COMMENT

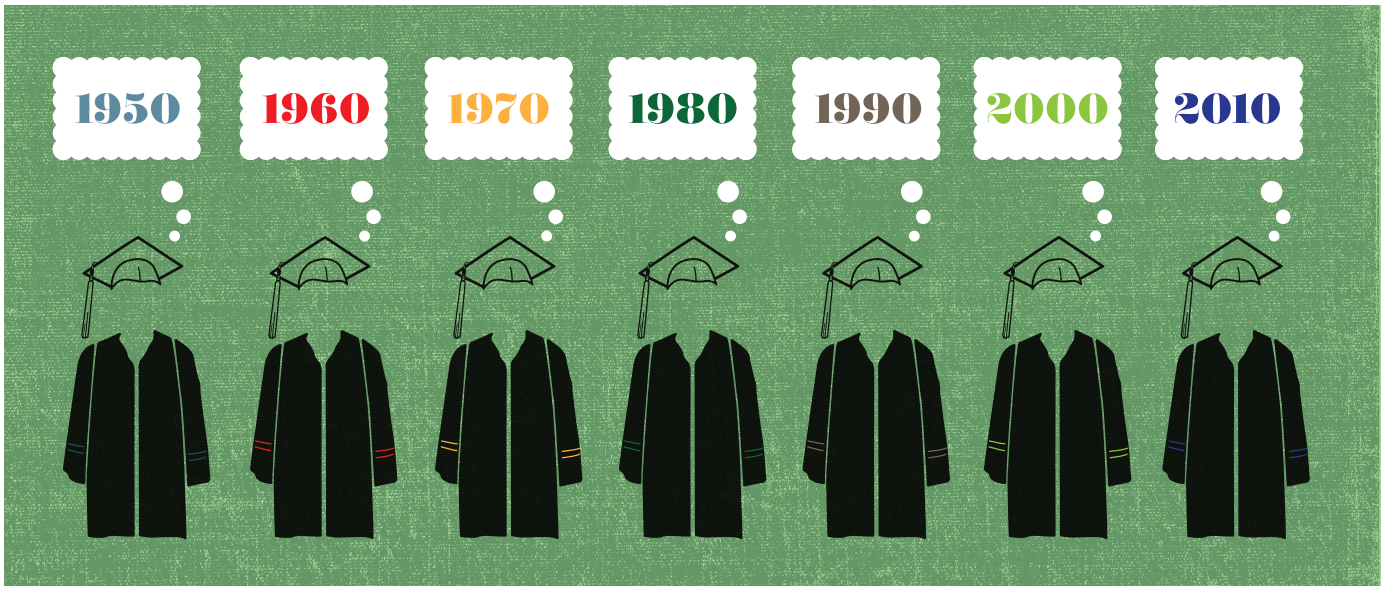


ILLUSTRATION BY OLIVER MUNDAY

Seven ages of the PhD

Scientists share memories of doing doctorates in different decades, disciplines and locations, from the hunt for the structure of DNA to deciphering the human genome.

RAYMOND GOSLING

1950s: The age of formality

Emeritus professor, University of London

PhD in structural analysis of DNA (King's College London, 1954).

Looking back on my PhD at King's College London, I realize that I was fortunate to experience the feudal process of research in a large department dominated by an enthusiastic professor, John Randall. Although I, like every other student, had to register for a PhD with Randall, I was free to collaborate with other senior scientists in the lab.

I worked closely with Maurice Wilkins and later Rosalind Franklin, under whose direction I pursued X-ray diffraction studies of the sodium salt of DNA. One of the highlights of my PhD was the now iconic photo 51, a diffraction photograph I took, which clearly showed the helical structure of the molecule (see image). I will always remember the moment I first saw that beautiful double diamond pattern.

