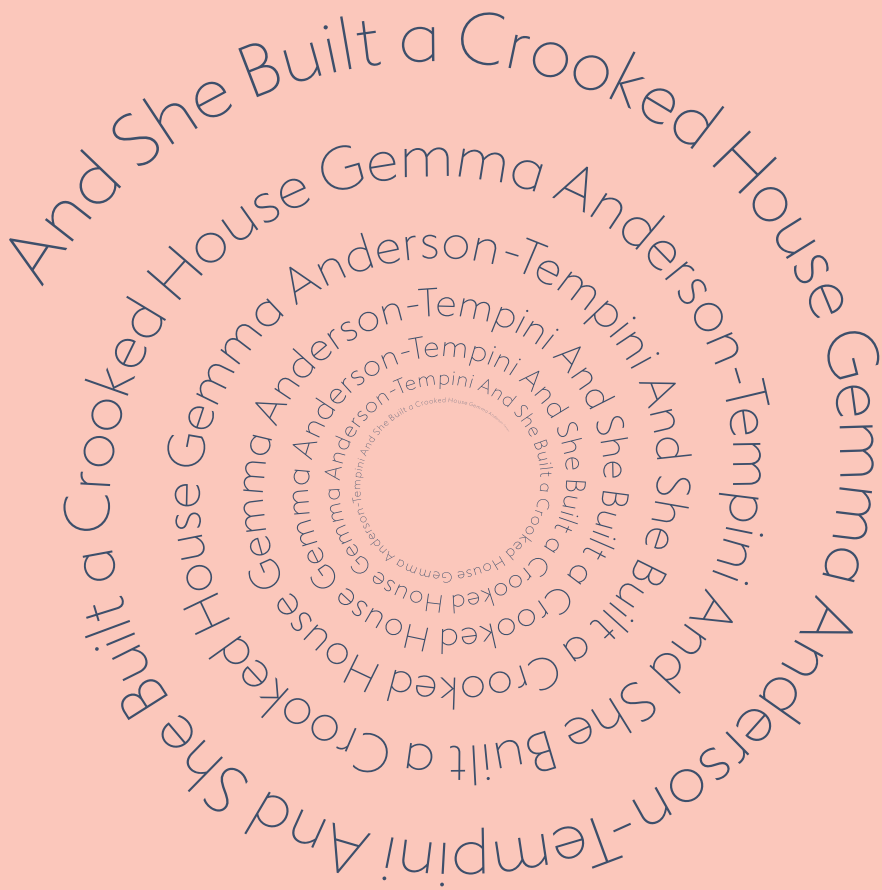
And She Built a Crooked House Gemma Anderson-Tempini
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Mother Bang and the Last of the Russian Dolls
by Gemma Anderson-Tempini

Suppose the Big Bang was not actually big at all, but rather it was small. The very first life forms that arose from this "small bang" were strings. When they were born, they were quite big relative to the size of the universe. Then as time went on, relative to us, who grow bigger in proportion to the world around us, strings have slowly become the smallest things that exist.

At the time of the "small bang" the strings were so large in proportion to the universe that people now think they have left imprints, like fossils of the universe, but even harder to see than the fossils in the seabed. Their imprints would lie in between stars and in places in the galaxy we have not even discovered yet.

On Earth, in a place called CERN, scientists try to find ever smaller things, building super machines to conduct their experiments. Not so long ago, scientists at CERN thought that they had observed a particle travelling faster than light. Since the time of Albert Einstein's Special Relativity, it is believed that nothing can travel faster than light. The only explanation for this that people could imagine would be that the particle had escaped through a higher dimension and taken a shortcut from A to B. In fact, the explanation turned out to be that there had been a mistake in the experiment. Special Relativity is a precursor to Einstein's General Theory of Relativity, which is a theory of gravitation. The latter tells us how large objects – people and aeroplanes, for example – are affected by gravity; that is why we can't float around and why spacecraft can orbit the earth.

Theories evolve and there is a more recent theory for tiny particles that incorporates Special Relativity; it is called "Quantum Field Theory". An even more recent theory that lots of scientists are working on now is called "String Theory". Since strings are thought to be the smallest pieces that form all other matter, if anyone can understand how strings work, then we will all understand the world better.

We are used to thinking about the world we live in as made of three spatial dimensions plus time. In string theory there are ten dimensions: nine spatial plus time. We cannot experience these spatial dimensions in the way we know our own three dimensions because they are too small.

To begin to grasp the idea of nine spatial dimensions, imagine three levels of space. The outer level is our three-dimensional space, then curled up inside our big three dimensions are three smaller dimensions. At every point in our three-dimensional space, we pass through them, but we do not know it ... and, curled up again inside those, are three smaller dimensions still ... the inner space of the strings ... the last of the Russian dolls.

The idea of spaces nested inside other spaces is not so unfamiliar to us; just imagine the pregnant woman with the embryo curled up inside, and, inside the embryo again, eggs for a future generation.

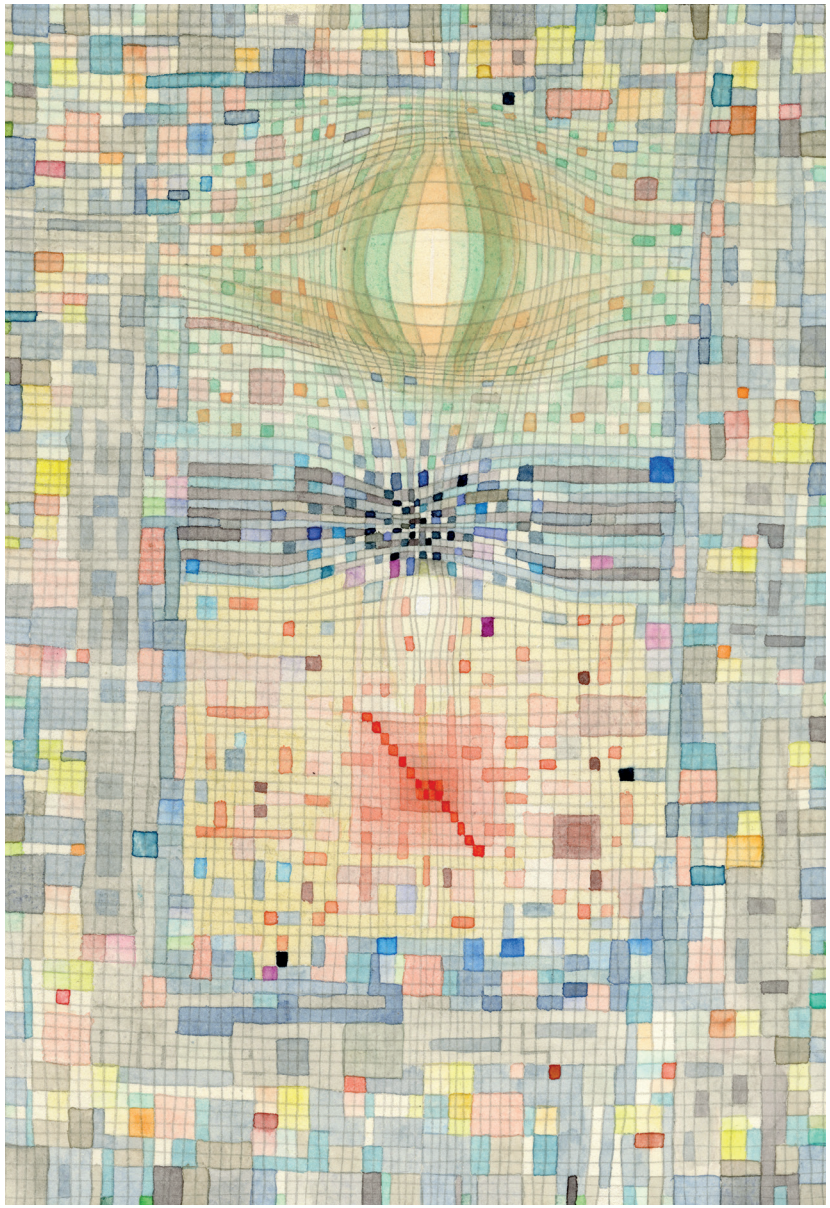
There are half a billion possible geometries that we know about for the inner space of the six additional dimensions. One way to get a sense of the shape of the inner space is to zoom out until the three smallest dimensions become invisibly small, until we are left with a 3D space that looks exactly like the outer 3D skin of a 4D polytope (a 4D polytope has an outer 3D skin, just as a 3D polytope has an outer 2D skin). In this house, you see the unfolded 3D skin in sculptural form and the projected 3D skin in my drawings. These 3D skins represent the spaces that the strings could inhabit. If we zoom back into these 3D skins the sharp

