WILEY-VCH

Michael Gross

The Birds, the Bees and the Platypuses

Crazy, Sexy and Cool Stories from Science

ERLEBNIS wissenschaft

Michael Gross

The Birds, the Bees and the Platypuses

Related Titles

Nicolaou, K. C., Montagnon, T.
Molecules that changed the World
2008
ISBN: 978-3-527-30983-2

Corey, E. J., Czakó, B., Kürti, L.
Molecules and Medicine
2007
ISBN: 978-0-470-22749-7

Emsley, J.
Better Looking, Better Living, Better Loving
How Chemistry can Help You Achieve Life's Goals
2007
ISBN: 978-3-527-31863-6

Wagner, E. J.
The Science of Sherlock Holmes
From Baskerville Hall to the Valley of Fear, The Real Forensics Behind the Great Detective's Greatest Cases
2006
ISBN: 978-0-471-64879-6

Bell, H. P., Feuerstein, T., Güntner, C. E., Hölsken, S., Lohmann, J. K. (eds.)
What's Cooking in Chemistry?
How Leading Chemists Succeed in the Kitchen
2003
ISBN: 978-3-527-30723-4

Michael Gross

The Birds, the Bees and the Platypuses

Crazy, Sexy and Cool Stories from Science

WILEY-VCH Verlag GmbH & Co. KGaA

The Author

www.michaelgross.co.uk

Michael Gross
School of Crystallography
Birkbeck College
Malet Street
London WC1E 7 HX
United Kingdom

Library of Congress Card No.:
applied for

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Typesetting TypoDesign Hecker GmbH, Leimen
Printing and Binding Ebner & Spiegel GmbH, Ulm

Printed in the Federal Republic of Germany

Printed on acid-free paper

ISBN: 978-3-527-32287-9

ISBN ePDF 978-3-527-64099-7
ISBN ePub 978-3-527-64098-0
ISBN Mobi 978-3-527-64100-0

Contents

Preface

Science is fun! In seven years as a hobby reporter, and almost eight as a full-time freelance science writer, I have accumulated dozens of stories which I still remember fondly, because they were so much fun to write (and hopefully just as much fun to read). These are the stories that still tempt me to waste my time rereading them for the *n*th time if I stumble across them in my archives. These are the stories that I have used and reused over the years, cited as examples, or attached to my CV. These are the stories that – in my eyes, at least – demonstrate that science is a cultural activity just as rich and varied as literature and music, and just as rewarding.

What makes these stories stand out among the roughly 1000 others I have written over the years? I have identified three defining criteria, of which my favorite science stories may display one or more. Borrowing a title from TLC, I sorted them into a table with the headings crazy, sexy, and cool. *Crazy* stories include the weird, the unexpected, and the plain crazy stuff that scientists come across, and quite often discover to be actually useful. My favorite example of this kind are the wildly unorthodox antibodies found in camels and llamas, which have turned out extremely useful for biotechnology. There are also some stories of challenges so daunting that only crazy scientists would take them on. The genome sequence of our Neanderthal cousins springs to mind. *Sexy* stories are sometimes about sex (from attraction through to reproduction), but sometimes about other obsessions and characteristics of our race. Some of them just tell us what makes us human. *Cool* stories are mostly about cool inventions, devices, gizmos, and gimmicks. Many of them were invented by scientists, but there are also a few that were invented by evolution.

For each of these stories, I have started from a manuscript I wrote for publication (in a magazine or newspaper), revised and/or expand-

ed it, and added an introductory paragraph explaining what makes this particular story special. Where appropriate, I also attached an epilogue summarizing further developments. Within each of the three main sections, stories are arranged more or less chronologically, so one also gets a feel of how science has progressed in the years I've covered. At the bottom of each piece, the year of its first publication is given in brackets.

Many of these stories appeared originally in *Chemistry World*, the magazine of the Royal Society of Chemistry, or in its predecessor, *Chemistry in Britain*. A few articles from *Nachrichten aus der Chemie* (magazine of the German Chemical Society, GDCh), and *Spektrum der Wissenschaft* (the German edition of *Scientific American*), however, were published in German only, so I've translated them for this book. A couple of old *Spektrum* pieces reached this book via reflection by the earlier books *Life on the Edge*, and *Travels to the Nanoworld*. So it's all a big hall of mirrors, like the Y chromosome (page 38).

Some of these stories have also appeared in *Bioforum Europe*, *Bio-IT World*, *Current Biology*, *The Guardian*, *New Scientist*, *Süddeutsche Zeitung* and *Chemie in unserer Zeit*. I am grateful to all the editors who have commissioned my work over the years. Some of them developed the ability to read my mind, which can speed up the process and make life easier for me. But even when they ask challenging or really silly questions they help me to share my excitement with the readers.