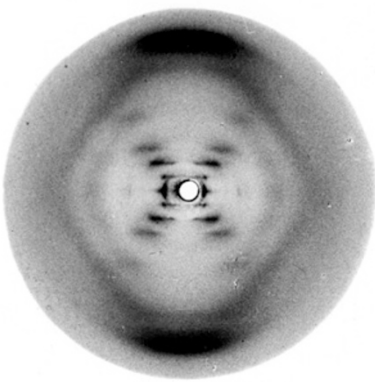
Of my two mentors, Maurice was friendly and determined but very shy. Rosalind had a more combative style and taught me the value of being a devil's advocate, so challenging and defending our developing ideas. However, I was unable to ease the tensions that developed between Maurice and Rosalind.

Randall's biophysics unit was a wonderfully energetic place to work. However, in those days relationships between staff and students were rather formal. All the men wore ties with their white lab coats, and the senior common room at King's was for men only. However, all the women scientists, including Rosalind, were an integral part of the lab's efforts.

Randall was exceptional because he found financial backing for all the members of his lab. The only other comparable example that I have experienced is the work at Cold Spring Harbour Laboratory in New York directed by James Watson. These days, students are not always so fortunate and have to spend time and energy seeking funding.

My advice to would-be doctoral students is to seek out a dynamic, flourishing research group. Do not start until you have agreed with your supervisor on a beginning, middle and an end to your project. A good PhD often raises more questions than it solves, so you should not be surprised if your work changes direction.

The University of London's advice to examiners states that PhD students should identify a distinct and new contribution to science, not just a review of the literature. Since those rather heady days of the 1950s, I have sometimes wondered whether this always happens. Some will say I was lucky ▶



R. GOSLING/KING'S COLLEGE LONDON ARCHIVES

Gosling's PhD photo revealing structure of DNA.

to be in the right place at the right time, and I would agree, but it is also important to have high standards, something I learned from Randall.

The less formal relationships between students and professors today probably improve communications. I have since directed the research of many PhD students, and have come to know them all personally, something that was just not possible with Randall. He told me that he didn't want to see my PhD until it was submitted — I can't imagine that happening nowadays.

CHERYLL TICKLE

1960s: The age of independence

Emeritus professor, University of Bath, UK

PhD in cell biology (University of Glasgow, 1970).

As an undergraduate, I became fascinated by the arrangement of cells and how it is key to understanding embryology and tissue biology. So I applied to do a PhD with Adam Curtis at the University of Glasgow in Scotland. He had recognized that cell adhesion was central to 'sorting out', the process by which a mix of different cells stratifies into regions of cells of the same type.

The highlight of my PhD was managing, at the end, to publish a paper in the *Journal of Embryology and Experimental Morphology*, with a statistician. The biggest pressure I felt during my PhD was the responsibility for the data I produced. I realized for the first time that others might base their own work on what I had found and that there was nowhere I could go and look up the 'correct' answers. Part of my anxiety stemmed from the fact that although I had done a lot of practical work, I had not carried out a research project during my undergraduate degree.

The person who influenced me most during my doctorate was my supervisor. Curtis took me on not knowing much about me, suggested the project and then left it to me to work out the details. This meant that my progress was slow and sometimes painful, but also that I learned for myself how to set about things and master new techniques. Fortunately other students and staff in the department were encouraging and supportive. One of my most important practical lessons I learned the hard way: you can never record too much detail about your experiments. I was perplexed because I was suddenly getting different results. I later realized that I had switched to using a different shaker to bring cells together. This changed the results completely and I hadn't initially been recording which shaker I had used.

Nowadays, PhDs are much more structured. Students are not given as free a rein as I was, nor are they allowed to make as many mistakes. There is a greater emphasis on acquiring data. Students also often work with others rather than alone. These differences reflect the changes over the past 40 years in the way in which research is carried out, and its growing pressures.

STEVE W. RUNNING

1970s: The age of innocence

University of Montana, Missoula

PhD in forest ecology (Colorado State University, 1979).

I finished my PhD in 1979, just before personal computers arrived. So it was written on a typewriter, with 53 hand-drawn figures. The subject of this labour of love was inducing water stress on 13 pine trees by cutting their leaves off and measuring desiccation responses. Looking back now, my PhD research seems highly esoteric. The work built fundamental understanding of leaf-scale physiology but had no policy relevance. The only practical value was in understanding why your Christmas tree turns brown. I think how innocent we all were then, doing weird science and looking for cheap beer.

