$\Theta = 0$ and β^2 is negligible compared to unity. This theory is rather reminiscent of the Compton theory of X-ray scattering by electrons.

We can easily generalize this theory to discuss the Doppler effect in a medium. If the refractive index of the medium is μ then we change β to $\mu\beta$. An interesting possibility in a medium is that the source can move with a velocity greater than the velocity of light in that medium i. e., $V > c/\mu$. Then a careful analysis leads to the surprising result that even if the source is not initially excited, it will be excited with the simultaneous emission of photons inside the Cherenkov cone $(\Theta < \Theta_0 = \cos^{-1}(\frac{1}{\mu\beta}))$. Then the excited source will make a transition to the lower state emitting photons outside the Cherenkov cone $(\Theta > \Theta_0)$. This is not a paradoxical result since the energy needed for exciting the source and for the emission of the photon are both derived from the kinetic energy of the source.

Suggested Reading

- **V L Ginzburg, L M Levin, M S Rabinovich and D V Sivukhin.** ***Problems in undergraduate physics.*** **Pergamon Press, 1965.**
- **V L Ginzburg.** ***Waynflete Lectures on Physics.*** **Pergamon Press, 1983.**

! Microbiology as if Bird Watching

Milind G Watve, M.E. Society, Abasaheb Garware College, Karve Road, Pune 411 004, India.

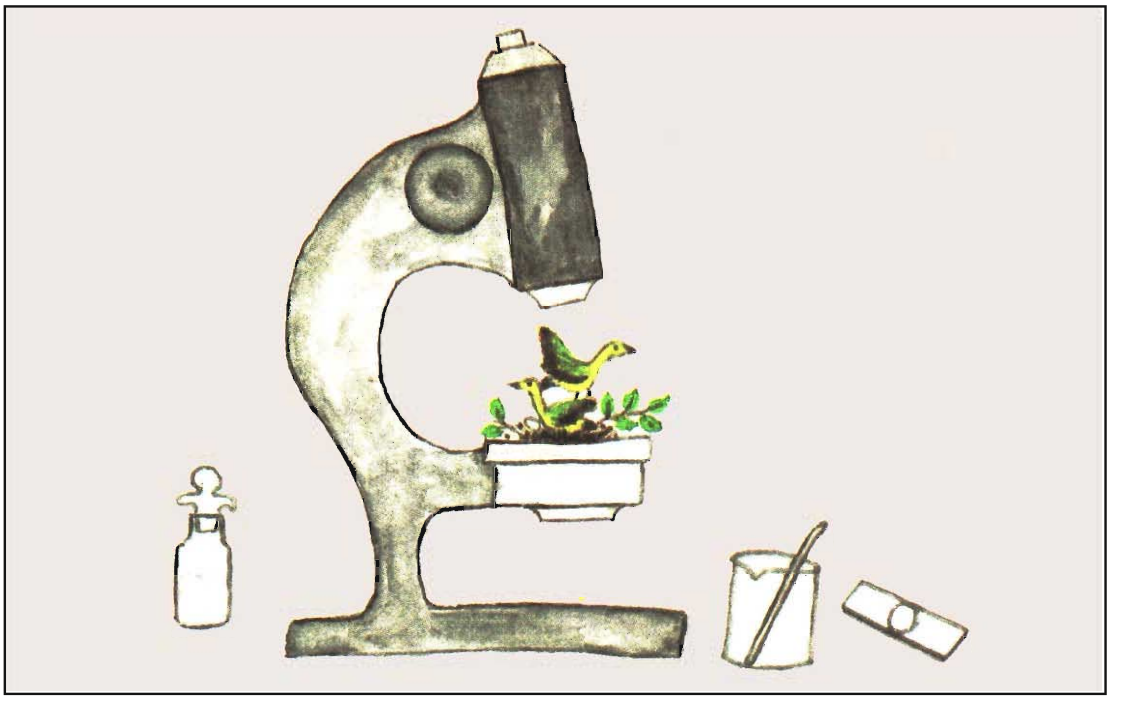
I became a bird-watcher much before I started studying Microbiology for my Bachelor's. I wasn't sure why I opted for Microbiology. Perhaps just by default, since in those days, there were few options for a student not going into medicine. I was equally uncertain about taking bird-watching seriously. It just so happened that one of our instructors, in a sort of hobby-club to which I subscribed in my high school days, took us bird watching once or twice. Somehow, this hobby lingered on and became more and more absorbing. Today I can say with confidence that if I am a good microbiologist, it is because of bird-watching.

