writing system that we know to be a derived one. This early branching point is thus the equivalent of speciation in biological evolution. The separate writing systems of these neighbouring regions must have been mutually incomprehensible.

Over a short time span — three centuries at most, but probably much less — the proto-Elamite script spread across Iran, offering a prime example of cultural diffusion. There is no archaeological evidence suggesting a mechanism for this spreading, such as central government or long-distance trading, so the rapid expansion remains one of the mysteries of proto-Elamite.

As the proto-Elamite script spread and developed further, it became richer in its sign repertoire, but Dahl notes that it also ran into problems. "There was an inflation of signs in proto-Elamite," says Dahl, "and even in high-level accounts, such as those for the household of the ruler of Susa, you see systematic errors and bad practice." For instance, scribes would cram in information at the end of a line, rather than planning for the space available, like their colleagues in Mesopotamia would have done. And they made elementary mistakes in the bundling of numbers, as it would be a mistake in Roman numerals to write IIIII instead of V.

The key cultural difference is that cuneiform was backed up by a lexical tradition from early on, says Dahl. In Uruk, lists of standardised signs were used for reference. No such lists have ever been found for proto-Elamite. Dahl can't resist the temptation to speculate that it may have been the failure to invest in the quality of proto-Elamite writing culture that led to its deterioration and ultimately to its downfall.

The ensuing period of five centuries without writing makes Europe's descent into the Dark Ages pale in comparison. Prophets of linguistic doom who worry about youth slang and text speak will delight in this example of cultural downfall that was possibly triggered or accelerated by bad writing practice. Seeing writing as a trait that has evolved in human populations, it is only natural that it can not only arise, diversify and spread, but also die out. That's just life.

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Q & A

Vincent Laudet

Vincent Laudet is Professor at the Ecole Normale Supérieure de Lyon, Director of the Institut de Génomique Fonctionnelle de Lyon and head of a research group called 'Molecular Zoology'. He is best known for his analysis of the phylogeny and evolution of the nuclear receptor superfamily. His group now focuses on the role of thyroid hormone receptors or retinoic acid receptors in evolution, with an Evo/Devo perspective. Some years ago he also started from scratch a new research program on teeth Evo/Devo, using rodent and fish as model systems.

Credit: Vincent Moncorgé

What turned you on to biology in the first place? I was fortunate to be one of those children who always knew what he wanted to do. When I was five years old, my grandmother accompanied me to the palaeontology gallery of the French National Museum for Natural History (MNHN) in Paris. This visit was revelatory and I decided to become a zookeeper of prehistoric beasts! Later, I became passionate about ornamental fish-keeping, and with hindsight this hobby played an important role as it led me into scientific reasoning and research. Following this natural interest, I went to study biology at Montpellier University as I was determined to do research in ichthyology. I often say that in France biologists are fascinated either by the Pasteur Institute or by the MNHN. Clearly I was, and still am, fond of the latter...

What is the best advice you've been given? During my first year at the university I met Michael Tovey who was working at the Cancer Research Center in Villejuif. He recommended two things: do molecular biology, because it would allow me to do any type of biological research later on; and do it in Strasbourg (at the university there), which largely due to the influence of Pierre Chambon at that time, was one of the most advanced molecular biology-oriented institutes in France.

So, after a Masters' degree in biochemistry and molecular biology in Strasbourg, I headed north to Lille, strikingly, to the Pasteur Institute, where I joined Dominique Stéhelin's laboratory, which was then at the top of oncogene research (the *myc*, *erb*, *ets* and *mil/raf* oncogenes were all discovered in his lab). In October 1986, he asked me to work on the v-*erbA* oncogene, shown a few months later to encode a modified version of thyroid hormone receptor a. This is how I became interested in nuclear hormone receptors. Dominique Stéhelin was a fantastic PhD adviser: inspirational, charismatic, always giving reward for audacity. The time I spent in his lab was a very formative period and I feel I owe a lifelong debt to him. Then I was enticed to establish in Lyon by Jacques Samarut, with whom I have been collaborating for over 15 years now. His unique manner of grasping the complexity of a scientific problem 'at a glance' still impresses me.

Do you have a favourite science book? Two biology books have been very important to me. When I was a PhD student, the discovery of James D. Watson's book *The Double Helix* was a strong moment for me, with its unique mix of ambition, faith in science and casual attitude. Years later, reading *Wonderful Life* by Stephen Jay Gould made me realize the power of mixing functional analysis (as in developmental biology) with more historical approaches like

those of palaeontology. This was at the origin of Evo/Devo and is a strong driver of my interests in this field.