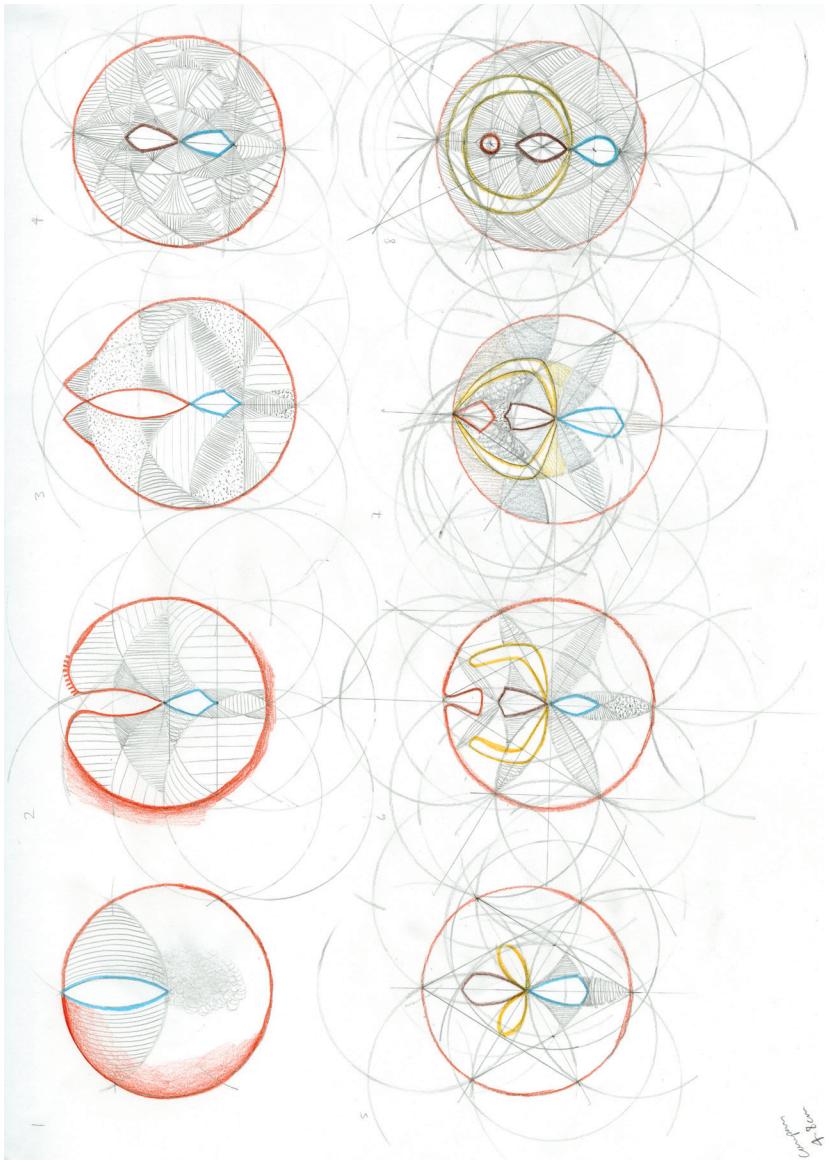
edges and corners get smoothed out and the additional three smaller dimensions come back into sight. The resulting six-dimensional space is the inner space.

Four-dimensional polytopes are fascinating in themselves. Although we cannot directly experience them, we can intuitively imagine them folding and unfolding, and we can draw projections of them in two and three dimensions. Because we can unfold a four-dimensional form to create a three-dimensional form, we can say that the fourth spatial dimension precedes the third spatial dimension. The skin facets of an unfolded four-dimensional form may appear to be separate from each other in three dimensions, but in the fourth spatial dimension they would be folded up, in full connection with one another.

I often feel a bit like one of these four-dimensional polytopes, unfolded in my daily life, living out many different roles ... mothering twins, doing art, writing emails, managing the struggle against the disorder of home, self, family. But I carry a sense that it is the same "me" behind all these activities ... and sometimes I just wish to be folded up.

Every now and then I imagine that all these facets of the polytope represent different people, and all living beings, in our little worlds – messy entangled processes that we are – still living an illusion of separateness from each other. Even so, we are aware that, on a deeper level, we are connected. Through meditation on four-dimensional forms, we can contemplate the multi-dimensional nature of reality and our limited experience of its fullness. We can imagine ourselves folding and unfolding and know that whatever our fleeting experience of wholeness may be, it is tapping into something real. Perhaps the mathematical object is more "alive" than we give it credit for.





Director's Foreword

> The time will come when diligent research over long periods will bring to light things which now lie hidden. A single lifetime, even though entirely devoted to the sky, would not be enough for the investigation of so vast a subject... And so this knowledge will be unfolded through long successive ages. There will come a time when our descendants will be amazed that we did not know things that are so plain to them... Many discoveries are reserved for ages still to come, when memory of us will be effaced. Our universe is a sorry little affair unless it has in it something for every age to investigate... Nature does not reveal her mysteries once and for all.
> –Seneca, Natural Questions, Book 7 first century[1]

Welcome to Burton Grange, a Victorian house in Far Headingley, Leeds, that has been taken over by artist Gemma Anderson-Tempini.

