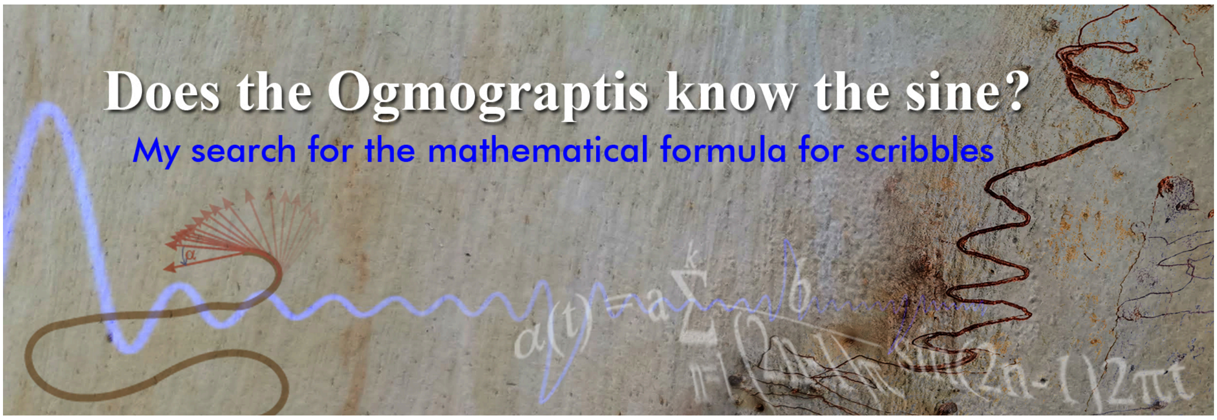

Before I saw scribbles with my own eyes, I admired them in Internet images, staring at their 'chaotic order' with fascination. I knew that they were one of the icons of Australian nature, and almost every Australian child knows them thanks to books such as *Snugglepot and Cuddlepie*. I also knew the poem written by Judith Wright quoted in most publications on scribbles, however, I must say that even though the author's main concept ('*...and found the written track of a life I could not read*')[1] is true on poetic level, is not on scientific level – if Ms. Wright knew the study by M. Horak and her group about scribbles[2], she would write: '*and found the written trace of life I could read a little*'.

An explanatory description should be given here on how *Ogmograptis* larvae create scribbles, but I refer you to a comprehensive, partially animated presentation on this subject at this link: [here]

I saw my first scribbles 'live' in Tilligerry Habitat (Tanilba Bay, NSW), and I was immediately surprised by two things: first, a much greater variety of tracks than those in the images seen so far and second, their considerable density on a single eucalyptus tree. And nothing changed apart from that – they were still fascinating!

One might look at scribbles with the eyes of a biologist, an artist or a poet, but – paraphrasing Ms. Wright – also like that:

'... and found the written track
and I saw sines and cosines
intertwined in the traces of life'.

Regularity in the scribbly tracks (I am referring here to the main zigzags) pushes us into the mathematical dimension of this phenomenon and gives rise to the following question:

Does a mathematical formula for scribbles exist?

Digging through the Internet in search of a mathematical function whose graph would be a scribble proved a failure. It is true that the work by J. Cooke et al.[3] is full of mathematical calculations, but it represents a statistical picture of scribbles regarding their dimensions, density, and certain 'mining behaviour'. My own self-suggestion proved to be a breakthrough:

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[1] J. Wright, *Scribbly-Gum*, www.abc.net.au/science/scribblygum/whatis.htm