Fifteen years is an extremely long time in scientific research, as I realized when editing the stories from the 1990s, some of which already had a somewhat historic, pre-genomic feel to them. Some of the things that I found exciting back then (and still do) appear to have fallen from fashion, while others have blossomed spectacularly. Some of the researchers involved have now got a Nobel Prize to their name; others appear to have disappeared from the radar. Such is life, even in science.

Above all, however, I am hoping to convey the impression that science in the last decade and a half was never boring, and that with every new answer that researchers work out, a host of new, even more exciting questions are likely to pop up, providing an endless supply of crazy, sexy, and cool findings.

Oxford, March 2008 *Michael Gross*

About the Author

Michael Gross was born in Kirn, Germany, but considers himself a European citizen. He began his writing career on the school's magazine, covering arts and humanities from Asterix to Picasso. As his Bohemian dreams of writing books in a Parisian café did not fulfil immediately, he opted for studying the sciences, and eventually managed combine his writing addiction and scientific training in a career as a full-time science writer after all not in Paris, but in Oxford. He earns his living mainly with the publication of articles in magazines, but also does some editing, translating, and lecturing, and occasionally writes entire books. Though his scientific interests span from quantum computation through to psycholinguistics, his heart-felt sympathy is with the strange creatures that live in volcanoes, the deep cold sea and hot geysers.

Michael Gross has been writing about science full time for the last eight years and as a night time hobby for the previous seven. From his treasure troves, he now presents his favourite science stories from these 15 years. What are the attractions that make him revisit a topic or reread an article again and again? Often, it's the sheer craziness of wildly unexpected findings or grotesquely oversized challenges. In other stories, there is a sexy element or a an unexpected insight into the human condition. And sometimes, when reporting new and future technologies, the author just can't help thinking: "cooooooool!" So here are xx crazy, sexy and cool science stories for you to enjoy.

1
Crazy Creatures

"If, at first, the idea is not absurd, there is no hope for it."

Albert Einstein

I have a natural tendency to favor slightly eccentric stories from science over the ones where a relevant question has been investigated and answered in a straightforward, almost predictable way. The craziness that interests me can arise from the random walks that evolution takes across time, or it may be found in the mind of the scientists who take on challenges so daunting that no sane person would bother with them. Or it could be both or somewhere in between. There is a whole spectrum of scientific craziness and crazy science.

But then again, some of the areas covered here started out as a blip of craziness in the margins of modern science but have since evolved to become mainstream research fields, possibly even with commercial potential. You never know what might happen, that's part of what makes eccentric topics so rewarding.

Squeezy Little Bears

The crazy creatures at the extreme ends of life on Earth have fascinated me for many years. As both my PhD thesis and one of my books dealt with life under extreme conditions, I'm no longer that easily impressed by tales of life in boiling water, sizzling deserts, or permanent ice. However, the following story (which unfortunately came up too late for the original edition of *Life on the Edge*) beats them all. If anybody wants to send animals to Mars, I suggest they try the "little bears" or tardigrades. The following text is adapted from a postscript included in the paperback edition of *Life on the Edge*.

Tardigrades are microscopically small animals reminiscent of downsized bears, at most half a millimeter long. They live in water droplets suspended in moss and lichens and can be found on all continents. Now if you're such a tiny little bear exposed to the elements, you need some very special survival skills.

Tardigrades have at least two major emergency routines. If their habitat is flooded and there is a risk of oxygen shortage, they inflate to a balloon-like passive state that can float around on the water for days. If, however, the threat comes from a lack of water, they shrink to form the so-called tun state (because it looks like a barrel), which could be described as the animal equivalent of a spore. Researchers have managed to resuscitate tardigrades by rehydrating moss samples after up to 100 years of storage on museum shelves, which proves the quite remarkable long-term stability of this state.

It was this tun state that Kunihiro Seki and Masato Toyoshima (Kanagawa University, Japan) used in their studies of resistance against high pressures. As the presence of water would have convert-

Figure 1 Electron micrograph of a tardigrade. Tardigrades or water bears are the most resistant animals known. (From: http://en.wikipedia.org/wiki/Image: Hypsibius-dujardini.jpg)

ed the animals back to the active state, the researchers suspended the tuns in a perfluorocarbon solvent before they applied pressures of up to 6000 atmospheres (more than five times the pressure found in the deepest trenches of the oceans). While active tardigrade populations in water are killed off by 2000 atmospheres (already an implausibly high threshold for an animal), the tun state allowed 95% of the individuals of one species and 80% of another to survive the maximum pressure of 6000 atmospheres.