Gemma works primarily with drawing, describing it as "a way to confront the limits of what you think you know". She possesses a remarkable ability to distil complex ideas and processes into highly accessible artworks. Whether imagining and visualising the Big Bang, or zooming in on the transformation of an embryo, Gemma's desire to bring visual clarity to the nature of existence is a thread that runs throughout her practice.

In a previous body of work, Gemma synthesised drawing with microscopic observations and multiple data sets to reveal complex biological relationships, like those between an organism, cell, and molecule. In our digital age, as we increasingly depend on computers to process large and complicated sets of data, Gemma champions the act of drawing precisely because it creates and maintains a direct human connection with the world. At a moment when the environmental and biodiversity crisis demands that we relate in radically new ways to the planet, Gemma's biological drawings invite us to connect deeply with the myriad neighbours with whom we share this planet.

And She Built a Crooked House sees Gemma shift her focus from life on this planet to the Big Bang and the origins of life itself. Her reflections on the traces left behind by our explosive cosmic beginning are presented across three floors, in the front garden, and in the poetic story she has written for this publication.

For over a decade, Gemma has been exploring the possible geometric shapes of the universe through the lens of spatial thinking – specifically the idea of a fourth spatial dimension, first popularised in the 1800s, that supported imaginative leaps in science, mathematics, literature, poetry, and art. The fourth spatial dimension is an imaginary space of possibility where the limits of our three-dimensional world can be transcended. Its existence and application has profoundly shaped society, as articulated in Dr Mark Blacklock's essay in this publication.

Central features of the fourth spatial dimension include turning inside out, mirroring, and being in more than one place at the same time. These ideas resonate with Gemma's personal experience of mothering twins and are recurring motifs in this body of work. Presenting her unique part-factual, part-historical, part-autobiographical take on the fourth spatial dimension in a domestic space evidences Gemma's well-honed skill of grounding complex ideas, making them accessible and relatable for a range of audiences.

And She Built a Crooked House invites us all to reflect on the generative role of spaces like the fourth spatial dimension, where rules can be defied and breaks with convention are encouraged. Much like the imagination itself, it is a space of enormous possibility.

Mariam Zulfiqar, October 2023

1 Carl Sagan, Cosmos (London: Abacus, 1995), p. 11. First published by Macdonald & Co., 1981.

Gemma Anderson-Tempini
And She Built a Crooked House

The standard view of the world is that there are four dimensions: three spatial dimensions plus time. However, in the 20th century, physicists considered several theories that there could be more than three spatial dimensions. An example of such a theory is string theory, postulating nine spatial dimensions plus one time dimension for a total of ten dimensions.

Beyond physics, explorers of higher spatial dimensions span the fields of maths, art, literature, and computing, charting their course across its imagined terrain through equations, sketches, stories, and coding. In doing so, they pose questions, reveal insights into the nature of existence, and give us new tools and languages that challenge the way we think.

Gemma Anderson-Tempini's And She Built a Crooked House is the artist's unique contribution to this unconventional line of enquiry. In this project, and in the story she shares in this publication, the artist invites us to reflect on the fourth spatial dimension as a way of further connecting with and understanding our relationships with our surroundings and each other.

And She Built a Crooked House is the artist's most ambitious project to date, giving form to the ideas produced in collaboration with Alessio Corti, professor of mathematics at Imperial College London. For over a decade their collaboration has explored what lies beyond our perception and understanding of reality. Their work unveils the beguiling reality of existence, something that has preoccupied the minds of scientists, mathematicians, artists, writers, philosophers, and thinkers across the ages.

Corti and Anderson-Tempini have conceived and drawn 4D embryos, 4D eyes, 4D trees, and 4D irregular polytopes – geometric shapes that map the "inner space" of the additional dimensions of string theory.

They have often done so by drawing on ideas and questions inspired by other fields of inquiry – for several years Anderson-Tempini also researched biological processes, combining microscopic detail with observational drawing to explore hidden connections between forms and species that share our planet.

And She Built a Crooked House weaves together cutting-edge mathematical research and the history of fourth-dimensional theories that emerged in the late 19th century to explore and make sense of personal human experiences through the lens of spatial thinking. For this project, Anderson-Tempini deftly brings together higher-dimensional geometry, art, and motherhood, and highlights the historical impact of fourth-dimensional thinking in quotidian places such as playgrounds and Victorian living rooms. In this house, the deployment of AI tips a nod to the Victorian fascination with the supernatural, serving as a reminder that in our present time we continue in the tradition of our ancestors by forming relationships with immaterial beings in the form of voice-activated devices. Technologies may change, but our yearning to connect with a higher reality persists.

Anderson-Tempini's latest project is presented at Burton Grange in Far Headingley, Leeds. This house was built in 1881, one year after mathematician Charles Hinton's seminal essay introduced his compelling ideas on the fourth spatial dimension into society. Across the indoor and outdoor spaces of this Victorian house, and in the writings presented in this publication, the artist invites you to reflect on the enduring impact and potential of these ideas.

A Manifold Dwelling: How Gemma Anderson-Tempini Built a Higher Spatial Home

Dr Mark Blacklock

From its first theoretical documents, *n*-dimensional space has fired the imagination. The mathematicians who began to allow a fourth dimension into their calculations to permit them more easily to solve certain problems, doing away with the experiential limitations of the three dimensions in which we live, could not escape the suggestive possibilities presented to them. Should we ever doubt that geometry itself is a creative discipline, describing forms and, at its origin, bringing them into being?

August Möbius, who first speculated that the fourth dimension might be useful for maths, is best known for his playful strip, a single 2D surface twisted in 3D. Felix Klein, who made significant discoveries regarding curves and "knots" in *n*-dimensional space, is likewise most popularly known for the bottle that bears his name: the Klein bottle takes Möbius's strip and ups the stakes, by making the surface into an impossible vessel. Sculptors, both. The great physicist, James Clerk Maxwell, was moved to verse:

> My soul's an amphicheiral knot
> Upon a liquid vortex wrought
> By Intellect in the Unseen residing,
> While thou dost like a convict sit
> With marlinspike untwisting it
> Only to find my knottiness abiding,
> Since all the tools for my untying
> In four-dimensioned space are lying,
> Where playful fancy intersperses,
> Whole avenues of universes;
> Where Klein and Clifford fill the void
> With one unbounded, finite homaloid,
> Whereby the Infinite is hopelessly destroyed.[1]

These playful experiments in form made it possible to experience in words and objects aspects of the imperceptible new spaces. Scientists and mathematicians made the imagination central to their practice, and in so doing invited us into it. Such polymathic approaches were common in the 19th century and are less common now. Gemma Anderson-Tempini's work, work that we experience throughout Burton Grange, radically transforms such creative practice for the age of string theory.

As the craze for four-dimensional geometry took hold in Britain in the 1880s – and it was a craze, winning mention in Boy's Own magazines, Oscar Wilde stories, news reports, and inspiring the novel Flatland – the possibilities afforded by an incredible form of space that allowed for the inversion of solid objects, or rendered them transparent, or allowed two beings to inhabit the same space at the same time, or objects to be moved from one portion of space to another as if teleported, were seized upon by metaphysical thinkers. This off-kilter house witnessed the period in which this rush of imaginative and intellectual activity occurred. Note the lintel on your departure: the threshold bears the date "1881".

