

Inga D. Neumann: Molecular underpinnings of the brain oxytocin system and its involvement in socio-emotional behaviour: More than a love story

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Professor Inga Neumann stands at the forefront of neuropeptide research, bringing over three decades of expertise to her role as Chair of the Department of Behavioural and Molecular Neurobiology at the University of Regensburg, Germany. Her journey in science began in East Germany at the Karl-Marx-University in Leipzig (now the University of Leipzig), where she earned both her diploma in biology and her PhD. After the fall of the Berlin Wall, her career path led her through a postdoctoral position at the University of Calgary in Canada and seven enriching years at the Max-Planck Institute for Psychiatry in Munich before assuming her current position at Regensburg in 2001. As the first woman to be appointed full professor at the Faculty of Biology and Preclinical Medicine, she has shaped the University's neuroscience landscape by establishing and directing the Elite Masters Programme in Experimental and Clinical Neuroscience. Currently, she heads the Graduate School "Neurobiology of Socio-Emotional Dysfunctions," a prestigious program funded by the German Research Foundation since 2017. The heart of her research lies in understanding how neuropeptides, particularly oxytocin, vasopressin, and CRF, orchestrate stress responses and social behaviours. Her work spans multiple levels of analysis – from molecular mechanisms and epigenetics to neural circuits and behaviour – primarily using rodent models to unlock the mysteries of the social brain. In this Genomic Press Interview, Professor Neumann shares her reflections on a life dedicated to unravelling the intricate relationships between brain chemistry and behaviour, offering insights into both her scientific journey and personal philosophy.

Part 1: Inga D. Neumann – Life and Career

Could you give us a glimpse into your personal history, emphasizing the pivotal moments that first kindled your passion for science?

My father, a physicist and mathematician working at the Carl Zeiss company in Jena, East Germany, kindled my interest in scientific phenomena, astronomy, physics, and genealogy. My parents also taught us critical and scientific thinking and how to appreciate nature. My early love for the beauty of nature arose along with my interest in horses, with the possibility of riding through the meadows and forests surrounding my Thuringian hometown. However, governmental restrictions in East Germany thwarted my original goal of becoming a veterinarian. Instead, I studied biology at the Karl Marx University in Leipzig, which has now returned to its original name of the University of Leipzig. At the Zoological Institute of that University, I became fascinated by the brain and ways of deciphering its secrets during my work for my diploma thesis in Rainer Landgraf's lab.

We would like to know more about your career trajectory leading up to your most relevant leadership role. What defining moments channelled you toward that leadership responsibility?

It has always been easy for me to develop ideas to take on leadership or responsibility in my private life and scientific environment. However, I had



Figure 1. Inga D. Neumann, PhD, University of Regensburg, Germany.

never seriously aimed to become a full professor at a university. Moreover, before being offered the position of Full Professor and Chair of the Department of Neurobiology and Animal Physiology at the University of Regensburg in 2001, I had never held the official group leader position. I only applied for the position because my contract at the Max-Planck-Institute was temporary, and my Heisenberg grant from the German Research Foundation (DFG) was limited to 5 years. Thus, I was thrown in at the deep end and suddenly led a group of elderly scientists and technicians working on cockroaches (*Blattella americana*) at the Institute of Zoology in Regensburg. I was the first woman employed as a full professor at the Faculty of Biology and Preclinical Medicine. I was the mother of 2 children, one of whom was just 3 years old, with the father working 120 km away from Regensburg and only returning home at weekends. This was where I started to oversee the substantial structural remodelling of more



than 30 rooms, old labs, and offices to enable my future research with rodents. I never considered attending a leadership or management course, nor did the University offer any such options at this time – you either succeeded or failed. But it was a fantastic time. I had complete freedom to shape the future research structures (limited only by financial restraints), to establish and build animal laboratories and behavioural facilities, to employ enthusiastic people, to think about how to hone my research profile, and, step by step, to successfully apply for research grants. Thus, there were no defining moments that channelled me towards that leadership responsibility; it was instead a continuous process during which I grew into the role.

