Ground-breaking research into learning honoured with the world's largest brain research prize

The Lundbeck Foundation's major research prize – The Brain Prize – goes this year to three UK-based brain researchers for explaining how learning is associated with the reward system of the brain. The prizewinners have found a key to understanding the mechanisms in the brain that lead to compulsive gambling, drug addiction and alcoholism.

Sophie is surprised and delighted by the great applause she receives for the new way she plays a piece of music. The applause motivates her to continue learning and improving and, perhaps, even become a professional musician one day.

The applause is an unexpected reward. This *unexpected* reward is associated with an increased release of the brain's neurotransmitter dopamine in specific brain cells, stimulating learning and motivation.

The three winners of the 2017 Brain Prize, English Peter Dayan, Irish Ray Dolan and German Wolfram Schultz, have identified how learning is linked with anticipation of reward, as in Sophie's case, giving us fundamental knowledge about how we learn from our actions.

Through animal testing, mathematical modelling and human trials, the three prizewinners have proven that the release of dopamine is not a response to the actual reward but to the difference between the reward we expect and the reward we actually receive. The greater the surprise, the more dopamine is released.

The Brain Prize is for 1 million euros, or approximately 7.5 Danish kroner, and is the world's largest brain research prize. The organisation behind the prize is the Lundbeck Foundation, one of Denmark's largest sponsors of biomedical sciences research. The chairman of the foundation's Selection Committee, Professor Sir Colin Blakemore, explains the reasoning behind the award:

"The research of these three prizewinners offers far-reaching perspectives on our understanding of human behaviour and how we make decisions. Their research has also provided a valuable key to

understanding what goes wrong when people succumb to compulsive gambling, drug addiction, obsessive compulsive disorder and schizophrenia."

"Small devils in the brain"

The human brain has one million brain cells that carry the neurotransmitter dopamine. These dopamine neurons are located in the centre of the brain but have pathways to many other parts of the brain.

Prizewinner Wolfram Schultz describes the dopamine neurons as "small devils in our brains". These are the cells that make us exert ourselves and act to gain ever greater rewards. But they are also the cells that are under attack when we consume substances such as cocaine, nicotine or alcohol.

The system becomes overstimulated by dopamine – or hi-jacked – leading to addiction in some. The same applies to compulsive gambling where anticipation of an ever bigger win leads to increasingly risky behaviour.

"Mapping the connection between learning and reward is essential if we're to understand human behaviour and how to improve treatment of brain disorders. With elegant experiments and mathematical models, the prizewinners have described how dopamine plays a crucial role in the motivation that drives learning," says Professor Morten Kringelbach, himself a researcher of the hedonic brain at the universities of Oxford and Aarhus.

Same mechanisms

The three prizewinners are receiving this award for increasing our understanding of dopamine neurons. In animal trials, Wolfram Schultz has mapped the parts of the brain in which dopamine neurons are located and has illustrated how they react to reward and external stimuli, helping control the behaviour of the laboratory animals.

Peter Dayan uses mathematical models to describe the way in which dopamine neurons react to the difference between what is expected and what actually happens. He has proved it probable that the dopamine neuron system helps control learning and actions.

In collaboration with Peter Dayan, Ray Dolan has tested these hypotheses in human trials and, applying brain scanning techniques to humans, has shown that human behaviour is controlled by the same mechanisms present in laboratory animals.

An asset to Danish brain research

The Brain Prize, which honours European brain research and international collaboration, is being awarded for the seventh successive year. The outreach programme attached to the prize invites the year's three prizewinners to Denmark to participate in meetings and workshops together with Danish brain researchers. The programme is organised in partnership with the three largest Danish universities and the Danish Society for Neuroscience.

Kim Krogsgaard, Managing Director of The Brain Prize, says:
"The Brain Prize and its associated activities help strengthen, internationalise and raise the profile of Danish brain research, providing a perfect supplement to the 250 million Danish kroner granted by the Lundbeck Foundation to Danish brain researchers each year. As a result, Denmark is gradually becoming a 'brain research nation', and opportunities for attracting leading international researchers are steadily improving – for the great benefit of Danish research."

_____

For further information about the Brain Prize and the prizewinners, please contact:

Dr Kim Krogsgaard, Managing Director of The Brain Prize
Tel. +45 3397 0001 or +45 2014 8384
Email: kk@thebrainprize.org

www.thebrainprize.org
www.lundbeckfonden.com

Facts

• The one million euro Brain Prize is awarded by the Lundbeck Foundation, which each year distributes grants of almost half a billion Danish kroner to biomedical sciences research. Around half of this amount is donated to brain health, which is the foundation's special focus area.

• The Brain Prize was established by the Lundbeck Foundation in 2010 as a European prize and was awarded for the first time in 2011. This year the prize is being awarded to research into the

mechanisms of the brain that link learning with reward. This research offers far-reaching perspectives and has given us a better understanding of human behaviour and how we make decisions. It has also provided a key to understanding what goes wrong when people succumb to compulsive gambling, drug addiction, obsessive compulsive disorder and schizophrenia.