In the years that followed, spiritualist journals were abuzz with reports of experiments that claimed to demonstrate that the communicating intelligences of séances were in fact reaching us from the fourth dimension. Great scandals and arguments erupted, as formerly respectable scientists – the chemist William Crookes and the astro-physicist Johann Friedrich Zöllner among them – lent their authority to such speculations.

In an effort to apply the brake to wilder speculations, the mathematician William Spottiswoode urged people to think of higher space differently:

> 'Like a rainbow, if we try to grasp it, it eludes our very touch; but, like a rainbow, it arises out of real conditions of known and tangible quantities, and if rightly apprehended it is a true and valuable expression of natural laws, and serves a definite purpose in the science of which it forms part … When space already filled with material substances is mentally peopled with immaterial beings, may not the imagination be regarded as having added a new element to the capacity of space, a fourth dimension of which there is no evidence in experimental fact?' [2]

The imagination, though, cannot be so easily contained. By the close of the decade, two significant movements further accelerated the spread of this mind-bending idea. The nascent scientific romance, as written by HG Wells, imagined time travel, trans-hemispheric vision, and invisibility made possible through this form of geometry, well known but little understood. The Theosophical Society, itself a trans-hemispheric, utopian enterprise, identified the fourth dimension with the eastern spiritual concept of *lôkas*, or planes. Theosophists were soon travelling in their minds to the astral plane, from which they could view four-dimensional objects, assisted in their quest by the practices of yoga and meditation.

The art historian Linda Dalrymple Henderson detailed in her 1983 book The Fourth Dimension and Non-Euclidean Geometry in Modern Art how a range of such ideas reached the emergent artistic avant-gardes. Stopping short of asserting a direct causal relationship between the early cubist painting of Pablo Picasso and the work of the mathematician Ernst Jouffret, author of *Traité élémentaire de géométrie à quatre dimensions* (1903), Henderson made a compelling case for influence simply by setting drawings and paintings side by side.

What is certain is that the Puteaux cubists, who included the poet Guillaume Apollinaire and the artists Jean Metzinger and Marcel Duchamp, encountered the fourth dimension in salons, through reading not just in theosophical magazines, and popular squibs, but also, directly, in the work of mathematicians such as Henri Poincaré and Jouffret. "The fourth dimension was primarily a symbol of liberation for artists," wrote Henderson.[3]

For Duchamp, who had read both Jouffret and Poincaré, this method found its apogee in The Bride Stripped Bare by Her Bachelors, Even (The Large Glass) (1915–23). As he told Pierre Cabanne in 1967:

> 'Since I found that one could make a cast shadow from a three-dimensional thing, any object whatsoever – just as the projecting of the sun on the earth makes two dimensions – I thought that, by simple intellectual analogy, the fourth dimension could project an object of three dimensions, or, to put it another way, any three-dimensional object, which we see dispassionately, is a

projection of something four-dimensional, something we're not familiar with.

It was a bit of sophism, but still it was possible. "The Bride" in the "Large Glass" was based on this, as if it were the projection of a four-dimensional object.'[4]

For the succeeding decade, the ideas of higher-dimensional space continued to circulate, reaching modernist writers, such as Gertrude Stein and Mary Butts, and further informing the work of abstract artists throughout Europe: Hilma af Klint, Wassily Kandinsky, Kazimir Malevich, and Piet Mondrian.

What came next was Einstein. Henderson writes: "When the popularisation of Relativity Theory in the 1920s enshrined time as the fourth dimension and Einstein as supreme scientist and philosopher, both Poincaré and a purely geometric fourth dimension were soon largely forgotten by the public and artists alike."[5] While high art might have neglected these mind-bending spaces, popular fiction, particularly horror and science fiction pulp magazines, kept the notion alive. Science fiction writers updated and experimented with HG Wells's "favourite motif" of the 1890s to allow for strange warpings of narrative space-time, which themselves fed into comic books and TV shows such as The Twilight Zone. One such example, Robert Heinlein's 1941 short story And He Built a Crooked House, describes an architect applying the principles of the fourth dimension to the building of a home. It was not so far removed from reality. The Rochester-based architect Claude Bragdon had worked such principles into his own practice.

This giddying cultural-historical account roars into the 20th century, towards Salvador Dalí, HP Lovecraft, the New Age, and imaginary spaceships powered by hyper-drives. But, all the while, another quieter tradition has existed alongside. Something more tactile, more domestic, but no less curious for that.

A young British mathematics teacher and writer called Charles Howard Hinton was also interested in ideas of the fourth dimension, publishing his first essay on the topic in 1880. For Hinton, direct contact with such a space would enable a form of mind expansion that would be accompanied by a blossoming of altruism: in higher dimensions, we are all one. Taking his lead from the writings of Goethe, and specifically the idea of a "delicate empiricism" – developed by Gemma in her book Drawing as a Way of Knowing in Art and Science (2017) as "the effort to come to know natural form through prolonged empathetic observation, grounded in direct experience" – Hinton sought direct contact with objects in space as a way of accessing the speculated fourth dimension.[6] He wrote:

'There are two distinct ways of studying space – our familiar space at present in use. One is that of the analyst, who treats space relations by his algebra, and discovers marvellous relations. The other is that of the observer or mechanician, who studies the shapes of things in space directly. A practical designer of machines would not find the knowledge of geometrical analysis of immediate help to him; and an artist or draughtsman still less so. Now, my inquiry was whether it was possible to get the same power of conception of four-dimensional space as the designer and draughtsman have of three-dimensional space. It is possible.'[7]

To achieve this power of conception, Hinton developed a system of colour-coded cubes which, if reflected upon correctly, would train the imagination. He described his system in a series of books and essays. It did not catch on.

Hinton's sister-in-law, however, was an able student of his system. Alicia Boole Stott had grown up with her mother Mary's instruction in mathematics at a time when women were excluded from formal mathematical education. Learning curve-stitching as a child – the same practice that feeds into Barbara Hepworth's stringed sculptures – she was already an able geometer, a constructor of parabolas, before mastering Charles's cubes.[8] By careful practice, moving the cubes through sequences devised by Hinton, Alicia learnt the modes of constructing four-dimensional solids.

Charles emigrated and Alicia became a mother and housewife before, in 1897, she sent some models she had made, cross-sections of the four-dimensional equivalents of the platonic solids, to the Dutch mathematician Pieter Schoute. Her brother-in-law's system worked, when the right mind employed it. Alicia was able to make material the 3D shadows of 4D objects. She went on to co-author three papers with

Schoute, and her models live in a storeroom in Pavilion E of the Mathematics Centre at Cambridge University.