Do you have a scientific hero? Clearly Stephen Jay Gould! His triple achievements as theoretician of evolution, popular science writer and palaeontologist are truly impressive. I think we are still only starting to fully grasp the strength of his influence. His essays about the myth of progress in evolution should be read by every biologist, as anthropocentrism is still so important in evolution today. Also, his unique manner of illustrating how science is not the product of purely objective minds disconnected from their environment, but rather a mix of subjectivity and reasoning, has brought home to me how very difficult it is to avoid bias.

What has been your biggest mistake in research? I proposed some years ago that the ancestral nuclear receptor was probably an orphan receptor and that ligand binding was acquired several times independently during evolution. We reached this conclusion because there was no correlation between the position of a given nuclear receptor in a phylogenetic tree and the chemical nature of its ligand. The most parsimonious explanation was the convergent acquisition of ligand binding. But we know now, in particular thanks to the work of Joe Thornton's group, that the first nuclear receptor did have a ligand and was probably a sensor that bound several compounds with low specificity and low affinity. The convergence is thus only in the change of selectivity and affinity experienced by the ligand binding domains of the receptors. I think this was a very fruitful mistake because it provided for the first time a testable hypothesis that could be challenged. Indeed it was! After all, this is how science works and I have no problem at all in having made this mistake.

Did your interest and direction change over time? I am an example of a non-focused scientist. My general interest is in understanding the role played by nuclear receptors in evolution and this has been a general theme underlying all my research. But from this nuclear receptor starting point I have gone on to study circadian rhythms, metamorphosis or teeth Evo/Devo. This dispersed approach for conducting science is certainly not very popular in those days of scarce funding, but I cannot resist a good scientific question and I love to jump with a fresh mind into a new field. It is so exciting! While in terms of scientific paper production this is probably not a good idea it remains very rewarding at a personal level and fosters a broad sense of biology.

What are you interested in at the moment? I am fascinated by the origin of metamorphosis. It illustrates very well the situation of many fields in biology: We understand quite well the process in two 'model' organisms, *Drosophila* and *Xenopus*, in both of which hormones — ecdysone for insects, thyroid hormones for amphibians — have been shown to trigger metamorphosis. But we do not know the origin of these systems and despite the fact that metamorphosis is widespread in animals we do not know how it is triggered outside these model systems. Furthermore, even in vertebrates the evolutionary variations of metamorphosis are poorly understood. The fact that thyroid hormone-regulated metamorphosis is conserved in invertebrate chordates such as amphioxus implies that this event is an ancient feature of all vertebrates. This allows us to suggest that thyroid hormones may play an important role in coordinating the post-embryonic development of apparently non metamorphosing vertebrates, such as mammals or sauropsids. Also, in other groups such as teleost fishes there are cases that are reminiscent of direct development, that is cases in which a larva transforms into a juvenile inside the egg and in which the newborn is a miniature adult. I believe we will be able to revisit the post-embryonic development strategies of vertebrates, and I anticipate much pleasure in studying the zoological, endocrinological and developmental aspects of this process.

Any advice for someone starting a career in science? I would say three things: be independent; don't be afraid to make mistakes; and don't be too focused. The excess of focus can be efficient in the short-term but it carries the risk of sterility. Curiosity is probably the most important quality for a scientist. I would also offer this advice to young lab leaders, many of whom devote themselves to writing only big papers in major journals, which I have seen ruin many a career — my view is that it is better patiently to construct an expertise and an international recognition. And I strongly believe funding agencies should also regard more highly the value of these types of career paths.

What is your greatest ambition? I head a new department, the Institut de Génomique Fonctionnelle de Lyon, which has just moved into a new building. The project for this institute is to mix people from different areas of biology — development, physiology and evolution — and have them working together, exchanging ideas and so on. I think this unique mix of Physio/Evo/Devo approaches will be very significant for biology in the future and my ambition is to push for mixing these different cultures and having them at work in my department that I see as a crucible for such a melting pot. Questions such as the strategies governing variations in post-embryonic development in vertebrates, the allocation of metabolic resources during development, the role of energy balance in phenotypic plasticity, or the role of hormonal systems in convergent adaptations are still poorly explored but are now ready to be scrutinized.

What is the biggest challenge to the scientific community in the long term? I believe it is critically important that science remains strongly connected to society and that we explain again and again the scientific basis of general problems. This is as much the case with regards to the effects of endocrine disruptors in our environment or the importance of conserving fish stocks. In the spirit of enlightenment, this is the common duty of scientists and counters the detrimental influence of pressure groups or fanatics on decision-making. It is so important to provide some rationality to our world.

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