• The Brain Prize is a personal prize, awarded annually to one or more scientists who have achieved distinction through outstanding contributions to European brain research.

• The Prize will be presented by His Royal Highness the Crown Prince of Denmark on Thursday, 4 May 2017 in Copenhagen.

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

About the prizewinners' research:

It is said that the greatest joy lies in the anticipation. This saying implies that we become disappointed if we don't receive the reward we expect – such as a good mark for an examination. If we get the mark we expect, we are satisfied. But if we achieve more than we expect, we are overjoyed and learn from the experience. The neurotransmitter dopamine gives us motivation and links the reward system of the brain with learning.

The human brain has one million brain cells that carry the neurotransmitter dopamine. These dopamine neurons are located in the centre of the brain but have pathways to many other parts of the brain.

It has been a well-known fact since the 1950s that electrical stimulation of this part of the brain triggers a feeling of pleasure in human beings, and tests have shown that rats implanted with electrodes are willing to seek stimulation or even induce it themselves by pressing a pedal.

If a laboratory animal receives the exact reward it is expecting, activity in the dopamine neurons will increase slightly. But if the reward is greater than expected, activity levels increase much more dramatically. Similarly, activity levels fall to below the baseline if the reward is less than expected. The researchers have also proven that the response steadily declines if the animals receive the same reward again and again.

We learn – also from our mistakes

Regardless of what we are doing, our brain will always keep an account of the reward for our actions and behaviour relative to our expectations. If the reward for an action is better or greater than expected, we will do more of the same in anticipation of a greater reward. If the reward is poorer or smaller than expected, we will avoid repeating the action.

We learn from both situations – we learn from our actions. We are rewarded for appropriate actions but we also learn from our mistakes. If the reward is exactly as expected, we learn nothing – our expectations remain the same and our behaviour pattern remains unchanged. We become spoilt or indifferent if we receive the same reward again and again.

We pick up signals

Not only do we learn from our actions – for better or for worse – we learn from signs and signals in our surroundings. As humans, we 'size up' the situation. We do this by picking up signs and signals which then play a part in controlling our actions. For instance, if you're feeling hungry on a road trip and you see a sign with a knife and fork, you are likely to leave the motorway to find a restaurant.

This action is also controlled by dopamine neurons. When a laboratory animal receives a reward for an action, an increase in dopamine neuron activity is triggered. A specific sign, such as a flash of light, just before the animal receives the reward will also increase activity in the dopamine neurons. The laboratory animal will gradually learn to react not only to the actual reward but to the signs that precede the reward and, consequently, change its behaviour.

About the prizewinners

Peter Dayan is from the UK. He read mathematics at the University of Cambridge and obtained a PhD from the University of Edinburgh for his dissertation on artificial intelligence. He has held postdoc positions at the MRC Research Centre in Brain and Behaviour in Oxford, UK, at the Computational Neurobiology Laboratory, The Salk Institute, La Jolla, USA, and at the Department of Computer Science, University of Toronto, Canada. In 1998, he was attached to the Gatsby Computational Neuroscience Unit, University College London (UCL), and has been director of the

unit since 2002. He is also a professor of computational neuroscience at UCL. Most recently, Peter Dayan was appointed Deputy Director of the new UCL-Max Planck Centre for Computational Psychiatry and Ageing Research.

Ray Dolan was born in Ireland, read medicine at University College, Galway, Ireland and later specialised in psychiatry. From 1981 to 1994, he worked at the Royal Free Hospital Medical School in London. In 1995, he moved to the Institute of Neurology, University College London (UCL), where he subsequently became director of the Wellcome Trust Centre for Neuroimaging. Ray Dolan was recently appointed Co-Director of the new UCL-Max Planck Centre for Computational Psychiatry and Ageing Research. He is a Fellow of the Royal College of Physicians, the Royal College of Psychiatrists, the Academy of Medical Sciences and the Royal Society. Dolan received the Minerva Foundation Golden Brain Award in 2006, the International Max Planck Research Award in 2007 and the Zülch Prize in 2013.

Wolfram Schultz is German. He read medicine, mathematics and philosophy at the universities of Hamburg and Heidelberg, Germany, from 1966 to 1971. He completed postdoc studies at Göttingen, Germany, from 1973 to 1975, at the State University of New York, Buffalo, from 1975 to 1976 and at the Karolinska Institute, Stockholm, from 1976 to 1977. Wolfram Schultz worked at the Institute of Physiology at the University of Fribourg, Switzerland, from 1977 to 2001, after which he moved to the University of Cambridge, UK, where he was appointed Professor of Neuroscience and Wellcome Trust Principal Research Fellow. Schultz has been honoured with many prizes, among others the Minerva Golden Brain Award in 2002 and the Ipsen Prize in 2005. He is also a Fellow of the Royal Society.