Gemma's work turbo-charges this tradition. Her research has taken its lead from the same ideas of Goethe that inspired Hinton to mediate thinking the fourth dimension through sets of kindergarten cubes.[9] Goethe's morphology and philosophy of experiment inform both Hinton and Gemma at a foundational level. Gemma writes of her own development of a drawing method:

> 'The approach is not an illustration of his ideas, but a visual adaptation of Goethe's "delicate empiricism" that combines imagination, intuition and observation ... Isomorphology builds on Goethe's morphology by establishing and visualizing a set of form species or Ur forms and symmetries that can be observed in animal, mineral and vegetable species.'[10]

Embedded with Alessio Corti and Tom Coates at Imperial College, Gemma's "delicate empiricism" has expanded, and she has picked up the baton left by the avant-gardes at a time when physicists and mathematicians working on string theory have again become invested in higher-dimensional space. Gemma is certainly the inheritor of Alicia Boole Stott's mantle, making in paper, and by 3D printing, material models of the slice forms of irregular lattice polytopes identified by Alessio and Tom. Gemma's various constructions recall not only Alicia's models, but also the wooden models of crystals that became popular pedagogical aids in the late 19th century, and the gifts manufactured by the educationalist Friedrich Fröbel to encourage children to encounter geometric forms in their play. Yet further models remain virtual: Gemma has made digital models of half a billion unfolded forms.[11]

How has the dimensional picture changed for scientists since Einstein? Gemma's story tells us:

> 'To begin to grasp the idea of nine spatial dimensions, imagine three levels of space. The outer level is our three-dimensional space, then curled up inside our big three dimensions are three smaller dimensions. At every point in our three-dimensional space, we pass through them, but we do not know it ... and, curled up again inside those, are three smaller dimensions still ... the inner space of the strings ... the last of the Russian dolls.'

Alessio and Tom work as explorers in the higher realm, returning with samples, imaginary objects, which Gemma makes real in her artworks. Gemma writes:

> 'Alessio tells me how the Islamic mystics of Iran spoke of Hurqalya, the world of imagination, a place between the spiritual and the material. He relates this to how the three of us together have carried an object from the immaterial world, where we could only have an intuitive grasp of it, coming from our "presence" in Hurqalya by means of our imagination, into the material world.'[12]

The shadows of higher-dimensional influence cannot be limited to straight lines. What has been astonishing for me, when discussing Gemma's work with her, has been to discover how instinctively her imagination has alighted upon echoes and reflections of the rich cultural history of the fourth dimension.

Of all the concepts that have emerged from these conversations, two have resonated powerfully with Gemma's domestic life. Twinned objects, mirror-images of one another in our space, are staples of four-dimensional literature: we need only glance at our own hands to see left and right forms that cannot be made to coincide with each other. For Immanuel Kant, these "incongruent counterparts" were ample proof of the resilience of three-dimensional space; by contrast, they crop up in Flatland, and in Hinton's writing, as demonstrators of how a higher space allows the "flipping" of lower-space objects. With the development of stereochemistry and the realisation that there existed molecules of the same substances which possessed mirror-imaged atomic structures, such twinned forms became important aspects of matter. Further, into the 20th century, the morphologist D'Arcy Wentworth Thompson identified such geometric "enantiomorphs" in nature, in spiral shells and the horns of certain mammals. While developing isomorphology during her PhD studies, Gemma worked in Thompson's archive at the University of Dundee.

As the mother of twins, Gemma has described the experience of needing to be in two places at the same time, a form of bilocation that, if only she had physical access to the fourth dimension, would be available to her. She has dreamt of being able to use a wormhole in order to permit this. She writes that "the idea of turning inside out was a feeling I got close to … the way that parenting twins – especially when my husband Nico broke his ankle and I potty-trained Una and Cosmo alone – has felt like stretching beyond my human limit."[13] This experience is reflected in the lyrics of her song / poem 4D Mother: "I went to the bottom and I went through." Gemma must satisfy herself with access to such abilities through the imagination.[14]

Wandering around this crooked house, we encounter mirrors, surfaces that fascinated another geometer, Charles Dodgson, and the artist Marcel Duchamp in his attempts to realise a 4D eye.[15] We hear the song by Plumm, with lyrics written by Gemma that closely recall James Clerk Maxwell's poem, unknown to Gemma when she wrote the words. We see origami forms emerging from wallpaper, models that simultaneously echo geometric craft practices and the model-making culture of the 19th century. We encounter a hologram, a sculpture in light; AI-voiced collage; and an AI séance, in which paranormal voices which have never had bodies will be able to answer questions on higher space.[16] Gemma is, naturally, a practitioner of yoga, as popularised by the Theosophical Society in the west. She has even devised a four-dimensional yoga sequence, based on practices to activate the third eye and "inner vision" to prepare the mind screen to visualise a 4D object. I chuckled when I remembered that Charles Howard Hinton had reviewed a yoga manual. In her paintings of four-dimensional crystal forms, Gemma's colour palette of pastels most frequently recalls – to this eye – that used by Annie Besant and CW Leadbeater in their experiments viewing "thought forms" from the astral plane. The parallels between these pioneers and how Alessio pictures his own mathematical work are striking.

Cross-references proliferate. Of course they do. Allow for more dimensions and you increase the number of connections possible. We can productively think of these interconnections as a form of four-dimensional travel, cutting across mundane time and space to connect categories, concepts, and relations. Venture into these expanded spaces and you meet others returning backwards before you.

By containing these references, and enabling us to think and experience glimpses of the unseen higher-dimensional physical world we inhabit, through innovative techniques developed precisely for the purpose, this crooked house expands us all. It domesticates the impossible. In the dwelling Gemma's work has possessed, the cross-references have included you, the visitors, connected by being present in the space. Be sure to climb the frame, a cubic grid exploded, of a type first climbed by Hinton's children.

1 James Clerk Maxwell, 'A Paradoxical Ode', quoted in Daniel S. Silver, 'The Last Poem of James Clerk Maxwell', Notices of the AMS, 55 (2008), 1266–70 (pp. 1266–7). Silver reinstates the poem from Clerk Maxwell's notebooks.

2 William Spottiswoode, 'Presidential Address', Report of the Forty-Eighth Meeting of the BAAS Held at Dublin in August 1878 (London: John Murray, 1879), pp. 22–3.

3 Linda Dalrymple Henderson, The Fourth Dimension and Non-Euclidean Geometry in Modern Art (Cambridge, MA: MIT Press, 2013), p. 492. First published by Princeton University Press, 1983.

4 Marcel Duchamp, as quoted in Pierre Cabanne, Dialogues with Marcel Duchamp (New York: Viking Press, 1971), p. 40.

5 Henderson, p. 494.

6 Gemma Anderson-Tempini, Drawing as a Way of Knowing in Art and Science (Bristol: Intellect, 2017), p. 119. Gemma develops in her reading of Goethe the idea of the "urpflanze", the "ideal plant" that once seen in the mind would provide the observer with an archetypal form from which iteratively to invent further plants based on the logic of the patterns and forms of nature. These ideas have underpinned hybrid works produced with Alessio, to visualise a 4D tree, and a 4D embryo.

