Review Article

Surform: An Architectural Vocabulary of Morphogenesis

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> Inner and outer seem sharply divided. How does thinking change if they are continuous? (Brown, 2011)[1]

I shall begin with a rather odd confession: I have become militantly anti-perspectival in this, the maturity of my adolescence. It might be considered 'odd' because the battle over perspective was fought early on during the culture wars and is mostly thought, at least in humanist disciplines, to be a settled matter.[2] It is not a settled matter for me because a stealth form of perspective controls our digital lives. The argument goes something like this: perspective is a subset of projective geometry. The analytic form of projective geometry is linear algebra. Linear algebra underpins the algorithms that determine our digital footprints as we work and play: searching and drawing to what is thought to be a brave new world.[3]

Far more tangible, it is not a settled matter for me because, especially in the practice of architecture (including the acts of design, education and reception) we seem to have nothing with which to replace perspective as the *language of vision*.[4] The situation might be characterised thus: we all understand that perspective is a contested (if not thoroughly discredited) discourse but we do not seem to be able to look away or rather wherever we look all there is to see are objects embedded in a propositionally infinite spatial expanse. In this context, it is clear to me, that the embedding medium of bodies, buildings and brains is not space – unbounded emptiness as is suggested by perspective – but light. Perspective is a fiction, a Truth (capital T) of ideation we confuse with the process of seeing. Seeing is better characterised as bringing objects and environments to light.

This notion, that light is the medium in which we perform architecture, is both commonplace and radical. Commonplace in the sense that it is a matter of uncommon, common sense: no light; little sight, no sight; no shape, no shape then space becomes exclusively acoustic. As Lawrence Gowing observed in 1952: 'All that the eye can possess is light.'[5]

The radical flip of this particular coin is the idea, increasingly commonplace in cybernetics, visual science and neuropsychology that the visual light field does not just adhere to the objects, but is equally defined in the empty space between the objects. In that sense, the ontological status of the visual light field is akin to that of visual space as a 'container'.[6]

The 'architectural vocabulary of morphogenesis' explores an alternative to the tyranny of perspective in *surface theory*. The goal is to develop architecture in a non-perspectival frame, indeed without the perspective frame altogether and in the context of cognitive activity patterns.[7] Morphogenesis is at the center of the inquiry.

Architecture, indeed all intellectual disciplines,

borrow the concept of morphogenesis from developmental biology where it pertains to fetal growth. It is a beguiling question: what is the mechanism of development such that something as complex as a conscious being is formed from a fertilised egg. Mechanism is likely *not* the right word unless one thinks of mechanism without a mechanic and the mechanical as *flow* – loopy processes in which emergent qualities are part and parcel of form evolving form.

What does it look like making design analogue to fetal development? On the most abstract level, the 'ontological perspective', morphogenesis studies processes in which matter actively co-produces its own formal expression.[8] Humberto Maturana and Francisco Varela, in a famous work from the early 1970s called this *autopoiesis.*[9] The term (from Greek αὐτο- [auto-], meaning 'self', and ποίησις [poiesis], meaning 'creation') refers to a system capable of reproducing and maintaining itself. I don't know about you but I own a house and it is very far removed from being 'capable of maintaining itself.' But let us not crack wise. The idea of self-sustaining structures is an ideal at the very center of current architectural discourse. Why? Because in order to meaningfully address climate change in our buildings, cities and regions, exactly what we must figure out is how to make structures autopoietic.[10] Buildings in the anthropocene *must* be autopoietic on purely existential grounds. The first decisive step in this process is moving beyond our learned prejudice of embedding objects in three-dimensional spatial expanse. This suggests another sense in which morphogenesis is relevant to architecture.

It has to do with the evolution of form in *perception*. Crucially, one must assume that the default condition of objects is that they are in constant motion. The root cause of the motion is moot – either the subject is moving or the object is moving, or both. Perceptual models that assume stationary observers and static objects (as most perspectival models do) are highly unlikely scenarios, as is the kluge that renders motion a series of static images succeeding one another below the threshold of fusion.[11] The conditions with which we must concern ourselves are in constant motion, almost always at multiple scales.

The evolution of form in perception, this other morphogenesis, I shall call *perceptogenesis*. Perceptogenesis is the mirror of autopoiesis, related to the evolution of form in development but subject to different constraints. This essay, an examination of some of these constraints, proposes another so-called *language of vision* grounded in the evolution of form in light.