When we started our course in Microbiology, I found it extremely monotonous, dry and rigid. I always compared it with bird-watching which was juicy, enlightening and ever- challenging. I always wondered what caused the difference. It might have been the beauty and the grace of birds, or the fact that they had simple names in English and vernacular so the Latin names did not trouble us, or just the feeling of being out of doors, or was it something else?

Today I think I have identified the most important reason. Our microbiology teacher showed us — "This is E. coli. It forms pink colonies on MacConkey's agar because it ferments lactose and produces acid. Salmonella produces colourless colonies because it does not ferment lactose." The bird watching instructor, on the other hand, had a different approach. "What will you do if you see a strange bird ? Note its size in comparison with known birds. Look at any peculiar features — the beak, the tail, shape of wings, style of flight, whether it hops or walks when on the ground. Draw and describe whatever you see. Then go to the library, get Salim Ali's or any other bird book and discover yourself." This I think was the key. Our formal training in Microbiology, Zoology or Botany seldom encouraged us to 'discover things by ourselves', be it a different type of colony, an odd insect or a weird mushroom.

Since our M.Sc course was the first one everything was crude, unstandardized and uncertain. This, I think, was the best that could have happened to us. Since we had to take the initiative, we started exploring.

Fortunately our M.Sc. course was full of opportunities for exploration. Ours was the first batch in the post graduate course at our centre. Everything was crude, unstandardized and uncertain. This, I think, was the best that could have happened to us. Since we had to take the initiative, we started exploring. We very soon came to realise that the microbial world was in no way less fascinating than birds. In fact it was much more diverse, beautiful and lively. There weren't only rods and cocci, there were the charming rosettes of stalked bacteria, the beaded spirals of actinomycete spores, the army ant like scavenging swarms of gliding bacteria, the never ending long beggiatoa, the star-shaped, pear-shaped, needle-shaped and ribbon-shaped odd



species and of all the brightest colourful flowers of the earth — the myxobacterial fruiting bodies! And all of them were very easy to find. The key to finding them was to be always curious and be on the look out and venture beyond the text-book methods.

Exploration led to frustration at times when the forms observed did not match anything in the literature. Several years later I read that above 90 % of the microbial world remains unexplored. There are 4000 different types of DNAs (and therefore as many types of microbes) to be found in one gram of soil. If we plate out, we get some 50–60 types of colonies. Many of them are unknown to science. Stretch your imagination, try a novel method of cultivation and you are almost certain to hit upon a cluster of strange species.

If exploration is a necessary element of science and having a standardized curriculum is detrimental to exploration, perhaps having a curriculum itself is against the spirit of science.

Unfortunately our Microbiology training seldom goes beyond E. coli. But this is nothing peculiar to Microbiology. While the spirit of science has to begin with exploration, the component of

exploration is missing in our science training. Part of the problem is that the present university structure demands that there should be uniformity in teaching in all the colleges in one university. It is therefore necessary that the syllabus specifies every detail to be taught. It follows naturally, or at least as the interpretation of students and teachers goes, that other things are not to be taught. In effect the stuff to be studied is precisely defined, rigidly standardized and that marks the end of exploration! You have only so and so species, such and such experiment in the curriculum and that is the final word. It follows logically that if exploration is a necessary element of science and having a standardized curriculum is detrimental to exploration, perhaps having a curriculum itself is against the spirit of science.

Can we teach science without a curriculum, or at least without a rigid curriculum? I tried it once when my boss asked me to conduct first year practicals. On the first day I handed over a microscope and a screw-driver to each group and asked them to play with it. Dismantle every part possible, and try to put everything back. On the next day I asked them to bring anything they would like to see under a microscope and observe it. It could be any crazy object. Thereafter things took their own shape. We observed a large variety of microbes. Obviously, the question that followed was "what is this ?". I did not answer the question. In fact, many times I could not. The organisms were so diverse and different that I had to say — I don't know. Probably nobody knows. Imagine that you are the first biologist on earth to see such a creature. How will you describe it? How will you draw it? That's almost like a bird-watcher looking into a microscope. The students were quite fascinated by what they were doing. From observations came questions. The questions prompted more observations and experiments. We did whatever everybody thought was the next logical step. The students did not prepare Nutrient Agar or MacConkey's agar, they prepared whatever they thought suited their organism. At the end of the year we looked at the syllabus and found that it had been already covered. Microbiology can be as exciting as bird watching!

Can we teach science without a curriculum, or at least without a rigid curriculum?