7 Charles Howard Hinton, A New Era of Thought (London: Swan Sonnenschein, 1887), pp. 85–6.

8 Gemma observes that Hepworth was the mother of triplets.

9 My own suggestion is that Hinton's cubes were also inspired by the German educator Friedrich Fröebel, whose sets of geometric objects called "gifts" were advertised by Hinton's publisher.

10 Anderson-Tempini, p. 122–3.

11 It has taken Gemma and Andrew Macpherson over a year to curate a full library of polytopes unfolded in a variety of ways using computer software.

12 Anderson-Tempini, notes from a conversation with Alessio Corti, February 2012.

13 Anderson-Tempini, personal correspondence, August 2023.

14 It should perhaps not surprise us that Charles Howard Hinton was also a parent to twins.

15 Alessio and Gemma have made drawings of a 4D eye, and also tried to draw 4D objects in perspective.

16 The holographic principle is an important aspect of string theory, proposed by Leonard Susskind: "The three-dimensional world of ordinary experience – the universe filled with galaxies, stars, planets, houses, boulders, and people – is a hologram, an image of reality coded on a distant two-dimensional surface." The Black Hole War – My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics (New York: Little, Brown and Company, 2008), p. 410.

ABOUT THE ARTIST

Born in 1981 in Belfast, Gemma Anderson-Tempini graduated from the Royal College of Art in 2007. She completed a practice-based PhD studentship at the University of the Arts London and University College Falmouth in 2015 and has been a Leverhulme Trust Artist in Residence at Imperial College London. In 2016 she won an AHRC award for the art / science / philosophy project "Representing Biology as Process" with philosopher John Dupré and cell biologist James Wakefield (2017 – 21) at the University of Exeter. She has published two peer-reviewed books with Intellect Press: Drawing as a Way of Knowing in Art and Science (2017), and Drawing Processes of Life (2023).

ABOUT BURTON GRANGE

Burton Grange was built in 1881, one of a number of Yorkshire stone mansion houses that make up the Spinning Acres estate in Far Headingley. The rapid expansion of the textile industry in Leeds in the mid-19th century led to the growth of estates such as this on the outskirts of the city.

Wealthy merchants and industrialists sought opulent homes that would reflect their status and achievements, on higher ground away from the urban smog. Architectural details throughout the house point to its history, from the chapel on the first floor to the grand stained-glass window on the staircase. A local Methodist family, the Burtons, lend their name to the house and the road it sits on.

ABOUT LEEDS 2023

LEEDS 2023's ambition is to deliver a transformational year of creative experiences connecting and benefiting people now and into the future. The planned programme will celebrate and transform the city's identity locally, nationally, and internationally – creating a lasting legacy of economic and social impact. LEEDS 2023 is supported by Leeds City Council, Arts Council England, and The National Lottery Heritage Fund. Thanks to National Lottery players for making this possible.

ABOUT ARTANGEL

Artangel has always gone where others fear to tread. We collaborate with artists who defy boundaries to give form to extraordinary ideas. The art we produce boldly responds to the environment in which we live. It's often unlike anything you have experienced before. We've taken over an empty prison, uncovered an underground opera house, made sculpture from solid air, commissioned a mile-high column of light, and a thousand-year-long piece of music.

We celebrate the artists of today and identify those of tomorrow, developing daring new works that reveal a different side to the world we live in.

SUPPORTING OUR WORK

Artangel relies on the generosity of its patrons, who are known as "Angels".

Throughout the year, the Angels are the first to experience extraordinary new projects in unusual places across London, the UK, and the world. From previews and premieres to our annual Angels' gathering and trips to see our international projects, our events bring you closer to artists and their groundbreaking ideas.

To find out more about becoming an Angel, visit artangel.org.uk/be_an_angel

Artangel is a registered charity (no. 292976).