This observation is unprecedented for any animal species. Only some bacterial spores and lichens could hope to compete with that. Still, tardigrade experts may have been only mildly surprised, as they knew already that the tuns can be revived after freezing in liquid helium – they are frost resistant down to 0.5 Kelvin. Detailed mechanistic explanations for these record-breaking achievements are not yet available. One thing that is known for sure is that the tuns contain high concentrations of the sugar trehalose, which is known to improve the stress resistance of baker's yeast.

The phenomenal shelf life of the tuns has aroused the interest of researchers in medical technology. Some are trying to copy the tardigrades' recipe to achieve similar long-term stability for human organs to be used in transplantation.

(2000)

Further Reading

M. Gross, *Life on the Edge*, Plenum, 1991.

What Happened Next

I am pleased to report that researchers actually followed up on my suggestion and sent tardigrades into space. The TARDIS (Tardigrades in Space) experiment was part of the FOTON M-3 mission, that launched on 14 September 2007 and returned safely on the 26th, after 189 orbits. At the time of writing, the tardigrade passengers were awaiting detailed analyses that will surely reveal how well they are suited to withstand space conditions.

http://tardigradesinspace.blogspot.com/

Can We Stomach the Bugs Bugging Our Stomachs?

The story of the bacteria that can give us ulcers has gone through many twists and turns over the years. Originally a heresy (everybody knew that ulcers are caused by acids!) the view that *Helicobacter* is bad for us soon turned into dogma (complete with recognition from Stockholm) which was challenged again by people suspecting that the bacteria may also have a beneficial effect. Here's just the basics, but I'll come back to the latest news on this towards the end of the crazy section.

When we prepare food, we often use extreme conditions such as high temperature or an acidic medium to kill off microorganisms. Industrial food preservation uses additional extremes including high pressure and gamma-ray sterilization. To a limited extent, our body can use similar methods. Thus, one of the functions of the acids in the stomach is to destroy bacteria taken in with the food.

However, scientists keep finding highly adapted microorganisms, known as extremophiles, thriving even under extreme conditions. For instance, hyperthermophiles can live at temperatures close to the boiling point of water, halobacteria can thrive in salt meat and *Deinococcus radiodurans* can survive gamma-ray sterilization. Similarly, there are other bacteria which can make themselves comfortable in the hostile environments of the mouth (like those which keep the dentists employed) and even in the stomach.

Much like the extremophile hunters in their field studies, the Australian pathologist J. Robin Warren found bacteria in a place where they should not be able to live according to textbook wisdom, namely in the human stomach. The spiral-shaped bacteria later classified as *Helicobacter pylori* had retreated into the mucus layer which covers the

walls of the stomach. Only after a series of failures did Warren and his co-worker Barry J. Marshall manage to cultivate the new kind of bacteria. When they published their results in 1983, researchers around the world confirmed the occurrence of such bacteria in the stomach, especially in patients with chronic superficial gastritis, a condition involving a persistent inflammation of the stomach.

However, the presence of bacteria in a diseased tissue does not prove them guilty of causing the disease – they might just have profited from the body's weakness and invaded an organ already afflicted by disease. Marshall and a second volunteer did a self-test to find out whether the presence of the bacteria was the cause or a consequence of the disease. The two healthy men swallowed a dose of *Helicobacter pylori* and indeed both became ill with gastritis. Obviously, the infection with *Helicobacter* nearly always leads to a superficial gastritis, which, however, may often be overlooked and blamed on a heavy meal, for instance. If the infection persists and is not treated in time, it can lead to ulcers of the stomach or the duodenum in the long term.

This finding overturned a dogma that was almost as old as Western civilization, namely that ulcers are caused by excessive acid production by the stomach. In the first century AD, the Roman physician Celsus recommended low-acid food against ulcers. Since the 1970s, there have been drugs that reduce the acid production of the stomach without major side-effects, and indeed reduce ulcers. However, when the treatment is stopped, the ulcer always comes back. In contrast, treatment with bismuth prescriptions or antibiotics that eradicate the *Helicobacter* population can heal the gastritis permanently.

