Grey matters

DAVID MYTON talks to a mathematician who's got some brainy new ideas on how the brain works

■ **George Christos *Memory and Dreams: The Creative Human Mind*, Rutgers University Press, ISBN 0-8135-3130-6, approx $60**

IF there's one place where the brain gets a daily workout it surely is in the education sectors. Thinking and teaching people to think is what most of the work is about – as is coming up with new ideas, that continuing drama of creativity, invention, innovation and breakthrough.

But what's going on up there in the old grey matter? How does the brain do what it does? How do we learn things? How is it that we can sometimes put disparate notions together to come up with something new? Why sometimes do we forget what we've learnt? And why oftentimes do we fail to learn anything at all?

Curtin University mathematician Dr George Christos, who studies neural networks, memory and learning and adaptive systems, has come up with some answers and theories relating to these questions – and others – in a remarkable new book, *Memory and Dreams: The Creative Human Mind*, published by Rutgers University Press.

To get some idea of what we are talking about, here's a few facts about the human brain, courtesy of Christos's book.

The brain has "vast and astonishing powers" which he says has led many scientists to declare that it is the most complicated system in the universe. It contains somewhere between 100 billion to 1000 billion neurons, the basic building blocks of the brain.

These are intricately connected and interact strongly with each other. Neurons communicate through small pulses of electrical and chemical current and each neuron simultaneously receives and interprets input from thousands to tens of thousands of other neurons and based on this information decides whether or not it should "fire" – that is emit an electrical pulse that travels to other neurons.

Each individual neuron, writes Christos, performs a very simple and almost trivial function, but collectively neurons are able to perform complex tasks and functions.

"Brain function is an emergent collective property of a large number of neurons, which seems to encompass more than the sum of its parts ... nature abounds with many beautiful patterns, structures and systems that emerge from rather trivial local interactions."

He points out that the brains of animals and insects are also amazing. Consider the ant: its brain is the size of a grain of sand, yet it enables the creature to move quickly over complicated landscapes, pick up chemical ant-made scents, detect changes in temperature, air movement and vibrations, search for food and interact socially with its own colony.

Christos says his book's main purpose is to present a tenable theory of how memory is stored, processed, retrieved and manipulated in the brain. Along the way he puts forward ideas of how the brain can generate new information and creative ideas, and considers what the brain may be doing during dream sleep.

Christos also promulgates a theory about Sudden Infant Death Syndrome (SIDS), a condition he links to the working of the infant brain during dream sleep.

If you're not of a mathematical or scientific bent, don't be put off – Christos has pitched the book at a general audience while at the same time keeping it interesting enough for scientists and their ilk.

Christos tells *Campus Review/Education Review* that he has developed his ideas over the past 10 years to come up with an explanation for how the components of the brain – its neurons, synapses and neural networks – store, retrieve and process memory, and why neural memory is so different to computer memory.

He also discusses how the brain develops after birth, and why he believes the brain does indeed forget, contrary to some prevailing theories that suggest we forget nothing.

"I am amused that some psychologists are only recently starting to think that the brain does not keep a trace of every experience," he says. "Neural network models suggest that memories are constantly competing with each other, they change with time and some memories are simply displaced. Memories are also lost as neurotransmitter stores – where memory is actually stored – decay with time."

Christos also looks at how the brain generates new ideas and creativity linked to a theory he calls "spurious memories".

He tells *Campus Review/Education Review:* "In the brain, memories are stored in a distributed and overlapping fashion, sharing neurons and synapses, quite unlike the way memory is stored in a computer.

"A consequence of this common storage arrangement is that the brain generates its own memory states, called 'spurious memories'.

"These states have been observed in mathematical models and there is every reason that they should also be present in the brain."

Spurious memories, he explains, generally comprise combinations of features of stored memories.

"I have suggested that these spurious memories are the basis of creativity, and that they allow us to adapt to an ever-changing environment. Spurious memories are actually also necessary for new learning."

This is a major shift on previous thinking, he says, as most researchers have been interested in finding ways to eliminate them from neural systems to improve the retrieval of stored memory.

"But the brain is not just a recording device," he continues. "I am saying that spurious memories may be the most important brain states, as they enable the brain to function autonomously, to adapt, to be creative, and to learn."

Commenting on a famous phrase by the genius physicist Albert Einstein that "imagination is more important than knowledge", Christos says: "That may be true, but if I am correct this should be supplemented with the fact that imagination is based on knowledge. This is because new ideas – spurious memories – are based on known information or memories.

"You would hardly get an idea about quantum field theory if you knew nothing about it, and in any case it would not mean much if you knew nothing about it."

The brain, he explains, functions autonomously, without any need for central control. "This is achieved by learning spurious memories. Without them the brain would only be able to recall what was stored in it. Neural network researchers normally store memories in neural systems by adjusting the links between neurons by hand, but there is no one that does this in the brain. The brain accomplishes this by itself and to my mind spurious memories are the way it does it."

He says this is interesting because it means that whatever we learn is in a sense already stored in our brain.

"WHEN you come to learn something new, a weak spurious memory that already exists in your brain is entrenched so as to become a strong stored memory."

This idea has serious implications for building real artificial intelligence systems, says Christos. "Most AI researchers are still looking at models with a central controller. In my model there is no need for central control."

Christos also explores what the brain may be doing during rapid-eye-movement (REM) sleep – normally associated with dreaming – incorporating neurobiological evidence such as what exactly is going on in the brain when we dream.

Dreaming is one of the main unsolved puzzles in systems neurobiology. "My theory on the function of dream sleep is based on an idea first put forward by Nobel Laureate Francis Crick and Graeme Mitchison, but with a twist.

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