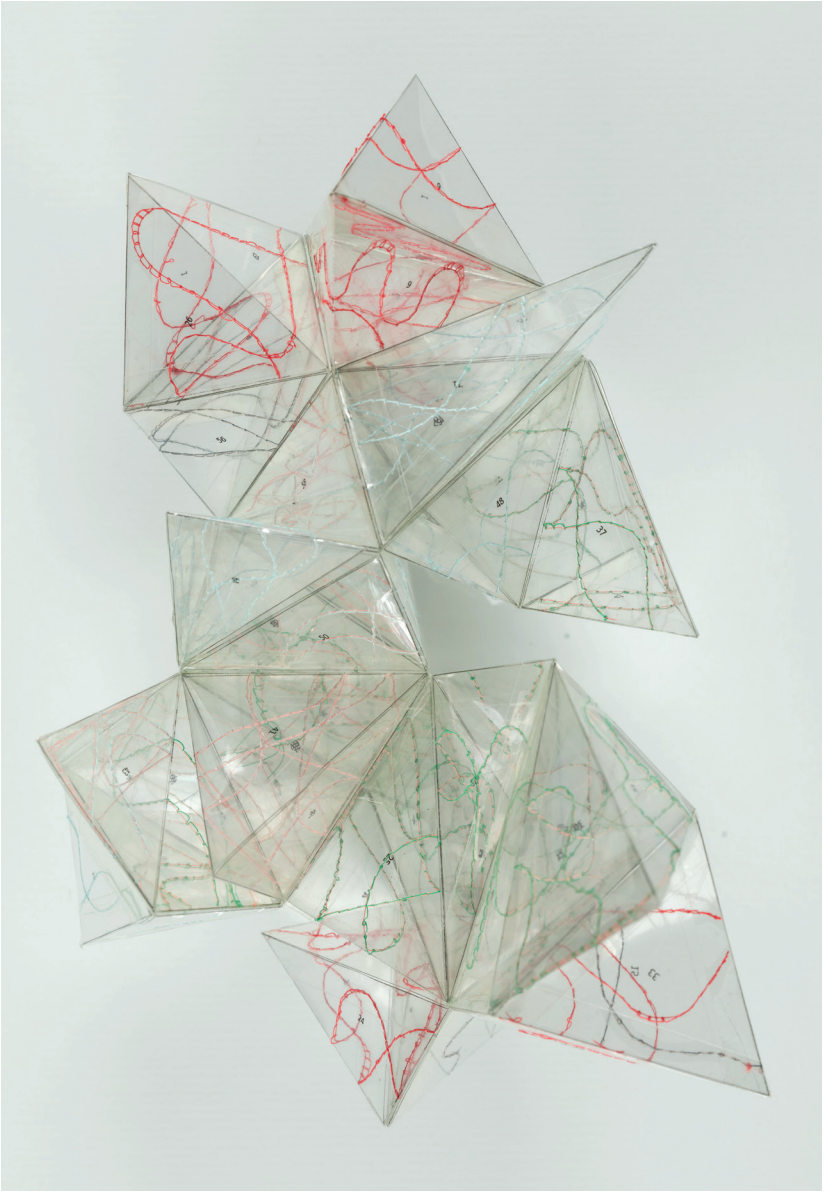
COLLABORATOR BIOGRAPHIES

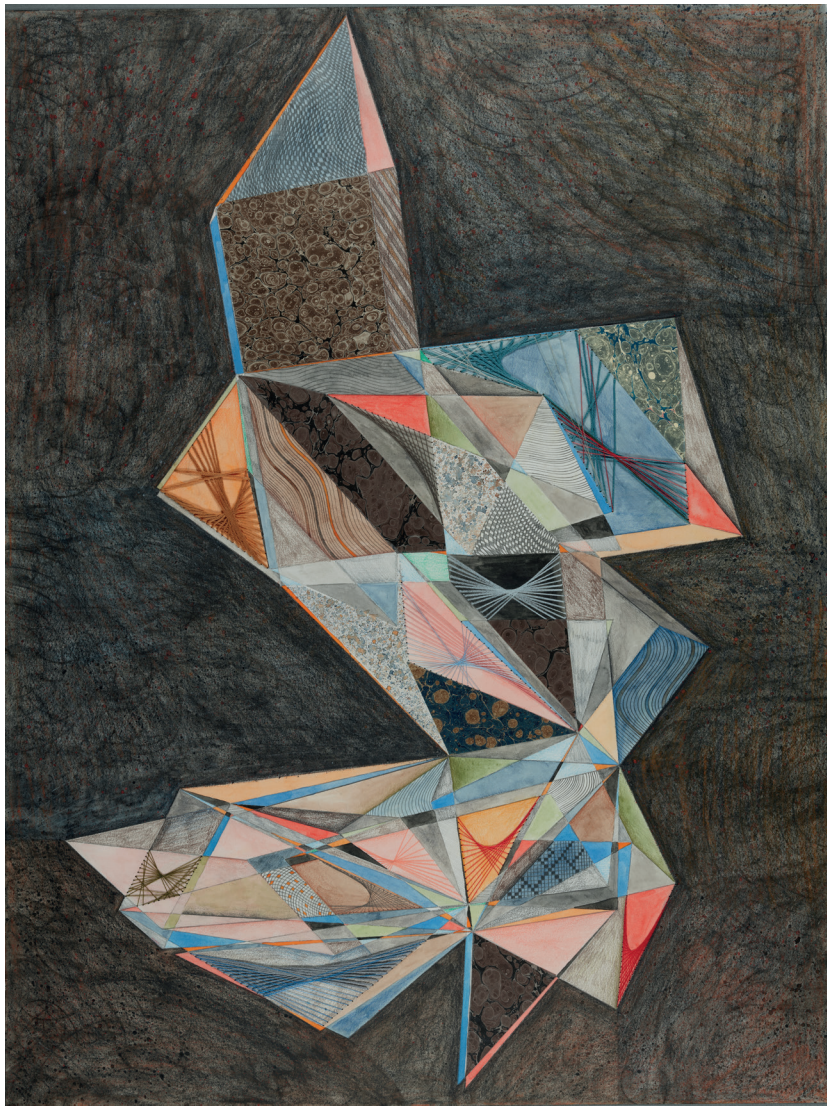
DR MARK BLACKLOCK is a writer, researcher, journalist, and author of the cultural history The Emergence of the Fourth Dimension (Oxford: Oxford University Press, 2018) and the novel Hinton (London: Granta, 2020), a reimagining from documents of the lives of Charles Howard Hinton and his family. His edited collection of the nonfiction of JG Ballard was recently published by MIT Press. Blacklock started Offal Industries with Gavin Weale and Roderick Stanley. Offal is an ongoing project that takes the form of a series of 10-minute "audio zines" using AI voices to perform human-written comic skits, surreal monologues, and literary extracts over a mix of experimental music.

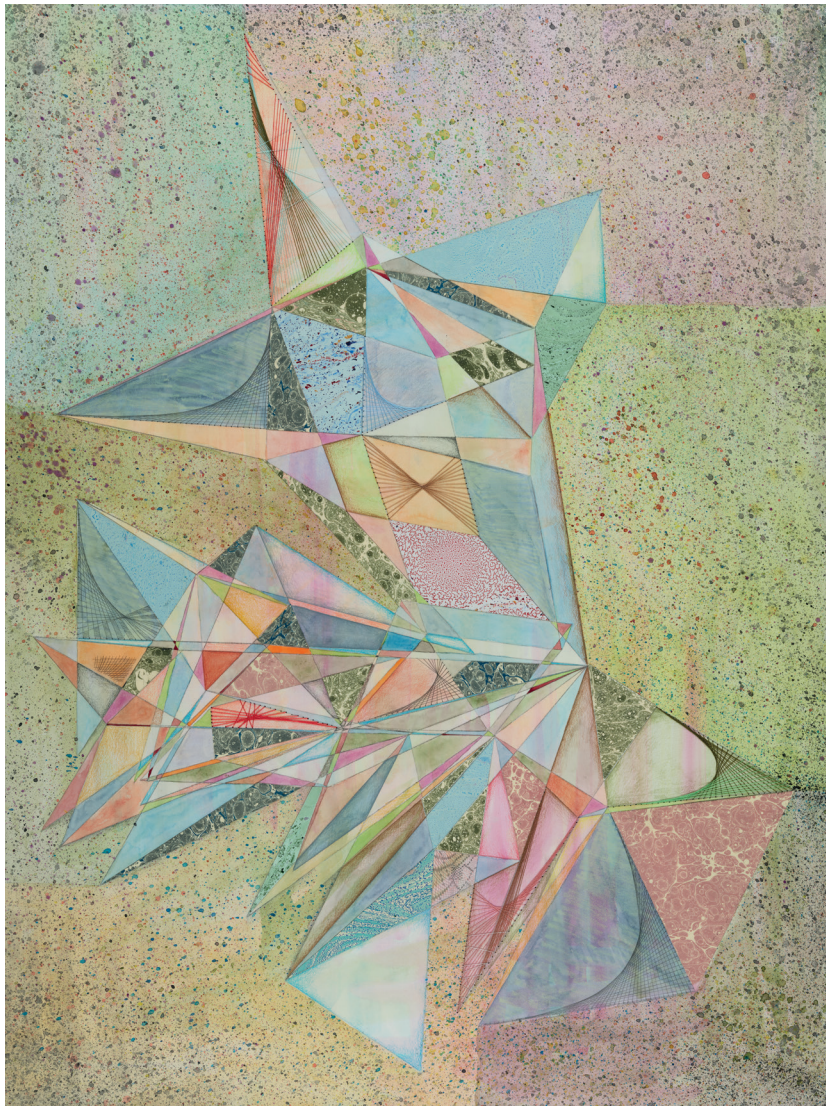
ALESSIO CORTI is a professor of mathematics at Imperial College London. Previously, he held positions at the Scuola Normale Superiore in Pisa, the University of Chicago, and the University of Cambridge. He works in algebraic geometry, particularly higher-dimensional birational geometry, Fano varieties, mirror symmetry, and the mathematical foundations of string theory.