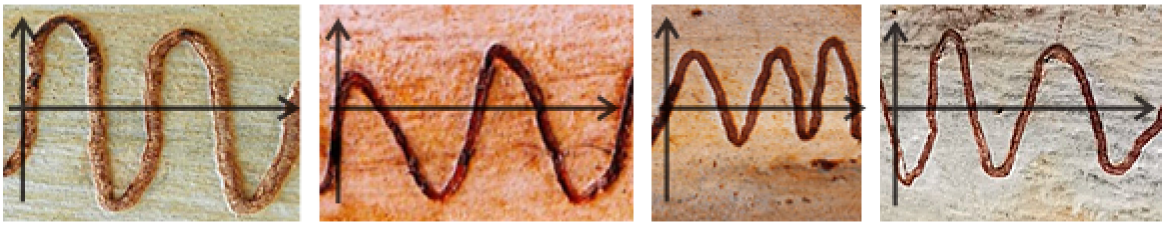
[2] M. Horak i in., *Systematics and biology of the iconic Australian scribbly gum moths Ogmograptis Meyrick (Lepidoptera : Bucculatricidae) and their unique insect–plant interaction*

[3] J. Cooke, T. Edwards, *The behaviour of scribbly gum moth larvae Ogmograptis sp. Meyrick (Lepidoptera Bucculatricidae) in the Australian Capital Territory*

I spent so much time on the Internet and found nothing – I would sooner discover the formula myself! And so it started!

<u>Tempting with simplicity</u>

When searching for a formula for scribbles (let me remind you that what I mean are the main zigzags) one naturally reaches for the basic trigonometric function – the sine. Many zigzags in fact resemble a graph of this function with additional random fluctuations (the scribbles represented 'in the graphs' have been rotated by 90 degrees).

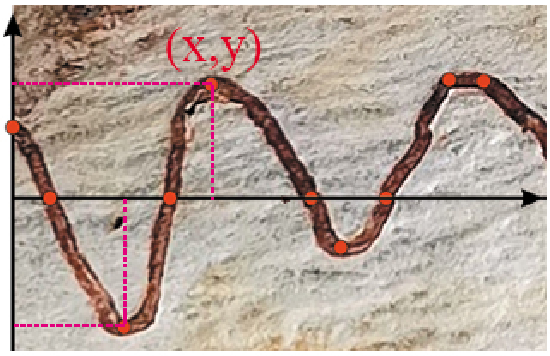


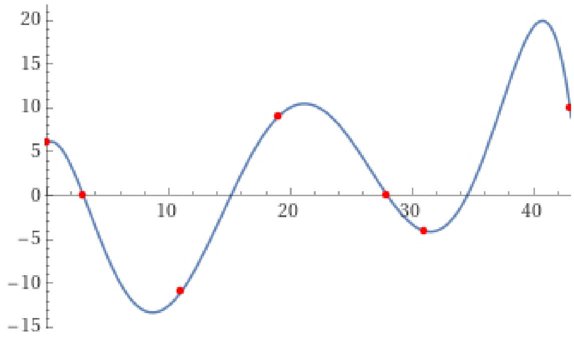
Tempting with simplicity is however illusory, because only small fragments of scribbles slightly resemble the graph f(t) = sin(t), and we should not forget about random fluctuations, different periods of zigzags, and a variable amplitude.

The next natural choice are polynomials, the graphs of which can form elaborate zigzags of varying amplitude. These are the steps leading to the polynomial formula for scribbles:

- select 'nice' scribbles, rotate them by 90°, and superimpose them on the coordinate system,
- select the key points of the graph and read their coordinates (x,y),
- subject the obtained (x,y) pairs to interpolation, a mathematical operation that determines an approximate pattern of a function whose graph passes through the selected points.

Interpolation is not 'manual work', but numerous tools to conduct this operation are available online (below is the result from *WolframAlpha* for a fragment of a 'nice' scribble). The result is 'terrifying', but these are only a few selected points. If we wanted to interpolate e.g. 20 points of a scribble, we would obtain a polynomial equation of 19th degree (i.e. x^{19}).





