Mind maths: Small world with big connections

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The brain is highly interconnected, with a networked architecture that makes the perfect platform for our mental gymnastics

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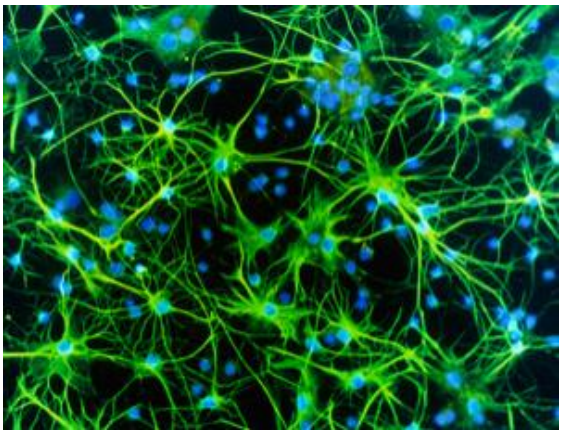

(Image: Nancy Kedersha/SPL)

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If you stretched out all the nerve fibres in the brain, they would wrap four times around the globe. Crammed into the skull, this wiring looks like a tangled mess, but in fact mathematicians know its structure well - it is a form of the "small-world network".

The hallmark of a small-world network is the relatively short path between any two nodes. You've probably already heard of the famous "six degrees of separation" between you and anyone else in the world, which reflects the small-world structure of human societies. The average number of steps between any two brain regions is similarly small, and slight variations in this interconnectivity have been linked to measures of intelligence.

That may be because a small-world structure makes communication between different areas of a network rapid and efficient. Relatively few long-range connections are involved - just 1 in 25 nerve fibres connect distant brain regions, while the rest join neurons in their immediate vicinity. Long nerve fibres are costly to build and maintain, says Martijn van den Heuvel at the University Medical Center in Utrecht, the Netherlands, so a small-world-network architecture may be the best compromise between the cost of these fibres and the efficiency of messaging.

The brain's long-range connections aren't distributed evenly over the brain, though. Last year van den Heuvel and Olaf Sporns of Indiana University Bloomington discovered that clusters of these connections form a strong "backbone" that shuttles traffic between a dozen principal brain regions (see diagram). The backbone and these brain regions are together called a "rich club", reflecting the abundance of its interconnections.

No one knows why the brain is home to a rich club, says van den Heuvel, but it is clearly important because it carries so much traffic. That makes any problems here potentially very serious. "There's an emerging idea that perhaps schizophrenia is really a problem with integrating information within these rich-club hubs," he says. Improving rich-club traffic flow might be the best form of treatment, though it is not easy to say how that might be achieved.

What is clear for now is that this highly interconnected network is the perfect platform for our mental gymnastics, and it forms a backdrop for many of the other mathematical principles behind our thoughts and behaviour.

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