Please share with us what initially piqued your interest in your favourite research or professional focus area.

As part of the research for my diploma thesis at the Karl-Marx-University in Leipzig, we aimed to monitor the release of the neuropeptides oxytocin (OXT) and arginine vasopressin (AVP) in the rat brain during relevant physiological stimuli; e.g., suckling or osmotic stimulation. At the time, it was a fascinating hypothesis that, on the one hand, these neurohormones in the blood have distinct physiological functions, such as milk ejection or antidiuresis, and, on the other, are simultaneously released in the brain to promote respective behaviours. During our early research, we used push-pull perfusion techniques, and then later, during my PhD studies, we advanced to using microdialysis approaches. For more than 40 years, these intracerebral microperfusion techniques combined with extremely sensitive and specific radioimmunoassays for detecting the neuropeptides in the brain samples were the tools of choice to reveal the dynamics of neuropeptide release within distinct brain regions in the conscious and behaving animal. Thus, we monitored the release of OXT and AVP in the hypothalamic regions of origin or other limbic regions during physiological conditions, including suckling and birth, mating, exposure to various stressors, or social interactions. We also compared the intracerebral release patterns of these neuropeptides their secretion from the neurohypophysis into the blood and realized distinct differences in their secretory profile.

However, my beginnings as a scientist behind the “Iron Curtain” were bumpy. We had to build the concentric push-pull cannula systems, the U-shaped microdialysis probes, and perfusion pumps ourselves.¹ A dentist donated an old dental drill and dental cement. We did not have access to a stereotaxic frame. We had to use a divider, a ruler, and our stable hands to determine the stereotaxic coordinates and to keep the pull cannula in the correct position until the dental cement solidified. After Germany unified and experimental conditions had substantially improved, I continued to combine intracerebral microperfusions with many other methods to reveal the functional impact of OXT released within the brain. Realizing that the same molecule has distinct but synergistic functions in the periphery of the body (promotion of labor, milk ejection) and within the brain (maternal behaviour, stress buffer, anxiolysis) in the period of motherhood was a fascinating insight.

At the Max-Planck-Institute for Psychiatry in Munich, where I was offered a senior postdoc position, my scientific horizon was broadened substantially by integrating psychopathological aspects into my research. My fascination with brain neuropeptides, their intracerebral release patterns, and behavioural or physiological functions remained unbroken. So we started to focus on the potential role of the brain's OXT and AVP systems as therapeutic targets for psychiatric diseases such as depression and anxiety disorders or autism. These aspects remain the focus of my ongoing research using suitable animal models of chronic stress, depression- and anxiety-related behaviours, and social anxiety disorder. I was always motivated by the fact that the development of clinically relevant animal models is key to revealing the underlying mechanisms of specific symptoms of psychopathologies.

¹Neumann ID. Monitoring oxytocin signaling in the brain: More than a love story. *Compr Psychoneuroendocrinol* 2023 Sep 6;16:100206. doi: [10.1016/j.cpnec.2023.100206](https://doi.org/10.1016/j.cpnec.2023.100206)

What impact do you hope to achieve in your field by focusing on specific research topics?

The large class of neuropeptides is a distinct group of neuromodulators that play a substantial role in all aspects of neuronal and glial functions and, thus, in all aspects of behaviour under healthy and pathological conditions. I am convinced that increasing our knowledge about the stimuli, dynamics, and consequences of their intracerebral release at the behavioural, physiological, cellular, and molecular levels will improve our understanding of general brain mechanisms. I hope that our studies revealing basic mechanisms of neuropeptide release, intraneuronal and intra-glial receptor-mediated signalling cascades, and their behavioural functions are helping to pave the way for interpreting the many and still growing number of human experiments targeting the OXT system. OXT can be applied intranasally in humans, and this treatment was shown to affect all different kinds of socio-emotional behaviour. Although there is still a long way to go to reveal transport into the brain, brain targets, suitable dosing, and treatment duration, the hope is that one day it will be possible to apply OXT reliably to treat – for example – treatment-resistant patients suffering from anxiety disorders, especially social anxiety, but also autism and schizophrenia.

