The fundamental rules of fairness in coyotes' playtime are: "Ask first, be honest, follow the rules, and admit you're wrong." Bekoff's observations suggest that animals that fail to play by these rules will usually fail to form strong social bonds and will leave the pack when they grow up. As these lone animals are exposed to higher mortality rates, Bekoff suggests, the ability to engage in fair play has a direct advantage for evolutionary fitness.

Peter Pongrácz from Eötvös University at Budapest, Hungary, reported sociocognitive research with dogs conducted with Ádám Miklósi. In a recent paper, Miklósi's group examined the response of dogs to behavioural interactions from other species by using robots as well as human partners in their experiments, in order to separate responses to the social behaviour as such from those to its physical embodiment. The experiments showed that the dogs soon began to form expectations regarding the behaviour of the robots, and that they recognised certain social aspects of it (PLoS One 2013, 8, e72727).

Bonobo comforts

The animals that are genetically closest to our species, bonobo and chimpanzee, are also strong candidates for consciousness research. Zanna Clay and Frans de Waal from Emory University in Atlanta, Georgia, USA, studied the consolation behaviour in young bonobos at a sanctuary in the Democratic Republic of the Congo (Proc. Natl. Acad. Sci USA (2013), doi: 10.1073/pnas.1316449110).

Having previously established that juvenile bonobos are more likely to comfort others than are adults and adolescents, the researchers have now found that those juvenile individuals who are good at controlling their own emotions will also be more likely to comfort peers in distress after a tantrum or after losing a fight. As the sanctuary where they studied bonobo behaviour harbours large numbers of juveniles orphaned by bushmeat hunters, the researchers could also establish that good emotional control and the ability to comfort others were more likely to occur in juveniles brought up by their own mothers than in orphans rescued and reared by humans.

The link between emotional control and sympathetic concern is well-established in children. Finding it in bonobos as well, the authors argue, shows that we share important parts of our socio-emotional behavioural framework with our animal relatives.

At the Brussels symposium, de Waal put this research into the wider context of his research on empathy in primates and presented what he calls a 'Russian doll' model of how animals perceive others. Their perception, de Waal explained, ranges from a core mechanism of emotional linkage arising from a direct mapping of another's behavioural state onto the subject's representations. This Perception–Action Model, according to de Waal, provides the basis for higher levels in which there is an increasing distinction between self and other, so that the other is recognized as the source of felt emotions.

Closing the Brussels symposium, Daniel Dennett from Tufts University warned of the dangers of drawing sharp lines between some animals that are conscious like we are, and others that are just zombies. He suggested that consciousness emerges from the massive interconnectivity of complex brains.

Frans de Waal summarises the experience: "Most of the participants at the meeting approached consciousness by evaluating capacities in animals that we associate with consciousness, such as mirror self recognition, time travel, insight learning, empathy and perspective-taking, and so on. So, instead of trying to demonstrate consciousness per se, we were looking for circumstantial evidence assuming that, if certain capacities engage consciousnesses in humans, then they probably also do in other species. We reviewed evidence from invertebrates and fish to birds and mammals, truly across the spectrum."

These considerations seem to suggest that there is a consciousness spectrum, even more finely graded than the four steps that Temple Grandin suggested in the 1990s, on which various animals may display distinct features of consciousness.

Rather than searching for a whole consciousness package, which may be as futile as earlier attempts at finding the seat of the soul, it may prove worthwhile for researchers to study those features separately, in the hope that they will later fit together into a meaningful understanding of human consciousness.

Michael Gross is a science writer based at Oxford. He can be contacted via his web page at www.michaelgross.co.uk

Q & A

György Buzsáki

György Buzsáki obtained an MD degree from the University of Pécs, Hungary in 1974, followed by his Candidate of Science (~PhD) degree in 1984. Following postdoctoral fellowships with Eduardo Eidelberg in San Antonio, Texas and Cornelius Vanderwolf (a student of D.O. Hebb) at the University of Western Ontario, Canada, he returned to Pécs as an Assistant/Associate Professor in Physiology; at that time he was also a visiting scholar in Anders Björklund's lab at University of Lund, Sweden, and the Nenski Institute, Warsaw, Poland. In 1986, he became a J.D. French Foundation Fellow and subsequently an Associate Professor-in-residence at the University of California at San Diego, a rewarding and fruitful collaborative epoch with Fred Gage. After spending 20 years at Rutgers University, as Professor and Board of Governors Professor, he moved to New York University where he is currently a Biggs Professor of Neuroscience and Physiology. He is an elected member of AAAS, Academia Europaea and the Hungarian Academy of Sciences. His honors include the 2011 Brain Prize, ISI Highly Cited, Krieg Cortical Discoverer Award, The Pierre Gloor Award, Henry Neufeld Memorial Award, Distinguished Scholarship at Rutgers University and Collége de France Distinguished Professor. He sits on the editorial boards of several leading neuroscience journals, including Science and Neuron. His primary interests are brain oscillations, sleep, memory and associated diseases. His main focus is 'neural syntax' — how the segmentation of neural information is organized by the numerous brain rhythms to support cognitive functions. His book Rhythms of the Brain *has received numerous accolades.*

