

Jeff's View

Letter to a young scientist

You ask me what is to be a scientist. What a profound question by someone just entering university! Profound questions have no general answers, so my answer will be quite personal. I did basic research in biochemistry all my adult life, closed my laboratory four years ago, and now often try to figure out what it was all about. I will first tell you what science can give you. Then I will mention the price you may have to pay. And finally I will tell you what science can not give you.

You only see what you know to look for, and scientific training will give you much better eyes. Not because of the facts you learn – they age quickly and you should always distrust them a little. A famous American biochemist said this to a Harvard graduating class: “Half of what we taught you is probably wrong, but unfortunately we do not know which half”. To a science student, cramming facts is what practising scales is to a piano student: there is no way around it, but it's not enough.

Science gives you better eyes because it removes mental blinkers and gives your brain a much bigger playground. Most people never worry about distances smaller than one millimeter – say, a tiny screw – or larger than a few hundred thousand kilometers – the mileage requirement in a frequent flyer program. That's a range of about 11 orders of magnitude. Your thoughts, on the other hand, will easily move from the behavior of a proton (10^{-15} m) to the size of the visible universe (approximately 10^{28} m) – about 41 orders of magnitude. It will be the same with time. Most of your friends who are not scientists slice time to perhaps one hundredth of a second – which may decide a ski race – and think back to the old Greeks or, at best, the Paleolithic – that's 2500 to 100 000 years ago. You will slice time into femtoseconds (10^{-15} seconds) – which may decide a fast photochemical reaction – and when you think way back, it will be the Big Bang – some 15 000 million years ago, or the beginnings of life on earth – about 3800 million years ago. Again, you will be ahead by 17–18 orders of magnitude. Science will not make you smarter, or wiser, or a better human being, but it will plug you into the brains of many smart people who were there before you. It feels good to stand on the shoulders of giants. If you want to know that feeling, science is for you.

Let me talk some more about numbers because they are the essence of our craft. As a scientist you will instinctively feel what numbers mean, or do not mean. Understanding numbers will be your Ariadne's thread that shows you the way in science and your everyday life. To you, 27.99 will be 28, not 27 – go tell this to the average shopper! If you hear that employees' motivation has increased by 26.67%, you will know that anyone claiming such precision is a fool – or a fraud. And if your local newspaper carries the headline that cadmium in your city's water has increased by 50%, you will not fly into a panic, but will want to know absolute levels and toxicity limits. It feels good to be friends with numbers.

Understanding numbers also means that you respect their mystic borders and do not take the names of Zero and Infinity in vain. You know that the real world has no zeroes or in-

finities and will mistrust anyone calling for zero risk, zero pollution, zero alcohol, or zero sex. It's the same for infinite resources, infinite patriotism, or infinite sacrifice. Zero and Infinity are the catchwords of fundamentalists. Or of fools, but (to quote Mark Twain) I am just repeating myself.

Science also teaches you to avoid numbers when they would make no sense. One can certainly assess scientific performance, students' satisfaction, success in teaching, and sometimes even originality, but no true scientist would do so by numbers. Don't be afraid to protest whenever your country's science managers clobber you with Citation Frequencies, Impact Factors, and similar nonsense. Giving a number to something that cannot be accurately quantified is Bad Science. Bad Science is Science's most dangerous enemy; it is the Fallen Angel that seeks revenge.

Scientists are not the only ones who understand numbers; bankers, accountants, traders and politicians can also be very, very clever with them. But if you are looking for someone who knows when not to use them, go for a scientist.

When you talk about such matters to friends and acquaintances, they will complain that “scientists are so arrogant – they think they know it all”. That's wrong twice over. First, those wide horizons science offers never let you forget how little you know and understand. Second, the natural sciences never give you absolute certainty, as pure mathematics can do. The scientific truth of today may be wrong tomorrow. We scientists try to inch closer to a truth that's still very far away and hope that our inching is mostly in the right direction. You may have ‘proven’ a theory by 1000 experiments – tomorrow's experiment may still disprove it. Don't let this dishearten you. If you read Karl Popper (which you should), you will learn that disproving an accepted theory is the only way to advance knowledge. Preachers, demagogues, psychics, gurus, faith healers – it's they, not the scientists, who know it all and who are untouched by doubt. I bet you that scientists say ‘I don't know’ much more often than most other people.