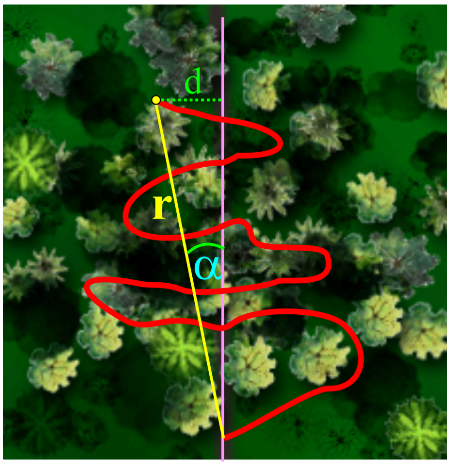
$$\frac{35\,054\,879\,613\,601\,x^7}{1\,080\,540\,997\,984\,269\,803\,520} - \frac{5\,196\,077\,891\,568\,191\,x^6}{810\,405\,748\,488\,202\,352\,640} + \frac{155\,308\,743\,459\,076\,363\,x^5}{324\,162\,299\,395\,280\,941\,056} - \frac{114\,894\,058\,874\,415\,119\,x^4}{6\,753\,381\,237\,401\,686\,272} + \frac{938\,666\,553\,210\,179\,037\,047\,x^3}{3\,241\,622\,993\,952\,809\,410\,560} - \frac{1\,599\,987\,437\,894\,841\,516\,799\,x^2}{810\,405\,748\,488\,202\,352\,640} + \frac{11\,743\,344\,023\,834\,011\,399\,x}{6\,753\,381\,237\,401\,686\,272} + 6$$

With the eyes of my imagination, I see an image of a several-millimetre long larva whose brain must 'process' such an equation for it to move. I know I am being ironic here, but in my opinion, such equations are simply not very 'elegant' for this small larva!

There is also a more important reason why simple trigonometric or polynomial equations cannot be the formulas for scribbles that we are, looking for – a 'classic' formula cannot 'go backwards', while it is exactly what scribbles almost always look like. It cannot go backwards, because this would mean that two or more different values would exist for the same argument x – the larva would be in two different places at the same time! On the other hand though, such an interpretation adds more mysticism to scribbles – after all, everything happens under the tree bark – and who knows what is going on there!

Going backwards? No problem!

Fortunately, the knowledge of quantum physics is not necessary to check that the graph 'goes backwards' – it is enough to use a different coordinate system; in this case – the polar coordinate system. To those who have forgotten what it is or do not know it, let the manner in which I picked up mushrooms in the woods as a child serve as an example: after leaving my bike on the edge of the path, I would start zigzagging the forest on both sides of the path (yes, I know, this route resembles something). I only had to keep in mind two values: the distance from the bike (r radius) and the distance from the path (d), which in the polar system is understood as the angle α of the radius deviation from the axis of the system. In such a system, each point is thus precisely determined by the pair (r,α).