After my PhD I got a tenure-track professorship at the University of Montana in Missoula, teaching tree biology. I never imagined being interviewed by national journalists, or getting hate mail from the public. As a lead author for the Intergovernmental Panel on Climate Change's Fourth Assessment Report, I have now experienced both. What happened? The policy relevance of my work is to be found at larger scales than my 13 trees. For example, it can apply to the hydrology management of a river basin. So what began as curiosity-driven research into water stress on trees evolved into global analyses of terrestrial carbon sources and sinks. And questions in forest ecology are now motivated by policy and economics, including carbon credits, carbon offsetting and biofuels.

The modern PhD student needs to be much more policy aware, because society has many environmental problems to solve, and not much time. There is a huge need for better quantification of ecosystem services, and connecting sustainable ecosystem principles with slow-growth economics.

Public outreach has become essential. Young faculty members are often devoting time to blog discussions, work that needs to be valued better by academia. During my PhD, I had no training in public speaking, yet it may now be the most important thing I do. Above all, I think that this next generation of scientists will have no choice but to pursue research aimed at saving the planet from catastrophe. I remind my public audiences that Earth doesn't need us — the cockroaches will gladly take over if we flame out.

S. RUNNING

A far cry from hate mail: Steve Running induces water stress in pine trees in 1972.

TAO IMAGES/ALAMY

Yao Tandong spent a month during his PhD on Glacier No. 1 in the Tianshan mountains of northwest China.

YAO TANDONG
1980s: The age of internationalism

Head of the Institute of Tibetan Plateau Research, Beijing

PhD in glaciology (Institute of Geography, Beijing, 1986).

I graduated from Lanzhou University in China's Gansu Province in 1978. At that time, the postgraduate system in China was immature. During the Cultural Revolution (1966–76), the whole education system was broken, and it was only after 1978 that the degree system was restored. There were probably only a few hundred PhD students in China. I was one of the first to study for a master's degree in physical geography at Lanzhou, and because no institution in my province could grant a PhD I had to travel to Beijing to study at the Institute of Geography.

The prestigious institute was part of the Chinese Academy of Sciences. In the 1980s, science was held in the highest esteem in China, and you had to get the highest marks in very strict exams to get into a PhD programme. However, there were still few senior scientists who were qualified by the Chinese government to supervise PhD students. I was lucky in that my PhD adviser was the famous Chinese glaciologist Shi Yafeng.

It was also popular at that time to study abroad. I passed all my exams to teach English as a foreign language and planned to go to the United States, but my adviser asked me to stay in China. He said I could go abroad for short courses, but he wanted me to do most of my research in China. It turned out to be the right decision for me because I spent a whole month with him at the Glacier No. 1 research station in the Tianshan mountains in northwest China. This glacier is famous worldwide with scientists and tourists, and it is shrinking at an accelerating rate. It supplies waters to the city of Urumqi and is the world's closest glacier to a metropolis.

Shi Yafeng was already in his sixties, but very dedicated to his work — a dedication that inspired me for the rest of my career. During the month we spent on the glacier he worked for every possible hour on the water-resource problem that was the subject of my PhD. While I was on the glacier I also got to know the famous glaciologist Lonnie Thompson from Ohio State University in Columbus. He was just starting his ice-core work in China and that meeting shaped the rest of my career. After I graduated in 1986, I spent three years abroad working with ice-core scientists in Grenoble, France, and in the United States.

I returned to China in 1989 and initiated ice-core studies on the Tibetan plateau. I have now supervised more than 25 PhD students in the same field, although the country's great passion for science has been replaced by a national passion for business.

I was lucky enough to have a good adviser and excellent collaborators, but I had to find collaborators outside China because there were so few scientists to work with at home. I always encourage my students to spend some time abroad. I learned important new fieldwork and lab techniques in the two months I spent in Alaska during my PhD. Scientifically, we still have a gap in China. Happily, almost all the students from my institute have returned to China from overseas, so everyone benefits.