The uncertainty of scientific knowledge does not weaken, but strengthen you. The blind faith of the fundamentalist, like any inflexible structure, will crumble at the next earthquake. Your vision of the world has dynamic stability. It is not rigidly tied to facts, but is a way of looking at them. Most institutions demand absolute faith, but science makes skepticism a virtue. You don't tell the world what it should be. You observe and accept it as it is, and not as you want it to be.

This was the good part. But there are other parts. In giving you the grand tour of the castle, I must now show you the kitchen.

Science has always been a communal effort, but its ability to spawn technological innovation has transformed it into Big Business. That's certainly true of biochemistry and other branches of molecular biology, which offer the promise of blockbuster drugs and a host of other medical revolutions. The biomedical sciences have become expensive, busy, manipulative, political, and harshly competitive. Worse yet, their practitioners are being forced to fiddle with the truth. When they describe their work, they must gloss over uncertainties,

or their manuscript won't get published. If they apply for grants, they must make wild claims, or they won't get funded. If they write letters of recommendation, they must tell white lies, or their letters will be counterproductive. And if they shoptalk with colleagues, they must hold back information, or they might get scooped.

Today's science is too much dominated by efficient people with cold eyes. They will tell you that hypothesis-driven research is a thing of the past and that you should go for Data Mining – the screening of computer-generated data banks; that good research only comes from large Networks; and that it is your social duty to Valorize Knowledge. If you get your first job at a European university, chances are that you will have to take orders from a senior professor and be kicked out after a few years, no matter how well you did. A company laboratory may treat you better at first, but still kick you out at the next restructuring, regardless of your performance. And if you are allowed to stay on, you will soon spend most of your time at your computer, toiling over mind-numbing questionnaires, mission statements, or grant applications. Every collaborator you take into your group will, over the years, need at least two dozen letters of recommendation from you, every trip to a foreign meeting will eat up at least one week of your time, and every committee you join will be at least twice the burden you expect. Very soon the entrance to Paradise – the laboratory – will be blocked by guardian angels with flaming swords. They will also stand between you and your family, your friends, and any other interests you may have. You will battle them on so many fronts that you are bound to lose.

Much of this has to do with forces beyond our control, but we scientists are also contributing to the mess. We want to be smart and forget to be warm. We think too much about competition, and not enough about generosity. We go for power, and forget that power and science don't mix. We are so anxious to become famous that we have no time to think about what science is all about. There are too many congresses, committees, evaluations, prizes, honors, and elections to academies. There is just too much noise.

For many of us, there is also loneliness. Memories of it still haunt me. The loneliness of being excluded from my research team by the never-ending stream of paper; the loneliness when my friends and colleagues disbelieved one of my discoveries; the loneliness at a far-away scientific meeting after I had given a bad talk; of reading a particularly vituperative rejection letter for a submitted manuscript; of facing tensions with my research group; of evenings with colleagues who only

talked about themselves; and, more than anything, the loneliness of trying to hear the static-mangled voices of my wife and my children over a very, very long-distance phone line.

Yes, science's kitchen can be crowded, hot, hectic and noisy. But it does turn out fantastic meals. In the end, it's those meals that count. They are well worth the price.

Those delicious meals, however, are nutritionally unbalanced and will not sate you. Don't forget to supplement them, because science gives you only one view of yourself and the world. For example, there are also the mystic and the artistic views. Having these different options is the genius of our human species; failing to balance them against one another is our curse. There are parts of you that science neither explains nor satisfies. If you see everything only through the eyes of science, your vision will be monocular and lack depth. Tens of thousands of years from now, our descendants may well conclude that our Scientific Age gave us only a distorted view of the nature of things. I do not consider this possibility very likely, but the Adagio of Mahler's Tenth Symphony, a Rilke poem, or van Gogh's last paintings tell me things about myself that science never told me. Art can be a second vantage point that grants binocular vision and lets one see in three dimensions. It could do the same for you. Make science your home, but also venture beyond its borders.

University will only teach you how to do science. To become a scientist, you must learn to look at science from the outside and make it the object of your skepticism. This is something you must do on your own.

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