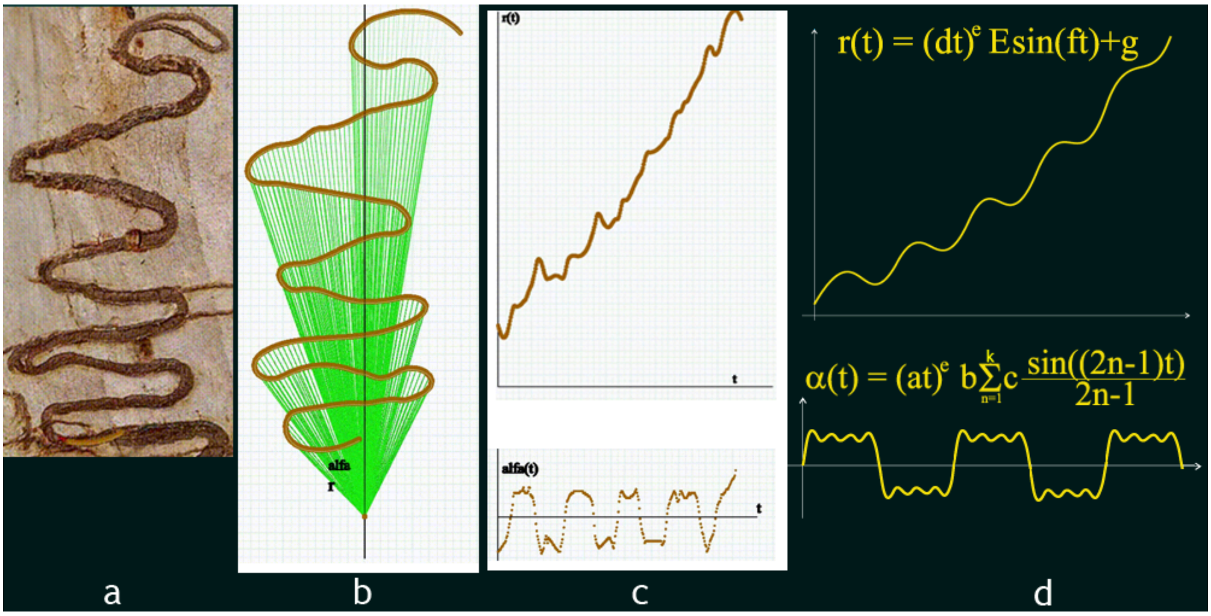
If we want to look for the formula for scribbles in the polar coordinate system, we have to find two equations (for α and r).

At this point, a computer was truly necessary, because the only rational way to search for these equations was digitalisation of a selected scribble. This is what it looked like:

- loading an image of a scribble into a software created for this purpose,
- marking selected consecutive points of the scribble on the image – the software calculates and saves the distance r and the angle α,
- drawing by the software of two graphs showing how the values of the distance r and the angle α change over time.

With such graphs and some mathematical knowledge, the types of functions with graphs having similar patterns can be indicated. The example given below is the result of digitalisation of a selected, not so 'nice' scribble:

a) the original scribble used for digitalisation,
b) the same scribble recreated after digitalisation and calculation of the distance r and the angle α,
c) r(t) i α(t) graphs drawn by the software, which describe the actual changes of the radius and angle at the time of creating the scribble,
d) selected functions whose theoretical graphs are a good representation of the trajectory of r and α (a, b, c, d, E, f , g – parameters, n = 1, 2, 3, …).



Do these formulas seem 'elegant' enough? Sure, but what is even more curious, these are not random formulas – both types are well known in physics or statistics and used to describe natural phenomena. Exactly! – natural ones, and scribble is natural to the core.
The first one is illustrated with a specific formula r(t) = $(0.004t)^e$ - 4(sin(0.4t) + 15). It is a sinusoidal wave which is going up exponentially, being a good representation of real scribbles, in which in the final phase of zigzags, the distances between them usually grow bigger.
The second graph is based on the formula $\alpha(t) = 0.01t + \frac{sin3t}{3} + \frac{sin5t}{5} + \frac{sin7t}{7}$). It is not a simple formula either, but one of the examples of the Fourier series, without which it would be difficult to imagine the mathematical description of cyclical phenomena.

The scribble simulator (here) can be used to check what they look like when created on the basis of a climbing sinusoidal wave and different Fourier series.