Developing the vocabulary

Speaking practically, I had a relevant experience in studio reviews with students who were designing using a formal vocabulary best characterised as biomorphic. I was quite impressed with the work of one student in particular. It showed a real flair for the non-carpentered envelope and even though the plan suffered from the difficulties endemic to such work, the project was satisfying. But as the conversation progressed it became clear that we had no vocabulary (certainly no common vocabulary) with which to speak about the work. This happened more than once. The problem is that these conversations very quickly devolve into 'I like / don't like …' – matters of opinion with no real basis on which to take principled positions or even explore alternatives.

This is unfortunate because a geometrical vocabulary for such formal explorations is at hand and has been for almost 200 years. Of course, I am referring to Carl Friedrich Gauss's foundational work in differential geometry, *General Investigations of Curved Surfaces* of 1827.[12]

The basic ideas are quite simple. What we might call the Cartesian plane can be generalised to describe all surfaces including curved surfaces.[13] What these surfaces have in common are: 1) lines (or axes) of principle curvature that can be shown to be at right angles and 2) a classification of these in terms of the relationship between their principle curvatures. Amazingly, somewhat counter-intuitively, only three types of surface are possible: surfaces of positive curvature, surfaces of negative curvature and surfaces of zero curvature.[14] Positive curvature is where the lines of principle curvature when multiplied, yield a positive number—in this case a surface with axes arcing in the same direction. Negative curvature is where the axes arc in different directions (their product is negative); and zero curvature is where one (or both) of the axis lines are straight (of zero curvature). Got it? Generically there are three types of surface: cup, saddle and sheet.

At the risk of belabouring the point, allow me a couple of clarifications. First, surfaces of zero curvature may be, for instance, planes or cylinders or cones. It is obvious why planes are of zero curvature but cylinders and cones are perhaps less so unless one returns to Gauss's definition. Given a surface where one axis is a straight line (of zero curvature) then the product of two axes is zero no matter what the curvature of the other axis is. These kinds of surface may take the form of cylinders or cones, among others.

Secondly, it is characteristic of perspective that it associates objects and their embedding medium. This causes problems for our understanding of geometries that are both simpler (less rule bound) and more complicated (more rule bound) than projective geometry. Regarding more rule bound systems such as Euclidean geometry, it is easy for us to anachronistically embed figures in spaces and very difficult for us to creatively re-think our way into a gestalt that views a figure (and its transformation) in itself. This is a learned prejudice. It presupposes a definition of transformations as operations between spaces that carry the figure along as one maps one field onto another. A shorthand for the distinction between transforming figures and mapping fields is the difference between *in* and *of*. Regarding surfaces, one can take a view *of* the surface – a field mapping that implies the view from without, or a view *in* the surface – a transformation engendering a view from within. In many cases this is a distinction without a difference, in others it is of crucial import.

Likewise, in geometries simpler than perspective, when presented with surfaces like saddles, cylinders and hemispheres, we suppose ourselves to be outside the surface regarding the spatial envelope *and* its extensive objects. In this case the distinction *of* the space / *in* the space – what above is a basically psychological distinction – can be given a rigorous formulation in geometry. This category shift leads to one of Gauss's fundamental findings. He described it as the difference between *extrinsic* and *intrinsic* geometry. Perspective is an extrinsic geometry because one may transform any four points of the image to any four points in the ambient array, thereby determining a unique projective transformation of objects in spaces. It is the virtue of perspective that one may explore the entire ambient array this way, as it is given from outside. Gauss, on the contrary, posited a geometry where a shape, a surface, a figure *is* the space. In Gauss's words:

> When a surface is regarded, not as the boundary of a solid, but as a flexible, though not extensible solid, one dimension of which is supposed to vanish, then the properties of the surface depend in part upon the form to which we can suppose it reduced, and in part are absolute and remain invariable, whatever may be the form into which the surface is bent. To these latter properties, the study of which opens to geometry a

> new and fertile field, belong the measure of curvature and the integral curvature, in the sense which we have given to these expressions.[15]

One of the implications of Gauss's invention (discovery?) is that surfaces may be transformed into other surfaces of *the same kind* but never into surfaces of a different kind.[16] This is breathtaking. If one restricts the notion of change to transformations that preserve continuity, then such surfaces have an integral curvature that uniquely generalises them as a family that can be one of only three kinds: positive, negative or zero. Perhaps more importantly, this suggests that perceptogenesis – the sensation of surface in light – may be, *must be* experienced (assuming we are operating at a primitive visual level) from *within* the shape itself, i.e. intrinsically.