But how do the bacteria manage to settle in the human digestive tract without getting digested? The secret seems to lie in their mobility and in some chemical specialties of their metabolism. Mobility is crucial when the contents of the stomach get flushed down to the guts. With the help of their flagella, the spiral-shaped bacteria can swim fast enough to escape the fate of ending up in the loo. And the special "trick" of their metabolism is that they produce enormous amounts of the enzyme urease, which can degrade urea (a product of the digestion of proteins) to form ammonia and carbon dioxide. One possible explanation of the acid resistance of *Helicobacter* is that the bacteria may be able to use the ammonia produced by urease for the neutralization of the gastric acid in their immediate environment.

What looks like a crazy case of adaptation to extreme conditions is in fact immensely important for healthcare around the world. Scientists have estimated that a third of the world's population carries a latent infection with *Helicobacter* but, as with the tuberculosis germ, only a proportion of the infection cases lead to recognizable illness symptoms. About ten percent of all human beings develop ulcers at some stage of their life. Both for ulcers and for stomach cancer, a clear correlation with the number of individuals infected with *Helicobacter* can be found in comparative studies. Infections, and the diseases now believed to be their long-term consequences, are more common in developing countries than in industrialized ones, and they have both been declining slowly over the course of the twentieth century. A large-scale campaign to fight the germ could prove a very efficient measure against ulcers and cancers of the stomach and the duodenum.

(1996)

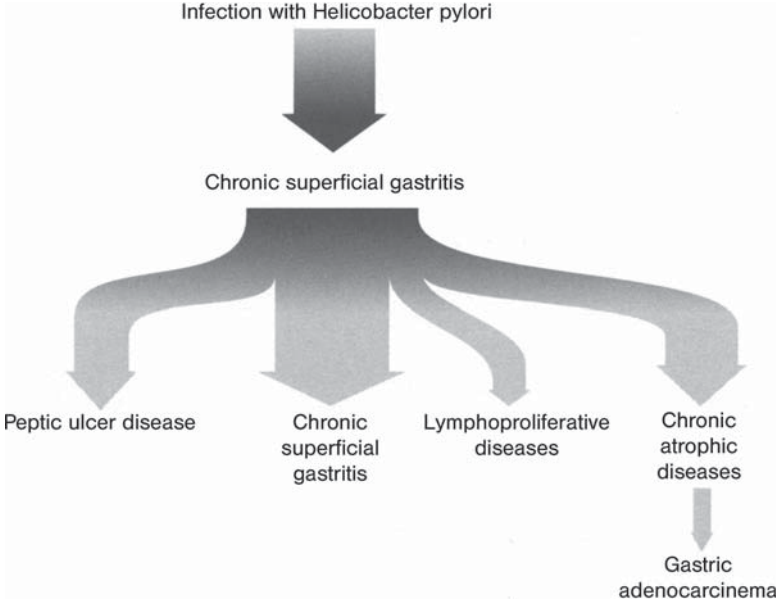

Figure 2 Consequences of an infection with Helicobacter. The relative widths of the arrows symbolize the different probabilities of the diseases concerned.

Further Reading

http://nobelprize.org/nobel_prizes/medicine/laureates/2005/index.html

What Happened Next

In 1997, Craig Venter's Institute for Genomic Research completed the genome sequence of *Helicobacter pylori*. Since then, plans have been mooted to eradicate the bacterium once and for all (the genome sequence would help to identify specific targets for a suitable drug), but some researchers have suggested that its ill effects on ulcers and some cancers may be counterbalanced by a more positive role in helping to avoid other cancers, so for the time being there is no systematic eradication program on the cards. In 2005, Barry Marshall and Robin Warren shared the Nobel prize for physiology or medicine "for their discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease."

Oh, and in 2007 researchers found out something really crazy about *Helicobacter*, but I'll keep that for a later chapter in this section.

Protein, Edit Thyself!

Back in 1996, I wrote a story about the genome sequence of *Methanococcus jannaschii*, the first ever sequence of one of the weird bugs known as archaea, which are quite distinct from bacteria, even though this fundamental division was only discovered in the 1980s. I suggested using a circular graph that had appeared with the original paper, showing the entire genome at a glance, with different types of functional elements represented by different colors. As I'm not really responsible for the images that accompany my pieces, I didn't pay much attention to the details of this graph. Until, that is, the editor came back to me with the question: "What on Earth are inteins?" It turned out that in that image, 18 sequences were marked as inteins, and I didn't have a clue as to what they were. As it happened, they turned out to be really interesting, so I got to write a sequel to the genome story. By now, small genome sequences are no longer exciting, but inteins still are.

