

Evolution & Behavior

The Rat's Euler Whiskers

by **V.G.A. Goss**¹ | Associate Professor; **E.L. Starostin**¹ | Research Fellow; **R.A. Grant**² | Senior Lecturer

¹: School of Engineering, London South Bank University, London, UK

²: Manchester Metropolitan University, Manchester, UK

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ABSTRACT

Rats have notably long whiskers. We wondered how one can best describe the shape of those whiskers. Our extensive analysis of 523 whiskers led us to conclude that all the whiskers on a rat's cheek can be well approximated by segments of a Euler Spiral. So what?- you may well ask. As Galileo Galilei put it: "[The natural world] is written in a mathematical language and its characters are triangles, circles and other geometric figures". This study therefore takes us one step closer to understanding the world around us.



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In 1970, Thomas Woolsey, a young neuroscientist, was peering through a microscope at thin slices of mouse brain, when he observed something quite remarkable. In a region of the brain called the cerebral cortex, which plays a key role in sensing, memory and emotion in mammals, Woolsey discerned long barrel-like structures assembled in rows and columns. Moreover, he realised that that arrangement exactly mirrored the layout of whiskers on a mouse's cheeks. So, tweak a whisker and its corresponding barrel of neurons 'lights up'.

Woolsey's discovery sent neuroscientists scurrying around in excitement, for the mouse's whisker system, also found in rats, presented them with a

relatively straightforward platform for probing the mysteries of how mammals decipher the information they receive from their surroundings.

Upon brushing against an object a whisker tends to bend a little. That bending is detected by 100-200 nerve endings located where the whisker attaches to the rat's cheek. It is those 'bending signals' that the barrels respond to. But the way a whisker bends when it comes into contact with an object depends on its intrinsic shape and length, both of which differ from one whisker to another along the matrix of rows and columns on the animal's cheek. Whilst one can fairly easily measure their lengths, determining their intrinsic shapes is not so straightforward.

If one pauses for a moment to reflect upon the shape of rat whiskers (as one does!), it quickly becomes apparent that they are not straight. Furthermore, only a few of the 30 most prominent whiskers on each of a rat's cheeks resemble a circular arc. Most of them either get more curved, from base to tip, or they tend to straighten out. And close inspection indicates that some curve one way and then in the other direction.

So if not straight lines or circular arcs, is there some other geometric description appropriate to the form of rat whiskers, one that embraces the variety we observe? Finding such a description was the task we set ourselves.

Our approach was to look for something simple, but not so simple that it sacrifices accuracy. So we decided to test a curvature that changes at a constant rate, as one moves along a curve. An interesting thing about such a curve is that it traces out a [spiral](#), first described, in 1744, by [Euler](#). This spiral, also known as a Cornu Spiral and clothoid, has been useful in diverse applications: from the textiles industry to the design of railway tracks that need to smoothly transition from straight lines to circular bends.

We managed to obtain data for 356 whiskers passed on to us by Professor Mitra Hartmann, of Northwestern University, an expert in rat whiskers. We additionally scanned another 167 whiskers at 12,800 dpi for a pixel resolution of approximately 2 microns, compiling a database of 523 whiskers in total. All the rats were laboratory rats of the species *Rattus norvegicus*, more commonly known as brown rat, sewer rat and/or street rat.

We then compared how well segments of Euler Spirals, circular arcs and nonlinear curvatures fitted the data.

Our results indicate that the Euler Spiral produces a very good fit to all the whiskers (British and American rats compare well!): it encapsulates the full range of natural curvatures. Whereas circular arcs produced poor fits, the nonlinear curvature function gave only minor improvements. We also found that, by a simple mathematical scaling, all the whiskers fall onto a Universal Euler Spiral, which portrays the extent of the variety of whisker shapes for one animal, or even for one species.

Euler was a Natural Philosopher who worked within an ethos of scientific discovery paved out by the likes of Isaac Newton and Galileo Galilei. The latter once wrote that one cannot possibly understand the natural world unless one first learns 'the language and recognises the characters with which it is written. It is written in a mathematical language and its characters are triangles, circles and other geometric figures.'

It is due to their incredible whiskers that rats have provided a fellow creature - us humans - with a prototypical system that sheds light on how mammals process the information we receive from the world around us. Consequently, it is in honour of that service that we are pleased to refer to their whiskers as Euler Whiskers.

We are currently busy applying our methodologies to whiskers obtained from a range of other mammal species. So far, our results suggest that the Euler Whisker may be a generic and robust evolutionary phenomenon.