The architect in me feels compelled to state the obvious: there is really only one kind of surface, what might be called a hybrid surface. This suggests another finding of Gauss's differential geometry: there exist seams between patches of differently curved surfaces in hybrid forms and these lines are said to be 'invariant.' They are called *parabolic lines*.[17] This is not because they take the shape of parabolas. It is, and this is conjecture, because parabola (from Ancient Greek παραβολή – paraboĺé) means juxtaposition or comparison. Parabolic lines are the joints or lines of juxtaposition between different surface types.

Fostering visual morphogenesis

The assignments devised for this, my first year studio, were designed to introduce architecture students to this concept of invariants as expressed by ever more sophisticated geometric transformations. The final module of the class, immediately preceding the final project and to some degree coincident with it, asks the students to take an irregularly shaped, non-carpentered object, find its parabolic lines and draw those lines on the object itself [Figs. 1-3]. These objects, which I call surforms or 'forms comprised of surfaces' are 3D models of analytically determined mathematical objects used in the psychophysical experiments of James Todd.[18]

The goal in developing these ideas in a first year studio is to introduce students to ways of looking that allows them to analyse and discuss biomorphic form. Let me be clear: I am not interested in promoting biomorphic form in architecture nor am I suggesting in any way that the most interesting problems of form are doubly curved surfaces. Personally, I'm not much interested in the architecture of blobs. What I am is interested in ways of seeing and deeply invested in fostering critical dialogue around form, form making, the perception of form and, most important of all, the inhabiting of built form. I believe that the introduction of Gauss's intrinsic geometry creates a foundation that promotes a unique and previously unarticulated way of negotiating architectural form that is fundamentally different from perspective. I hope such exercises might: 1) foster a view from within, thereby promoting object space/times synoptic with place; 2) elaborate the ways architecture and design are critically dependent on seams, edges and transformations (not new but using an expanded – parabolic – definition of edge); 3) introduce the notion of a first-person inquiry as distinct from a third-person interrogation; 4) promote allocentric rather than egocentric attitudes; 5) favour intrinsic as opposed to extrinsic approaches; 6) recreate structure as autopoiesis founded on perceptogenesis; and 7) elaborate the ways that light is the embedding medium of building.

Now, in retrospect of this educational experiment, I find myself even less tolerant of perspective, the humanist debate around perspective and the encoding of perspectival prejudices in digital networks. In short, we do our students a grave disservice educating their seeing in perspectival modes. Instead we must work to put perspective in