Why did you choose to study biology in the first place? I did not. I wanted to become an electrical engineer. As a young radio ham my goal was to establish effective Earth–Moon–Earth radio communication; but, given the expense of studying in a different city (the Engineering School was in Budapest), my parents asked me to choose between Law School and Medical School. While listening to a physiology class about feedback control in the brain in medical school, I found my future. The professor of that lecture, Endre Grastyán, became my future mentor and friend. Endre was the smartest and most generous person I have ever met. It is interesting and typical how an early 'imprinting' by charismatic individuals can shape young people's minds in both science and other walks of life and determine their career choices and goals.

How did you become a systems neuroscientist? Back then that term did not exist. I 'inherited' the hippocampus with all its problems from Endre Grastyán. Studying oscillations was a natural fit for me, given my strong interest in amplitude, frequency and single side band modulation of radio waves. After the introduction of the *in vitro* slice preparation and the discovery of LTP, nearly everyone moved into this direction or studied the responses of single neurons in whole animals. However, the slice was just too inert for me and my interest was always on how collective behavior of neuronal populations contributed to our cognitive abilities and I kept working on methods that allowed us to record and study large-scale activity of multiple neurons and their mesoscopic derivatives. In retrospect, this was a good choice and contributed to the creation of today's very active systems field. Slowly, emergent phenomena, collective phenomena and brain rhythms have become 'trendy'.

Do you have a favourite paper? Not really. It would be hard to single out one or two for me. One tends to remember papers because they had a great impact on our thinking, only to realize too often that those great ideas also had a rich history. I also admit that some of the papers that have most informed and influenced my thinking have been works from outside of neuroscience, from electronics to graph theory and pattern formation. I am also not a believer in 'discoveries'. Discoveries rarely happen as a single, punctate event, especially in the field of biology. Hypotheses mature slowly with time and become discoveries post-hoc. Sir John Eccles did not think of his discovery of the postsynaptic potential as his most important contribution to neuroscience.

What is the best advice you've been given? Perhaps a brief statement from one of my professors: "The best hypothesis is always your hypothesis". Do not follow trends because you simply become a follower.

If you knew what you know earlier on, would you still pursue the same career? The same career, yes. It has been rewarding at all fronts to be a neuroscientist. The public learned the term and appreciates neuroscience. We are the rocket scientists of the new age. Perhaps I would take a different path, most likely becoming a neurosurgeon. These days one can learn amazing things from neuronal recordings and stimulation trials in humans. As neuropharma industry is becoming more stagnant with few if any new psychoactive drugs on the horizon, closed-loop, electronics/optics-based interactions with the human brain are coming to the front. This is an open territory for new discoveries and therapeutics.

What is your favourite conference? My favorite events would have been the Macy Foundation meetings in the first half of the last century. The contents of these events are well documented in great detail in the conference proceedings. Presentations were followed by intense discussions, sometimes as long as two days! You can really tell from reading these discussions that the participants were truly interested in the subject matter. They did not ask questions because they wanted to look smart. They did ask penetrating questions that today would sound 'nasty', and most people would not consider asking, perhaps being afraid to be punished at the next round of a paper or grant review.

Do you have a scientific hero? I find the Tycho Brahe and Johannes Kepler duo very fascinating (perhaps best documented in Arthur Koestler's *The Sleepwalkers*). They represent a true antithesis and complementary form: the experimenter versus theoretical modeler, data collector versus synthesizer, outgoing versus solitary, rich versus poor, exploiter versus exploited, physical strength versus crippled, and so on. Yet, they knew that they needed each other and it is fascinating to see how they tolerated each others' idiosyncrasies in the hope of a bigger reward. I always wondered how the trajectory of physics would have been shaped if those personality differences overruled the noble goals of acquiring new knowledge.

What was your most memorable moment in science? The mid-1980s were dominated by studies of long-term potentiation and *in vitro* slice experiments. The big question was whether the favorable conditions for synaptic plasticity *in vitro*, such as tetanic bursts at 100–200 Hz, also existed in the intact brain. Yet, very few of us recorded from behaving animals back then. I had a rat with eight electrodes placed in the pyramidal layer of hippocampus area CA1 in which I previously cut the subcortical inputs to the hippocampus to study sharp waves. I already suspected that sharp waves, being the most synchronous patterns in the brain, could provide the needed natural tetanus. I stimulated the entorhinal input with brief bursts of 100 Hz, which evoked a unique spatial pattern of evoked responses.