ANDREW MACPHERSON graduated with a PhD in geometry from Imperial College London in 2014. Since then he has worked around the world in pure research institutes, notably IHES, Paris-Saclay (2014–16), and IPMU, Tokyo (2017–20). During this time, he has made contributions to many subfields of geometry and topology, received funding from the LMS and JSPS, and spoken at numerous international conferences. Andrew has been involved in art collaborations with the Fanosearch group at Imperial since his student days there.

PLUMM is a genre-bending, stage-strutting chameleon, dining with both light and shadow. An eccentric performer, Plumm recently sold out the Jazz Cafe with her Led Zeppelin band, has her own Rock/Jazz band that has played the likes of the Royal Albert Hall, and performs in larger collectives such as Levitation Orchestra. Selected by Clash Magazine as "one to watch", and as a Jamz Supernova "After Dark Discovery", Plumm is also currently a "Future Bubbler" under Gilles Peterson.







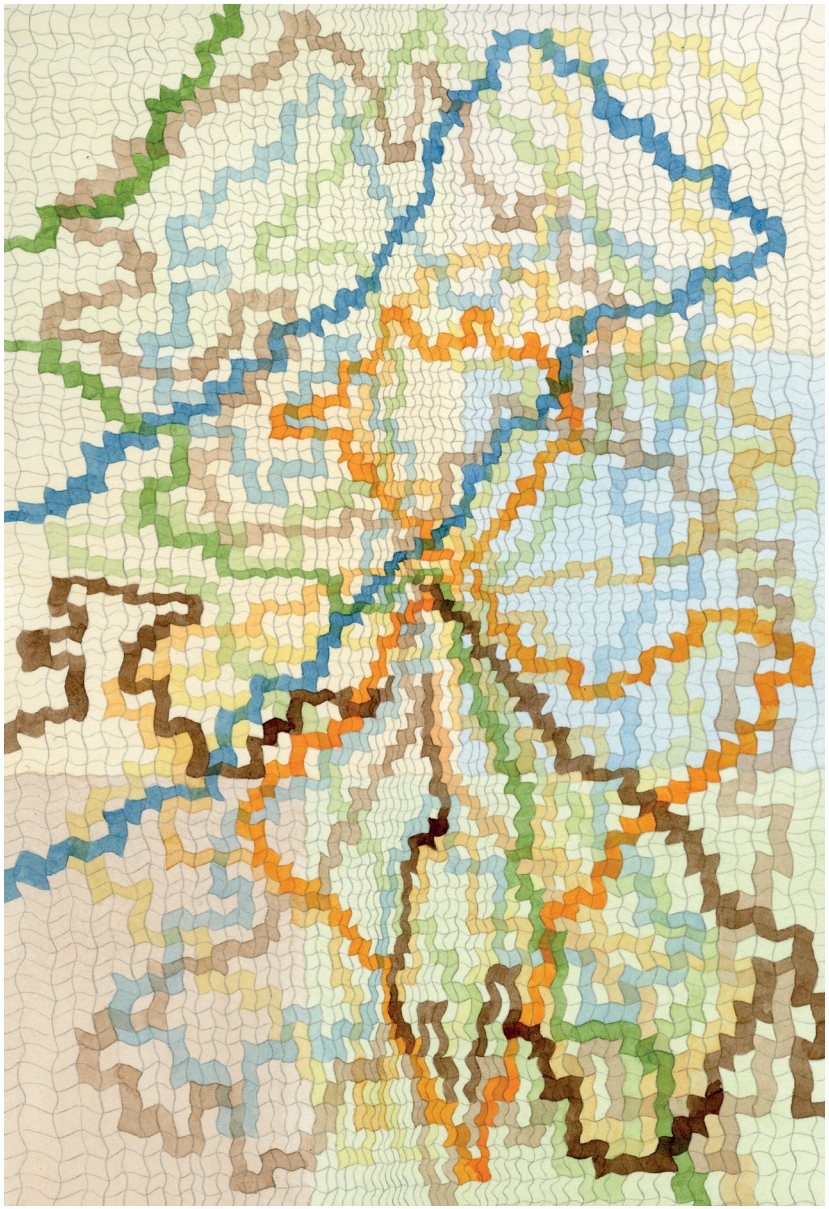


Image credits:

1. x,y,z,w,ana+kata (1), 2022.
   Watercolour, pencil. 18 x 26cm.

2. 4D Embryo Compass (1), 2018.
   Colour pencil on paper, 31 x 41cm.

3. 4D Embryo Compass (2), 2018.
   Colour pencil on paper, 31 x 41cm.

4. Garden of Forking Paths;
   Mitosis Score no. 4, 2019.
   Pencil, watercolour and colour pencil on paper,
   31 x 41cm.

5. 3D Skin of 4D Polytope, 2023.
   Film, cotton thread, tape, 40 x 35 x 30cm.

6. x,y,z,w,ana+kata (14), 2023.
   Watercolour, colour pencil, marbling paper,
   cotton thread, 46 x 61cm.

7. x,y,z,w,ana+kata (15), 2023.
   Watercolour, colour pencil, marbling paper,
   cotton thread, 46 x 61cm.

8. x,y,z,w,ana+kata (3), 2022.
   Watercolour, pencil, 18 x 26cm.

Audio work credits:

'Folding to infinity' composition and performance by Plumm, production and lyrics by Gemma Anderson-Tempini.

'The dangers of setting up an autonomous process in one's own mind' by Offal Industries.

And She Built a Crooked House is commissioned by Artangel and LEEDS 2023.

With thanks to Pickard Properties.

Artangel is generously supported using public funding by Arts Council England, and by the private patronage of The Artangel International Circle, Guardian Angels, Special Angels, and The Company of Angels.

The artist would like to thank everyone who has helped to realise this project: Niccolò Tempini, Una Tempini and Cosmo Tempini, Alessio Corti, Mark Blacklock, Plumm, Andrew Macpherson, Tom Coates, Sara Veneziale, Alexander Kasprzyk, Thomas Prince, Martin Paul Eve, Gavin Weale, Roderick Stanley, Martyn Windsor, Bronte Lyster, Jordanna Broom, Molly Rigg, Joe Waller and the team at Fabrication Facility, Splinter Scenery, and Duke Makes.

With special thanks to the Artangel team: Tara Bhasin, Alice Boff, Persilia Caton, Sam Collins, Marina Doritis, Lili-Maxx Hager, Anita Lawlor, Gabrielle Le Cocq, Anna-Fleur Rawlinson, Tony Stevenson, Sandy Yu, and Mariam Zulfiqar.

Design by work-form

Gemma Anderson-Tempini
And She Built a Crooked House

Burton Grange
17 Burton Crescent
Leeds
LS6 4DN

20 October 2023 – 28 January 2024

Opening hours
12:00 – 18:00
Wednesday – Sunday

The exhibition will be closed to the public from 18 December 2023 until 2 January 2024

Free entry, booking essential

Book your visit and find out more about our programme of events:
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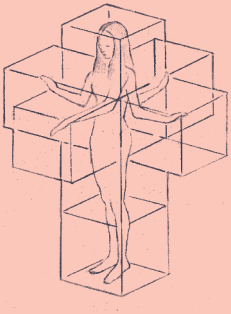

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