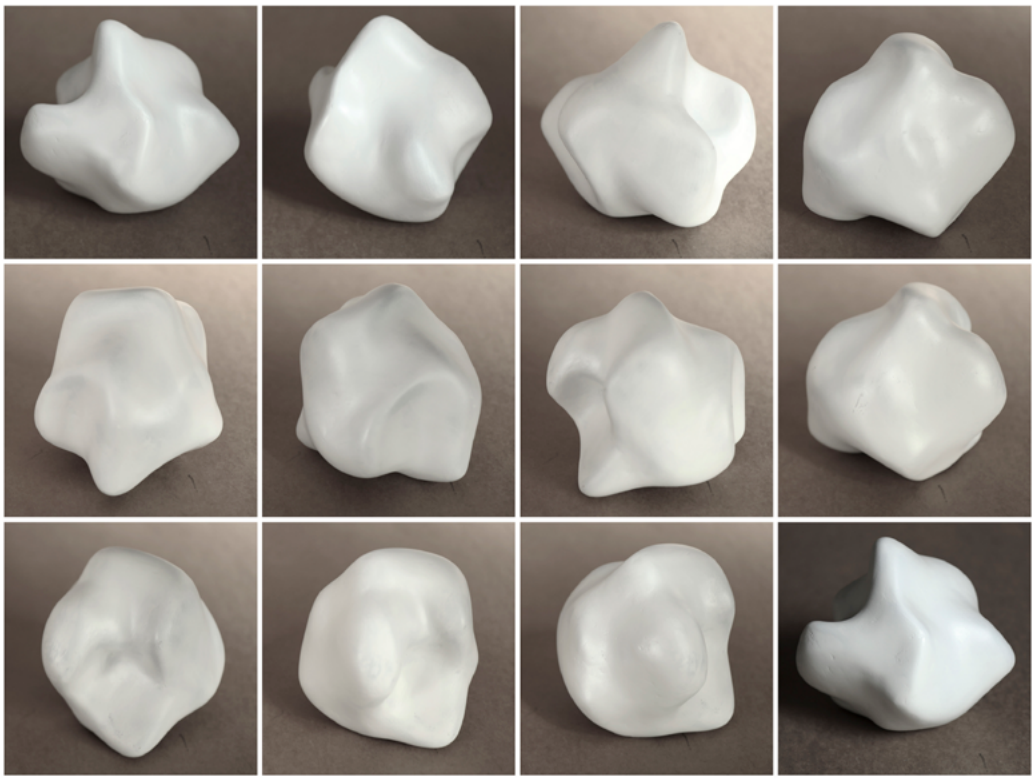

Fig. 1: A pristine surform from multiple angles, after surfacing. The students were working in groups of three to five people. There were five groups. Each group was given their own surform that they were required to prepare by coating and sanding and on which they were to draw. No one in the class seemed to notice that all the surforms were identical. I did not contradict that misapprehension. Image: author.

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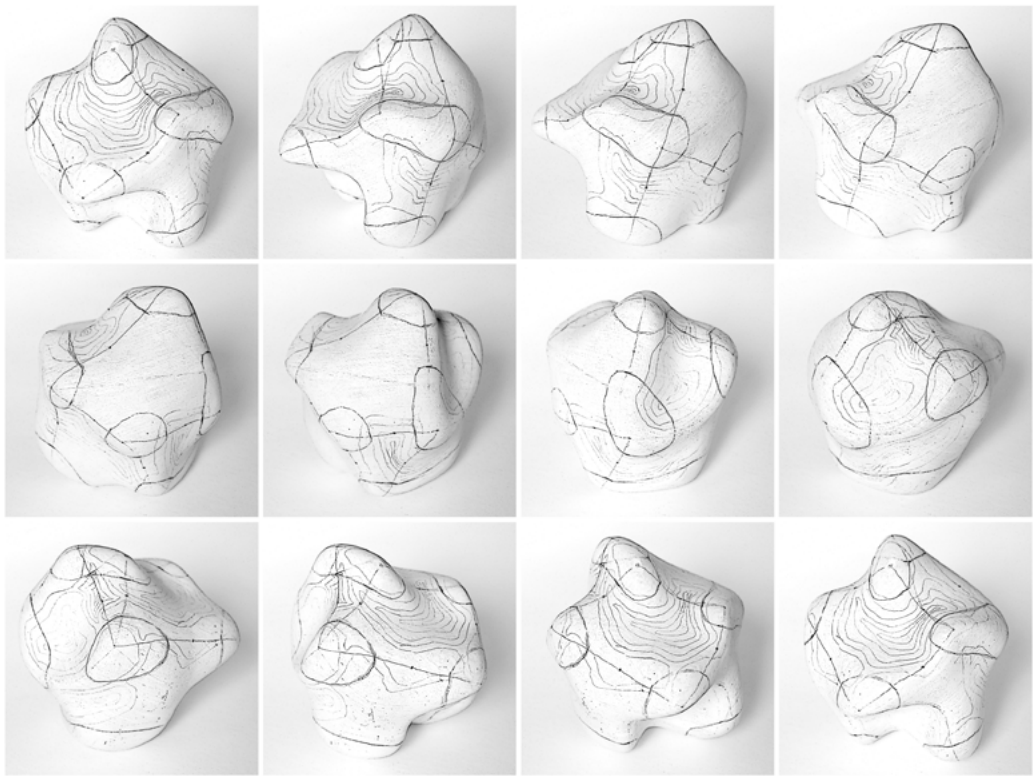

Fig. 2: There are several different ways one may approach finding parabolic lines on surforms. In the ‘constructive’ approach one locates the Morse critical points, the so-called peaks and passes, and then connects those with ‘ridge’ lines. After that, paying attention to each ridge, identify the points where the line goes from being convex to concave. That is a point of inflection. With those inflection points anchoring the process, one may then locate the parabolic lines as seams connecting the ridge line inflections. Image: author.