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ANDRAS DINNYES
1990s: The age of revolution

Professor of biotechnology, Szent Istvan University, Gödöllő, Hungary

Candidate of sciences in veterinary science (1995)

The year 1989 was a remarkable one for me and for Hungary. I obtained my veterinary diploma in Budapest, and my country saw the official end to four decades of Communism. Free multiparty elections produced a new political system and in principle a new era in Hungarian science. I was eager to start a doctoral programme, because I had already done three years of scientific research during my veterinary studies and had become a recipient of the Pro Scientia Gold Medal of the Hungarian Academy of Sciences in the first year it was awarded.

In later years this award would have been a ticket for automatic admission to a doctoral programme, but in 1989 I still had to take an entry exam. I was admitted to the Academy of Sciences for a three-year fellowship programme towards a 'candidate of sciences' degree. This was the old Soviet-style degree — usually obtained by scientists in their forties, and an entry into the closed Hungarian scientific community. By the mid-1990s, it was replaced by a Western-style PhD, aimed at younger students and opening up the entire system. But along the way the academy's fellowship programme was new and brave, breaking with the old gerontocracy, and offering a 'fast-track' doctorate for a few young scientists.

To my surprise, I found my activities tightly controlled by my supervisor. I had to spend one year doing veterinary obstetrics work for the university, unrelated to my fellowship research in embryo cryopreservation. So during the second year, I applied for and won a Fulbright Fellowship to the Smithsonian Institution in Washington DC. There, I spent 16 months with William Rall, the 'godfather' of embryo vitrification technology (which uses high dose chemicals to aid embryo cryopreservation without the ice causing damage).

The fellowship changed my life. At first it was a culture shock to work for a strict American boss — David Wildt, the head of department — who demanded six days a week, ten hours a day. Rall provided me with training, advice and friendship and allowed me to work fairly independently. I gained self-confidence and became a workaholic. Soon I found international friends and enjoyed free museums and classical music concerts. The methods I learned determined the next ten years of my career as a scientist and inventor in embryo, ▶

gamete and stem-cell cryobiology.

In Washington, I produced sufficient data for my first publication and my thesis. Naively, I turned down an offer to do a PhD at Cornell University in Ithaca, New York, because I was so close to proudly completing my degree in Hungary.

I returned to Hungary in 1992 and submitted my completed thesis to the academy. My Hungarian supervisor thought it was premature, but I was stubborn and self-confident. Frustratingly, the scientific degree committee of the academy took more than two years to process my submission. So in the interim I did a one-year European Union postdoctoral fellowship in Belgium, for which the submitted thesis made me eligible. Finally, in 1995, at the age of 29, I was allowed to defend my thesis and became one of the youngest veterinarians to obtain the 'candidate of sciences' degree in Hungary.

After several positions abroad I am now back in a much-changed Hungary, working on genetic reprogramming, cloning and stem-cell research as a professor and chief executive of my own stem-cell company. I supervise six PhD students from Hungary and Thailand, who enjoy the reforms that came just a little too late for me. I always encourage my students to pursue international experience — which I can provide through the European Marie Curie projects I coordinate.

A. A. OSOWOLE

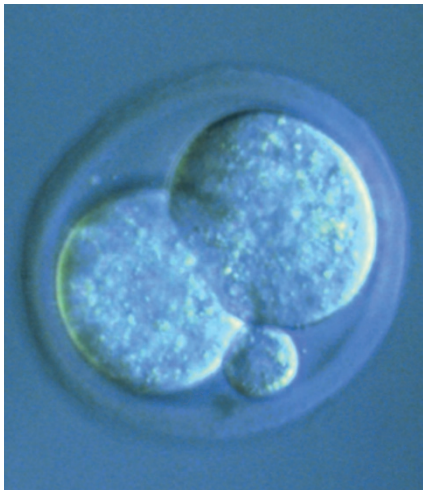
2000s: The age of perseverance

Department of Chemistry, University of Ibadan, Nigeria

PhD in inorganic chemistry (University of Ibadan, 2002).