Please tell us more about your current scholarly focal points within your chosen field of science.

To reveal underlying mechanisms of social fear, we are currently focusing on the role of brain OXT and CRF and other potential neuroactive molecules, such as non-coding RNA or endocannabinoids, in social anxiety (DOI: [10.1038/npp.2011.329](https://doi.org/10.1038/npp.2011.329)). In this context, we have developed a reliable mouse model of social fear conditioning, an operant conditioning paradigm (DOI: [10.1038/s41583-023-00759-w](https://doi.org/10.1038/s41583-023-00759-w)). Here, we also include aspects of increased vulnerability to social fear after exposure to chronic psycho-social stress, early life stress, or, in contrast, of being resistant to social fear conditioning: for example, during lactation (DOI: [10.1016/j.cub.2018.02.044](https://doi.org/10.1016/j.cub.2018.02.044)) or after mating (DOI: [10.1016/j.psyneuen.2024.107083](https://doi.org/10.1016/j.psyneuen.2024.107083)), i.e., at times of highest activity of the brain OXT system.

What habits and values did you develop during your academic studies or subsequent postdoctoral experiences that you uphold within your research environment?

As the responsible scientist behind many PhD and postdoctoral students' work, I feel obligated to win sufficient research funding to ensure their livelihoods and research for as many years as possible. THINK BIG is the word I often use to encourage innovative research without thinking of the financial limits in the first instance. The manuscripts we submit to any journal also reflect our work's quality. Thus, first (and last) authors have to earn these positions by producing the best manuscript draft possible, which I then revise thoroughly and repeatedly – up to 13 times, a time-consuming learning process for all persons involved.

What do you most enjoy in your capacity as an academic or research leader?

I feel incredibly privileged always to work with the most talented, interested, and intelligent young people, with whom I can share my fascination with neuroscience in general and with the neurobiology of socio-emotional behaviour. Although, the development of their academic skills is a bumpy and energy- and time-demanding way, it is rewarding to see PhDs and postdocs grow in their role as future research leaders, starting with the supervision of student research assistants, Bachelor's and later Master's students, and continuing their careers in academia or industry.

Outside professional confines, how do you prefer to allocate your leisure moments, or conversely, in what manner would you envision spending these moments given a choice?

Here, I want to mention three aspects that are particularly important to me and help me to maintain a good work-life balance. The first is spending time with my family and, for the last 2 years, enjoying being a grandma for the first time. The second is the high-quality time I spend singing in various choirs and enjoying performances of classical pieces by Bach, Brahms, Mendelssohn, or Handel as a small individual being part of a large team.



Figure 2. Inga D. Neumann working at the Tacugama Chimpanzee Sanctuary in Sierra Leone, preparing enrichment material for chimpanzee orphans.

And – last but not least – I want to mention my passion for nature and preserving biodiversity. Hiking in the incredible Alps or in the nearby Bavarian Forest is a great way to exercise and gives me inner peace. At a very local level, I support environmentally friendly strategies as a municipal council member.

Further afield, I substantially support the Tacugama Chimpanzee Sanctuary in Sierra Leone, where I run a small scientific project on chimp orphans (see [Figure 2](#)). I also support their fantastic work in raising the environmental awareness of pupils and young adults or supporting the communities around the national parks, where wild chimpanzees are still found but endangered. In these villages, Tacugama supports their agricultural work and educates rangers. I plan to spend more time at Tacugama in the future.

Part 2: Inga D. Neumann – Selected questions from the Proust Questionnaire²

What is your idea of perfect happiness?

Lucius Annaeus Seneca said “true happiness is to enjoy the present without anxious dependence upon the future”. I do not think there is perfect happiness, but we have moments of great happiness.