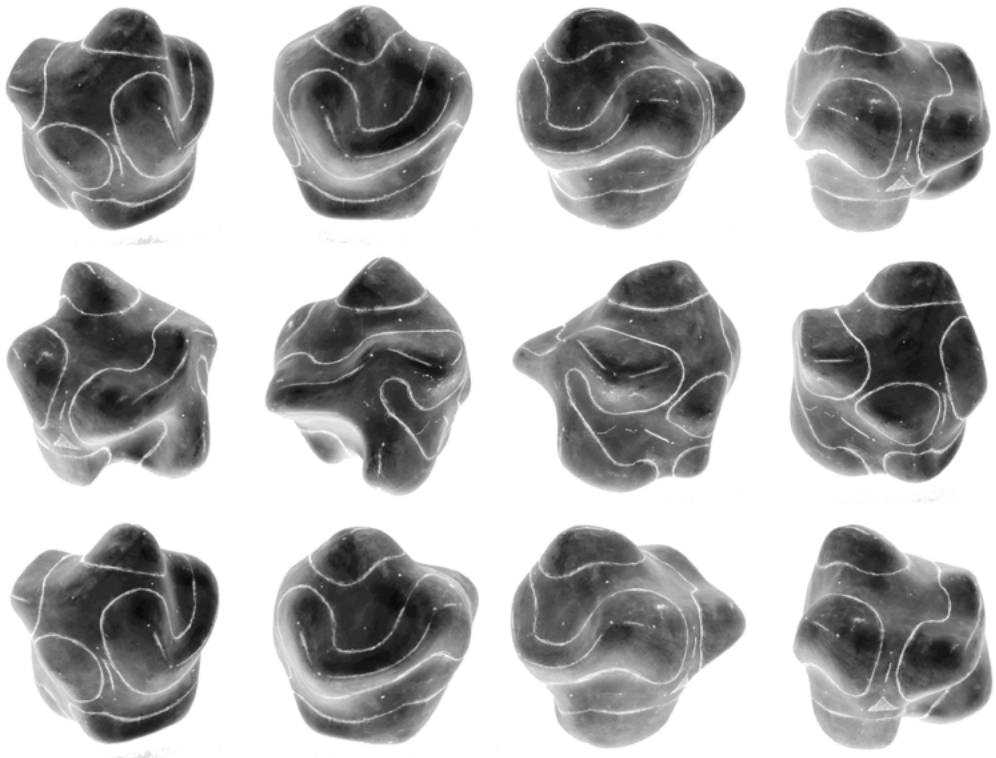

Fig. 3: One precocious student worked without a net, as it were. She simply regarded the surform as an object and ‘read off’ the lines that acted as ‘edges’ separating the surfaces of positive and negative curvature. No construction lines needed. Acquiring this skill – reading the edges of biomorphic forms as easily as one reads the boundaries of crystalline forms – is one result expected of this educational experiment. Image: author.

its place as one among many geometries. We could teach the fundamentals of similar, affine, inversive, differential and topological geometries as real alternatives to perspective, a system that above all frames and embeds. One unintended consequence of such an approach might be citizens equipped to better evaluate the way algorithmic tools based on mathematical systems influence our decisions in the world. More relevant for architecture might be a shift away from frozen metaphors of biomorphic forms towards explorations that evolve structures from perceptual processes and envision buildings as organisms developing in slow time in symbiotic relation with their environments. This might go a long way towards embodying human minds continuous with physical nature, further deploying an architecture that meaningfully addresses catastrophic environmental change.

Notes

This is a review article related to the course Arch108; taught in the spring of 2017; the faculty of the School of Architecture, University of Kansas; coordinated by Anne M. Patterson.

1. Jason W. Brown, *Gourmet's Guide to the Mind* (Brussels: Les editions Chromatika, 2011), 89. Brown elaborates this aphorism thus: 'A subjectivity of the inorganic that is continuous with human mind is a theory of mind continuous with physical nature. … The appeal to process thinking of a genetic psychology rooted in subjectivity is that patterns in the actualization or becoming of the mental state can be mapped to features in the concrescence of physical entities that would otherwise be opaque to causal science.' Jason W. Brown, *Neuropsychological Foundations of Conscious Experience* (Brussels: Les editions Chromatika, 2010), 125.
2. I am engaging in a bit of hyperbole here. Of course, the literature on perspective is vast and continues to grow. A prudent qualification might be: "logocentric scholars" or "scholars reflexively adopting a post modern attitude." Hal Foster, *The Anti-Aesthetic: Essays on Postmodern Culture* (Port Townsend: Bay Press, 1983).
3. For an exposition of search algorithms see Dominic Widdows, *Geometry and Meaning* (Stanford: CSLI Publications, 2004).