I started my PhD on the kinetics of novel organometallic compounds at the University of Ibadan, Nigeria, in 1994, and completed it eight years later. After a year, a piece of kit that was crucial to my kinetics studies broke down and could not be repaired — the machine was ten years old and the manufacturer had stopped making it. Such technical difficulties are common in Nigeria because equipment is rarely well maintained.

I had to change my research topic to something I could do with the equipment available. So I began to investigate molecules containing both organic and inorganic components. This required the synthesis of novel metal complexes. The other researchers in the team encouraged me, gave me tips and taught me to use the equipment. A faculty member, Gabriel Kolawole, provided the expertise and a chemical to solve the hydrolysis problems I was facing.



D. SPEARS LTD/SPL

Andras Dinnyes worked on embryo preservation during his PhD in Hungary and the United States.

Even with the right tools, the work was challenging. I did not isolate a single complex in the first year.

I also had three BSc students working with me, who needed to finish their dissertations within six months. The students were intended to facilitate my research, but they all needed close supervision. I spent about 35% of my time teaching and 65% on research. I was under enormous pressure: I worked virtually every day, about six hours on the bench as well as teaching and practical classes. By the end of 1998–99 year (the 1995–96 and 1996–97 sessions were cancelled due to industrial crises) I had managed to isolate about 100 metal complexes — a good result.

My next challenge was interpreting and writing up my results. In 1999, the University of Ibadan library had limited access to journals, the most recent ones dating to 1996. To get more up-to-date chemical papers I had to rely on colleagues abroad. Back then, things weren't as computerized. Furthermore, analysing my samples required equipment we did not have, necessitating sending my samples abroad for analyses. But I could not afford the fees.

I realized I would not be able to complete my PhD at Ibadan with these limitations. Again, help came from Kolawole, who suggested that I apply to the Third World Organization for Women in Science — now the Organization for Women in Science for the Developing World.

I was awarded a fellowship and used it in 2000 at the Indian Institute of Science in Bangalore. There I was able to complete the outstanding analysis, and learn porphyrin chemistry and various chromatographic techniques. I defended my thesis in 2002 and got about ten publications from it.

The lessons I learned from my doctorate which I try to pass on to my students are: be focused, persevere, work hard and be honest. Where there is a will, there is a way.

ERIKA CULE

2010s: The age of communication

Imperial College London

PhD in statistical genetics (Imperial College London, due for completion in 2012).

The first draft of the human genome was published when I was still at school. I was excited by the opportunities this milestone would offer, and back then I imagined that I would become a laboratory scientist. During my undergraduate degree, however, I found that I preferred analytical questions to cell and molecular biology. Today I am privileged to be working in a high-profile and rapidly evolving field — statistical genetics.

The biggest challenge of my PhD so far has been mastering the skills I need to do computational genetics, and building the confidence to use them effectively. The transition from undergraduate studies in biochemistry has been a steep learning curve. A master's in bioinformatics and theoretical systems biology enabled me to tackle programming and statistics and gave me some tools to get started.

Fortunately, I have had support. My late grandfather, himself an academic, helped me decide to study for a PhD and gave me practical advice. My elder sister is a recent PhD graduate, and she understands the ups and downs of the process. I also have an excellent relationship with my supervisor, who is actively interested in my work — I know that this is not always the case. A PhD can be an isolating experience, but it helps to work in a friendly and sociable department. Invaluable support also comes from my partner and friends who provide me with a perspective from outside academia.

Working in a computational discipline, and having an interest in writing, it seemed natural to start a blog. Blogging about my PhD (go.nature.com/zkcy5l) has helped me to connect with scientific bloggers from around the world who share their experiences and suggestions. I also hope that my blog writing will help me when it comes to writing the thesis.

As a new PhD graduate I will face a difficult climate in which research funding from the government is being squeezed and the academic job market is increasingly competitive. I hope that my PhD will equip me with specific and transferable skills — such as networking and presenting — that will give me options after I graduate, whether in academia or elsewhere. ■ SEE NEWS FEATURES P.276 & P.280