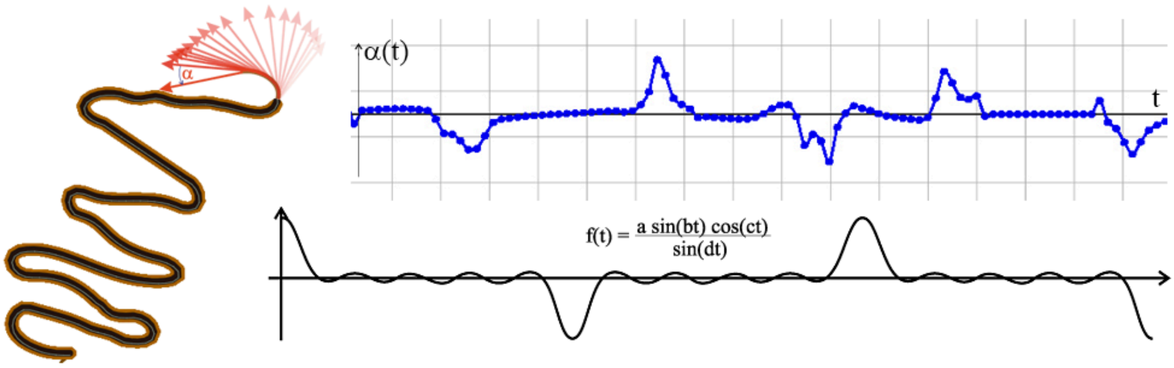
The first impression is that the formulas referred to above not only describe and create scribbles (which can be seen in the simulator), but also capture well the nature of the *Ogmograptis* larva, which seems to have to remember 'where it left the bike' (it most probably must return there), but also to know the deviation from the tree or branch axis (often, the zigzag amplitudes for a given scribble are almost equal – see on the right). But this is only the first impression, because even though the patterns represent scribbles, do they really capture the nature of the larvae? Return to the starting point of regular zigzags is certainly not the effect of the phenomenal memory of the larva, but a natural consequence of its movement on a parallel or tangential track with regard to the previous one, while the zigzag amplitude is probably most affected by the presence and thickness of the cork cambium. I admit that I wrote the last phrase without great enthusiasm, as even though the initial, often chaotic shape of the scribble is certainly related to the larva's search for cambium, the zigzags of the later phases (when cambium is already in abundance) are difficult to explain. In fact, it is not entirely clear what stimuli the larva receives and interprets – certainly chemical ones relating to its food and the reaction of the eucalyptus tree and mechanical ones connected with its movement or vibrations in the bark, and maybe thermal ones. But how does the larva know that the bark above its feeding area will fall off in a few months? How does it know when to make the first turning loop? Does it recognise this moment based on chemical stimuli or otherwise? We will probably never find out.

<u>To think as a larva</u>

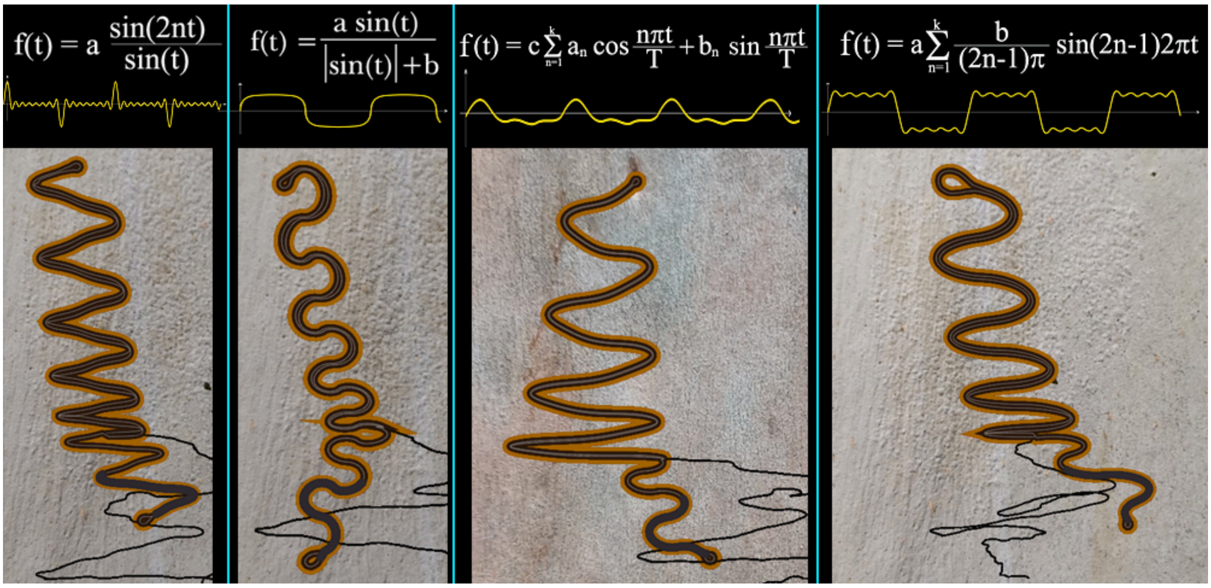
And if we give up studying the larva location by superimposing different coordinate system on the tree and focus on its very movement: '*I will continue a little bit more while chewing the food, and then I will start turning right*'. These are simple organisms and their movement must be determined by some 'simple programme'. Two formulas are too many!
I focussed on the analysis of one value only turning into the larva movement – the turning angle. This subsequent digitalisation looked like this:

- loading an image of a scribble into a software created for this purpose,
- marking consecutive, closely situated points of the scribble on the image – the software calculates and saves the larva turning angle,
- drawing of a graph by the software showing how the turning angle was changing during the creation of the scribble.

The turning angle changes visible in the blue graph could in reality be drawn 'from memory', without digitalising the scribble: the horizontal fragments of a near-zero turning angle correspond to the time when the larva moves forward, and the 'hills and valleys' of the graph are turns to the left or right.



Is there any known function that generates a similar track? If only there were one! We are dealing here with a type of a graph describing natural or artificially generated pulsation phenomena, which is well known in science, and the black graph with sines and cosines is only one of the types of functions describing pulsations. These are selected examples from the scribble simulator, which are based on 'pulsation graphs'.



The two last formulas are consecutive Fourier series, which are capable of describing everything that 'vibrates, undulates or pulsates', but the first of them seems to be the most interesting one:

$$f(t) = a\frac{\sin(2nt)}{\sin(t)}, n = 1,2,3,\dots$$

Einstein once said that 'everything should be made as simple as possible, but not simpler'. This 'elegant' formula is the quintessence of this saying.

There are generally numerous formulas that are capable of generating scribbles in different coordinate systems, although probably many of them could be brought to a few (several) types using mathematical transformations.

<u>And what if AI drew scribbles?</u>

My greatest disappointment when creating the Scribble Project! Nobody 'taught' AI about scribble, so even this encyclopaedic knowledge it has is scarce and full of errors: '*I'm very sorry, you are right, these larvae are Ogmograptis not Ogmozeles*'. Then a bunch of examples coming from two popular platforms, showing how AI understands scribbles. The last example is the result of a longer 'teaching' – ChatGPT finally generated a software drawing the curve f(y) = sin(3y) with fluctuations from the *noise* function.
What is most surprising and discouraging about working with AI is a kind of 'dementia' – a few steps further, AI ignores previous information and findings and generates something idiotically contrary to the instructions.

It is easy to guess that AI's basic knowledge of scribble is so poor that venturing into platforms generating images of scribbles based on the text feed will be equally fruitless. Just look below – no comment! Of course, AI will sooner or later generate scribble images that will be indistinguishable from the original ones, but today, it is not capable of doing it (maybe because scribbles are an icon of Australian and not American nature ;).

<u>Concluding words</u>

It is time to answer the question in the title – yes, *Ogmograptis* surely 'knows' the sine – it forms part of its DNA, being the unnamed instinct that affects the larva's movement.
Is it already the end of this story? On the contrary! It is only the beginning, because this article will certainly be read by someone who will think: 'I will check it my way' and discover not only the new formula(s), but also the underlying concept; colloquially speaking – they will tell us 'how the *Ogmograptis* thinks'.

And returning the paraphrase of J.Wright's poem:

'... and found the written track
and I saw sines and cosines
intertwined in the traces of life
I could read but I couldn't understand'.