   For an exposition of CAD algorithms see Wolfgang Bohm, Gerald Farin, and Jurgen Kahmann, A Survey of Curve and Surface Methods in CAGD', *Computer Aided Geometric Design* 1, no. 1 (1984): 1–60. I intend all the sarcasm Huxley's *Brave New World* intones.
4. The notion of *languages of vision* is exceedingly problematic for me. Rather than unpack it here, suffice it to gesture towards Robin Evans: 'Those of us who are wary of words would judge the excellence of a work of visual art by the degree to which it is unsullied by them. This cannot be right. It simply reverses a recurrent phobia … Attempts to prove either that the visual arts are languages or that they are independent of language are equally wide of the mark. In the whole gamut of art, only vision and language count for much, and each is deeply imbued with the other.' Robin Evans, 'Mies van der Rohe's paradoxical symmetries', *AA Files* 19 (1990): 60.
5. Lawrence Gowing, *Vermeer* (Berkeley: University of California Press, 1997), 32.
6. Jan J. Koenderink, S.C. Pont, Andrea J. van Doorn, A.M. Kappers, and J.T. Todd, 'The Visual Light Field', *Perception* 36, no. 11 (2007): 1596.
7. As Paul Weiss observes: 'You may sense already my own design. It is to reorient thinking from static *form* to formative *behavior* across all orders of magnitude.' Paul Weiss, 'One Plus One Does Not Equal Two', in *The Neurosciences: A Study Program*, ed. Gardner C. Quarton, Theodore Melnechuk and Francis Otto Schmitt (New York: Rockefeller University Press, 1967), 808.
8. This definition is lifted from the *Footprint* call for papers: 'from an ontological perspective, morphogenetic studies deal with the processes in which matter actively co-produces its various formal expressions … one that examines the reciprocity of formal emergence.'

9. Humberto R. Maturana, and Francisco J. Varela, *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht and Boston: D. Reidel, 1980 [1972]).
10. Patrik Schumacher has marked *autopoesis*. Do not assume his elaboration of parametric architecture is related to my argument here. To be or not to be parametric misses the point in a way analogous to be or not to be 'modern' misses the point. The crux is what parameter one chooses to render and whether or not the rendering is actually dynamic or just a simile of objects evolving in time. Patrik Schumacher, 'Parametricism and the Autopoiesis of Architecture', *Log*, no. 21 (2011): 62–79.
11. A kluge is a quick fix that works. Andy Clark identifies this as a central design feature of cognitive architectures as they evolve from 'speedy sensorimotor processing' to something 'capable of sequential conscious reasoning'. Andy Clark, *Microcognition: Philosophy, Cognitive Science, and Parallel Distributed Processing* (Cambridge, MA: MIT Press, 1989), 134. In this case the kluge is an assumption by experimental psychologists that the algorithms of sensorimotor processing mirror the physics of motion.
12. Carl Friedrich Gauss, ed. and trans. James Caddall Morehead and Adam Miller Hiltebeitel, *General Investigations of Curved Surfaces of 1827 and 1825* (Hewlett: Raven Press, 1965 [1902]).
13. By 'generalised' I intend 'rendered generically.' Generic surfaces in this context are surfaces that when slightly perturbed preserve their defining characteristics such as intrinsic curvature.
14. This statement should be qualified: 'in low dimension.'
15. Gauss, *General Investigations*, 21.
16. Technically Gauss's *Theorema Egregium* shows how a surface whose principal curvatures, when multiplied and found equal, can be continuously transformed into each other.
17. Parabolic lines, in this sense, are what I think Deleuze regards as 'folds' i.e. le pli. I am frankly not entirely sure because the argument is obscure in Deleuze and obfuscated in Greg Lynn, Folding in Architecture (London: Architectural Design Magazine, 1993). By contrast, in the mathematics of Gauss it is marvelously clear. Regarding the recent history of 'the fold' in architectural theory, I follow the lead of Mario Carpo in The Second Digital Turn: Design Beyond Intelligence (Cambridge, MA: MIT Press, 2017) and especially The Alphabet and the Algorithm (Cambridge, MA: MIT Press, 2011).
18. James T. Todd, 'The Visual Perception of 3D Shape', *Trends in Cognitive Science* 8, no. 3 (2004): 115–21.

Biography

J.M. Rees directs a design practice based in Kansas City, Missouri. Within the framework of a business established in 1958, Rees designs envelopes, interiors, furniture and surfaces. His approach is analytical, site specific and multidisciplinary. Rees edited and contributed to the books *The Sixth Surface: Steven Holl Lights the Nelson-Atkins Museum of Art* (2007) and *Urban Stories of Place* (2006). He has shown in New York and Kansas City. Since 2008 Rees has been collaborating with clients, contractors, architects, engineers and manufactures to develop the next generation of high performance homes tuned to conditions particular to Kansas City.