Nothing has changed. As a student, I had accepted it blindly. We used to have our experiments only in books. The concept of doing an experiment was simply non-existent. As a teacher, I started doubting the experiment. What about the carbon dioxide produced? What about the temperature changes associated with burning and extinguishing the candle? Won't the air expand and contract?

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One batch of students actually did the experiment. It works, in the sense that some amount of water rises. What I was astonished by was a variation of the experiment. One boy decided to burn two candles instead of one. To everyone's surprise, water was seen rising to a higher level. What followed was the most logical conclusion from the students, "When one burns two candles, there is more oxygen in the air!".

I leave it to the readers to do the experiment and reach their own conclusion.

Did you know? ... One can measure deformations that are less than an atomic diameter — provided they are oscillatory and thus can easily be transformed into electric signals. The human ear can also "measure" similarly small deformations of the eardrum. (from *Quantum*, September-October 1995).

Did you know? ... It is possible to combine opposite mechanical properties in "composites" — compound materials that include a light pliable base and a fibre filling made of a very strong material. (from *Quantum*, September-October 1995).