To my astonishment, after the stimulation the same spatial pattern recurred numerous times spontaneously on my precious multi-trace oscilloscope in the form of 'exaggerated' sharp waves and unit firing. An hour or so later when the pattern vanished, I reversed the polarity of stimulation to induce a different evoked spatial pattern. Now, the spontaneous sharp waves resembled the new evoked patterns. I have seen only a few of these new patterns since the rat began exploring, which suppressed the sharp waves. I also realized that my camera failed and I had no documentation of the experiment. But I knew after that experiment that I was onto something very important. This 'failed' observation led to my 'two-stage' model of memory consolidation (1989). It not only shifted the thinking about the role of sleep in memory from REM to non-REM but also identified a specific physiological pattern, the hippocampal sharp wave ripple, as the key compression mechanism for hippocampal–neocortical transfer of learned information.

Perhaps an equally elevated moment was when I recorded from my first interneurons in 1979 and saw their clear firing relationship to various oscillations.

What are the big questions to be answered in your field? I leave it for others to make a priority list. For me, the most important ones are those that actually can be answered. Understanding and being able to explain the mechanisms of anything is a big reward for me. An equally big reward is to synthesize large chunks of knowledge from multiple levels. Seeing a connection between previously non-connected things, such as kicks of the fetus that we have known for centuries and spindle patterns in the brain was a true revelation for me. Perhaps a real big question for me is something I am actually not pursuing actively, which is scaling of the brain. What are the fundamental rules and constraints that allow the mammalian brains to grow >10,000-fold yet keeping the same temporal organizing mechanisms, as reflected by brain rhythms? How can new qualities, such as cognition, emerge from fundamentally the same but more complex architectures?

If we can document the entire knowledge of mankind with the combination of 30 letters, are there similar syntactical rules in the brain that allow its rich information capacity to be compiled from assemblies of spiking neurons? Answers to these would reflect real progress. Yet, neuroscience spends little effort in understanding the syntax of brain operations. Instead, we are simply examining the correspondences between arbitrary physical stimuli and neuronal responses. But this approach is like learning correspondences between English and Hungarian words. Such methods are not sufficient to understand a language, especially when only small fragments of correspondences are available. Two examples come to mind. Thomas Young progressed a bit in the understanding of the Egyptian hieroglyphs using correspondences but it took Jean-François Champollion, who studied the syntax of Greek, Coptic and related languages, to decipher the code. Similarly, Alan Turing could make quick progress in the cryptoanalysis of the German code because the syntactical rules were given to him by the Polish Cipher Bureau in the form of Enigma machines. Without some a priori knowledge of the syntax, the polyalphabetic substitution cipher is practically unbreakable and the brain of course is not an exception.

What do you think about the electronic revolution in publishing? Our species is distinct and special in one major respect, the ability to externalize brain function. With language and its material versions, books, movies and other depositories we managed to create a super large, species-specific knowledge base. In the process, the individual share of the ever-increasing total knowledge of humankind is exponentially decreasing. Every other primate acquires as much knowledge during his/her lifetime as the knowledge of all primates, give or take. But think of us. Who could build television tomorrow if all documents perished? With the internet, humankind entered into a new evolutionary path with its own pressures and challenges, even if we try to ignore this fact. Almost the entire knowledge of humankind is now available (somewhere) in electronic form, externalized from the individual brains. But the value of such a huge library is only as good as its searchability. Our personalized search engine, the hippocampus, is a good librarian for the brain and effectively assists us to navigate in the vast knowledge base stored in the neocortex, separating the irrelevant from the important in a matter of a few search cycles.

In contrast, Google (and the like) is not up to this job yet. It is excellent for searching explicit information but pretty hopeless for creating new knowledge, largely because it is not well prepared for prioritizing information for individual needs. In my view, this problem applies to non-selective electronic publishing as well. If all acquired information is simply uploaded to the web without any filtering mechanism, it becomes more and more difficult to separate the wheat from the chaff, unless some smart classifier algorithms are invented. A single individual simply does not have enough time to extract every bit of potentially relevant information from the enormous data base being uploaded daily. In short, the opportunity and appeal are there but the solutions are still missing. The big issue therefore is not electronic versus paper but whether some effective preprocessing is available as exemplified, for example, by peer review.

What is your favorite thing about being a researcher? The freedom to explore anything; the vital essence of discovery science is that one can walk on a road pursuing an idea, serendipitously finding something unusual that does not fit and then pursuing that new problem to understand why it does not fit. Such sidetracks have led generations of researchers to unexpected and totally novel territories.

The fundamental value of this process and its efficacy are so difficult to explain to taxpayers and politicians, especially in today's push toward 'translational science' initiatives, a slogan introduced by university bureaucrats in a quest for quick return of investment. It can easily be proven that when time and other resources (financial, for example) are limited, the 'random walk' approach is superior or at least as efficient as any other pre-planned specific strategies and desires in solving tough problems. Random walk is what all animals do when in search for food or shelter in unknown territories.

Another important factor in discovery and research is human motivation. People pursuing their own ideas work harder than when working on someone else's. If support and liberty for fundamental discoveries are taken away (as one can see such dangerous tendencies these days with emerging mega-projects in neuroscience), the long-term costs will be very high.

NYU Neuroscience Institute, School of Medicine and Center for Neural Science, New York University, New York, NY 10016, USA.
E-mail: gyorgy.buzsaki@nyumc.org