Imagine you bought a music cassette – yes, the ones with good old-fashioned magnetic tape in them – from a shop of magical music down at Diagon Alley. You take it home, open the box, and notice a loop of the tape hanging out of the cassette. The loop folds up in the shape of scissors and cuts itself loose from the rest of the tape. Not wanting to leave you with an unplayable cassette, though, the stray piece of tape now conjures up a small brush and glue, and sticks the loose ends of the remaining tape together, before it just wanders off. This may sound really crazy, but if you replace the magnetic tape with RNA or indeed with protein, it starts to make sense.

Inteins – self-splicing proteins – used to be considered as rather exotic, until 1996, that is. Then, in the genome sequence of *Methanococcus jannaschii*, the first genome from the domain of the archaea, 18 such sequences were discovered in 14 different genes, which more than doubled the number of known examples. In analogy to RNA introns, inteins can cut themselves free from the a longer polypeptide chain and link the remaining bits (called exteins in analogy with RNA exons). This process, however, was only discovered in 1990 and has not received as much attention as RNA splicing.

Although most of the known examples of inteins come from the domain of the notoriously idiosyncratic archaea (formerly archaebacteria), the prototype was discovered in a well-studied organism which has been of service to humankind for millenia: *Saccharomyces cerevisiae* (baker's yeast). Tom H. Stevens and his co-workers at the University of Oregon at Eugene observed that the TFP1 gene of yeast obviously codes for two protein products. The smaller one is coded in the middle region of the gene and flanked by the separate halves of the bigger one. This finding on its own would not have been very remarkable. There are many examples of overlapping or nested genes. It was unusual, however, that instead of the expected two messenger RNAs (one for each protein product) only one was found, and its length corresponded to the sum of the lengths expected. Stevens' group therefore suspected that the genetic information is not, as in many other cases, edited on the mRNA level. Rather, the single mRNA seemed to get translated into a single fusion protein, which splits into the final two components after translation.

To test this hypothesis, the researchers generated mutations in the middle part of the mRNA, leading to a shift of the reading frame, i.e. to a wrong segmentation of the string of nucleotides ("letters") into three-letter words specifying the amino acids to be incorporated into the protein. This kind of mutation not only affects the word where it occurs – the whole text behind it will be distorted as well. If there had been a splicing on the mRNA level, the frameshift would have only affected the intron cut out of the mRNA, as the spliced exons should still have had the correct frame. Therefore, only the protein coded by the middle segment should be mutated, not the one coded by the outer parts. It was found, however, that both proteins were affected by the frameshift. (Of course, one has to take care that the mutations of the middle part do not affect the splicing reaction, as can be confirmed by

the molecular weights of the two products.) However, the researchers did not succeed in isolating the uncleaved precursor protein. This led them to suspect that the splicing might be an autocatalytic process. In this case, the protein itself would make the splicing reaction occur so rapidly that it would be impossible to get hold of the original translation product.

This difficulty was only overcome when inteins were also dicovered in several hyperthermophilic archaebacteria, such as *Thermococcus litoralis* and various species of *Pyrococcus*. Francine B. Perler and her co-workers at New England Biolabs constructed an artificial self-splicing system around the intein of *Pyrococcus* DNA polymerase by putting the gene for a maltose binding protein (M) in front of it (as a so-called N-extein, as it is at the amino-terminal end of the sequence) and a paramyosin gene (P) behind it (as a C-extein, for carboxy-terminal). They introduced this fusion gene into the intestinal bacterium *Escherichia coli* (a widely used laboratory workhorse), whose protein synthesis apparatus duly made the fused polypeptide (MIP) at temperatures between 12 and 32 °C. At these low temperatures, the self-splicing reaction occurred only very slowly, as the intein involved came from an organism adapted to life near the boiling point of water. In fact, the whole process was slowed down to such an extent that the researchers were able to purify the unprocessed precursor protein. Incubating this polypeptide in aqueous solutions containing only small amounts of sodium chloride and phosphate buffer, and then warming it up slowly, they could observe the onset of the self-splicing at higher temperatures. This way, they could also isolate an intermediate (MIP*), which behaved rather paradoxically. It appeared to have a higher molecular weight than MIP, as it moved more slowly through electrophoretic gels, and it also seemed to possess two different versions of the amino terminus (the "beginning" of a protein chain). The riddle was solved by the finding that the intermediate obviously has a branched structure, whose bulkiness decreased the mobility in gels. What must have happened is that the exteins M and P formed a link even while I was still attached to P.

In addition to their self-splicing abilities, inteins share a further characteristic with certain introns – or, more specifically, with certain proteins derived from intron translation. Both act as endonucleases, which means that they can recognize certain DNA sequences and cut the DNA at a well-defined position within or near these sequences.