²In the late nineteenth century, various questionnaires were a popular diversion designed to discover new things about old friends. What is now known as the 35-question Proust Questionnaire became famous after Marcel Proust's answers to these questions were found and published posthumously. Proust answered the questions twice, at ages 14 and 20. In 2003 Proust's handwritten answers were auctioned off for \$130,000. Multiple other historical and contemporary figures have answered the Proust Questionnaire, including among others Karl Marx, Oscar Wilde, Arthur Conan Doyle, Fernando Pessoa, Stéphane Mallarmé, Paul Cézanne, Vladimir Nabokov, Kazuo Ishiguro, Catherine Deneuve, Sophia Loren, Gina Lollobrigida, Gloria Steinem, Pelé, Valentino, Yoko Ono, Elton John, Martin Scorsese, Pedro Almodóvar, Richard Branson, Jimmy Carter, David Chang, Spike Lee, Hugh Jackman, and Zendaya. The Proust Questionnaire is often used to interview celebrities: the idea is that by answering these questions, an individual will reveal his or her true nature. We have condensed the Proust Questionnaire by reducing the number of questions and slightly rewording some. These curated questions provide insights into the individual's inner world, ranging from notions of happiness and fear to aspirations and inspirations.

What is your greatest fear?

On a personal level, I fear losing my cognitive functions with aging. At a global level, I fear the further loss of our world's incredible biodiversity due to continuous and almost unchanged human activity, our careless use of available resources, and climate change.

Which living person do you most admire?

I deeply respect people who change their lifestyles and habits for environmental reasons. This can be their food choice, travel methods, altering consumption habits, or actively demanding appropriate political decisions.

What is your greatest extravagance?

To take a large jar of Nutella with me while traveling to and working at the Tacugama Chimpanzee Sanctuary in Sierra Leone, which significantly brightens my otherwise dry breakfast each morning (see [Figure 2](#)).

What are you most proud of?

To have successfully combined children and research at a time when this was not so usual in united Germany, when kindergartens and afternoon care in schools were not always available.

What is your greatest regret?

That I did not learn a musical instrument properly to a high standard as a child.

What is the quality you most admire in people?

Honesty, including acknowledging one's failures and weaknesses.

What is the trait you most dislike in people?

Selfishness and ignorance of the need to change our living habits to prevent further damage to nature and climate change caused by our species.

What do you consider the most overrated virtue?

Intelligence.

What is your favourite occupation (or activity)?

Listening to or performing classical music, discussing new research projects, but not answering questionnaires.

**Where would you most like to live?**

In the Bavarian village close to the banks of the river Danube where I have lived for the past 24 years.

What is your most treasured possession?

The old genealogy tables showing the many different branches of my ancestral family tree going back to the 15th century, along with old letters and family photos.

When and where were you happiest? And why were you so happy then?

I remember exceptionally happy moments reading books to my children when they were very small and when they started talking, which are repeated from a different perspective with my grandchild now. I have happy and enthusiastic moments during a triumphant performance by our choir. I am also happy sitting in my garden, listening to and watching birds, wild bees, bumble bees, and dragonflies with a good cup of tea, and knowing I can repeat these moments anytime. Moreover, there were always truly delightful moments when we were awarded substantial research funding, for example, the funding for our Graduate School in 2017, and again in 2021 by the German Research Foundation.

What is your current state of mind?

I am among the many people who are deeply concerned about current worldwide political and ecological developments. It takes an immense amount of optimism to feel confident about a bright future for our grandchildren.

What is your most marked characteristic?

Optimism and determinism.

What do you consider your greatest achievement?

That I completed several half marathons, and that I was almost able to keep pace with the local rangers in the rainforest of the Loma National Park in Sierra Leone setting up camera traps for monitoring wild life.

If you could change one thing about yourself, what would it be?

Being more patient with myself and with people.

What do you most value in your friends?

Being good partners to talk to in happy and sad moments, and humour.

Who are your favourite writers?

From Stefan Zweig to Ken Follett.

Who is your favourite hero of fiction?

Peter Pan.

Who are your heroes in real life?

I admire people who show civil courage or take real risks to protect civil rights or our environment.

What aphorism or motto best encapsulates your life philosophy?

"He or she who has a why to live can bear almost any how." (Friedrich Nietzsche – who was my great-great-grandmother's cousin).

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