your party trick, bent over, with a lighter in a darkened room. Woese found that the methanogen gene sequence was very, very different to those of other bacteria he had sequenced. What could this mean?

At the time, and before, microbiologists had been looking for life in apparently ridiculous places, and finding it. We now know that archaea can live everywhere: in hot acid fluids that can dissolve steel, in fluids as alkaline as those we use for floor strippers, in pressures and temperatures as high as that in autoclaves that hospitals use to sterilize equipment. It is not just that they can tolerate such environments. These are their natural habitats and species adapted to them die in conditions that we would consider benign. Sequencing more and more such 'extremophiles' from different environments, Woese found that they all naturally grouped together in the 'bacterial' family tree.

Previous workers, such as the exalted Thomas Brock, had observed that the biochemistry of the cell walls of 'bacteria' was similar in specimens from very different extreme environments and quite different from that of typical bacteria. This had been explained away as convergent evolution — the same adaptation by bacteria to extreme environments, of whatever sort. But Woese pulled all the evidence together and made the intellectual leap that is now accepted: there is a third domain of life — the archaea.

All of this is told, and much more. Friend quite rightly does not restrict himself to archaea. For example, there is a fascinating chapter on the *Titanic*, which is literally being eaten by enormous, macroscopic consortia of symbiotic microbes from all three domains — superorganisms called rusticles with vasculatures and immune systems, ultimately powered by the fact that the sunken passenger liner is functioning like a giant battery. Having learned all about them from the scientists, Friend went down to the *Titanic* to see for himself. I'd quit my job for that as well. ■

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SCIENCE IN CULTURE

Mind tricks

Cognitive scientists take a lesson from magicians.

Susana Martinez-Conde and Stephen L. Macknik

Teller, the mute half of the magician duo Penn & Teller, apparently pulls a coin out of thin air for the umpteenth time. The audience breaks into applause. It's another great performance in Las Vegas, Nevada — only tonight, Teller is part of a special symposium hosted by the Association for the Scientific Study of Consciousness, bringing together magicians and cognitive scientists.

Vision scientists have often turned to the visual arts to rediscover the principles underlying visual perception, such as how to convey the illusion of depth on a flat canvas. Similarly, cognitive scientists have much to learn from magicians, who have developed cognitive principles and illusions that trick audiences.

The Magic of Consciousness Symposium on 24 June attempted to plumb directly the depths of the intuition of world-class magicians. Magicians are behaviour experts who artfully manipulate attention and awareness. Their wealth of knowledge on cognition and behaviour is now ripe for picking.

James Randi — aka The Amaz!ng Randi — explained that spectators will easily accept unspoken assumptions. He made his point by fooling more than 200 consciousness researchers into thinking that his voice was being amplified by a dummy microphone, and by pretending to read with glasses that were merely empty frames.

Teller pulled coins out of thin air, conference bags and spectacles. He used water from his drinking glass to make a ball disappear. Shedding his normally silent stage persona, he described with eloquence how magicians make their audiences incorrectly link cause and effect. We all infer cause and effect in everyday life. When A

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precedes B, we conclude that A causes B. The skilled magician takes advantage of this inference by making sure that A (pouring water on a ball) always precedes B (the ball disappearing). However, A does not really cause B. The magician only makes it look so. Audiences assume that each repetition of a trick is done by the same method. "When a good magician repeats an effect, he varies the method in an unpredictable rhythm," said Teller. "That way, each time observers suspect one method, they find their suspicion disproven by the subsequent repetition." For instance, the disappearing ball is first secretly palmed by the other hand, but in the next repetition it is instead dropped on the magician's lap (allowing the magician to show that the other hand is empty).

Johnny Thompson — aka The Great Tomsoni — refers to this principle as "closing all the doors". That is, a good trick will appear to rule out all possible explanations, except for magic. Mac King illustrated these points by impossibly pulling a melon-sized rock out of his shoe — three times. The first two times he purposely used the same method, making it easier to see the trick the second time around. The third time he changed the method, deceiving the audience once again. "Much of our lives is devoted to understanding cause and effect," Teller said. "Magic provides a playground for those rational skills."

He also explained that "action is motion with a purpose". In normal social interactions, we constantly search for the purpose motivating other people's actions. An action with no obvious purpose raises questions. However, when the purpose seems crystal clear, we look no further. "Skilled magicians inform every necessary maneuver (motion) with a convincing intention," said Teller. Thus, the real purpose of the motion (hiding the ball) is hidden by the apparent purpose of the action (pouring the water).

Apollo Robbins, a professional thief who once pickpocketed Jimmy Carter's secret service detail, demonstrated the use of interpersonal distance and eye contact to control a target's gaze and attention. In doing so, he looted, undetected, every single pocket of a journalist from the audience.

James Randi tied the evening together by effortlessly escaping ropes knotted by philosopher Dan Dennett. The intuitive insights offered by magicians will frame future cognitive experiments, from measuring the dynamics of attentional blindness to determining the neural correlates of causal inference. Where in the brain is motion perceived as action? Does this same brain area encode the purpose of the action? For cognitive scientists, the second act of the show will take place in the lab. ■

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