***Catalog essay for the exhibition:***
***<u>Seeing the Invisible: Data, Design, Art</u>***
***Williamson Gallery – Art Center College of Design***
***Part of PST ART: Art and Science Collide (2024)***

***Essay by Margaret Wertheim***

## ***<u>Making and Knowing: The Vernacular Science of the Crochet Coral Reef</u>***

In the elegant anthology *Ways of Making and Knowing* (2014), science historian Pamela H. Smith proposes that "histories of science and art are not simply histories of styles, but histories of the making and using of objects to understand the world."[i] We come to knowledge of the world around us, Smith notes, "through material and human interaction with, and manipulation of, nature." *Interaction with* and *manipulation of* nature are processes we instinctively associate with science—what, under the banner of "science," are enfolded into the term "experimentation." But Smith and her fellow essayists want to alert us to the ways in which artists and artisans also manipulate materials and employ experimental practices in the service of knowledge production.

As a Renaissance expert, Smith's focus is the influence of artisanal culture on the emergence of science in the early modern period. For the purposes of this essay, however, my interest lies in her assertion that artists working today with material processes can also be said to be engaging in a kind of science.[ii] Various artists in this exhibition, for example, use material substrates for cognitive explorations and ontological engagements. In *Ways of Making and Knowing*, Smith gives us a framework for thinking through such relationships. She writes: "an examination of material practices makes it clear that the methods of the artisan represent a process of knowledge making that involves extensive experimentation and observation that parallel similar processes in the sciences."[iii] I agree wholeheartedly and present here a case study of a contemporary craft-based practice that constitutes an elaborate form of what I call "handmade science."

### **Coral *contrefaict***

Smith speaks of "imitation as knowledge making," and her research zeroes in on artisanal techniques from the fifteenth through nineteenth centuries developed to represent and imitate nature: How were pigments created and applied to emulate distinct qualities of animals, flowers and so on? What "lifecasting" techniques were invented to capture the soft bodies of lizards, snakes, beetles, and roses? And how did artisans then reproduce these forms in durable materials? What methods did they concoct to make imitations of precious stones or *coral contrefaict* (a faux version of branched red coral) to cater to a growing market for these exotics and as a means to understand how nature makes itself? Smith's work, however, extends far beyond the usual modes of academic scholarship, for at Columbia University (in 2014) she founded the Making and Knowing Project, where she has set up laboratories to re-create processes described in centuries-old texts. Not content to have her students merely read such manuscripts, she challenges them to actually *make* faux jasper and coral, to cast lizard toes, to taxidermy rats.

Smith argues that early modern artisans who developed these techniques should be seen as partners in the evolution of science, for their explorations helped shed light on how nature works. Moreover, from around 1400 CE, artisans began to formalize the knowledge they were producing in "written documents such as handbooks, guides, treatises, tip sheets, graphs, and recipe books." In addition to passing along knowledge in their workshops, "literate artisans" started to publish their findings for a wider audience, thereby creating "an early kind of technical writing" which, Smith writes elsewhere, helped to "lay the groundwork for how we think about scientific knowledge today."[iv] To recognize the contributions to science of these non-academic *material thinkers*, Smith proposes the term "vernacular natural history" to be understood as a parallel practice to the usually told story of science as the progress of increasingly academic *conceptual ideas*.

In what follows, I describe a project of contemporary "vernacular natural history" that I and my sister Christine Wertheim created and spearhead—the *Crochet Coral Reef*—a worldwide endeavor now engaging tens of thousands of women across the globe who are emulating coral reefs using the craft of crochet. To draw on another term Smith deploys, the *Crochet Coral Reef* is "*a material imaginary*—a knowledge system that articulates relationships between materials and provides a framework for practice."[v]

Along with Smith's Renaissance artisans, our *Crochet Coral Reef* begins with a desire to model a natural phenomenon, in this case the Great Barrier Reef. We grew up in its home state, Queensland, where the Great One's fragile beauty looms large in public consciousness; during our lives, coral bleaching events have become ever more frequent and dire. As I write, in mid-2024, the Great Barrier Reef is experiencing the worst bleaching on record.[vi] Average earthly temperatures are now more than 2˚ Fahrenheit (1.2˚ Centigrade) above preindustrial levels, far beyond the comfort zone of corals. Being delicate creatures, corals were among the first organisms to signal the here-and-now of climate change, and coral bleaching has become a kind of organismal meter for gauging water temperature, a living index as it were of the rapid transformation of our climate.

The aquatic equivalents to rainforests, reefs are home to perhaps a quarter of all marine species. They protect coastlines, provide sustenance, and fuel tourism. Yet reefs are tricky structures for humans to imitate because the frilly shapes we recognize as their hallmark don't conform to the kind of geometry we learn at school and to which modern Western aesthetics has often reverted. The straight-edged Euclidean geometry Renaissance painters strived to represent doesn't apply to corals, kelps, and sea sponges. These ancient lineages are biological manifestations of an alternative geometry, known as *hyperbolic*, which distinguishes itself in swoops and curves. Although human mathematicians spent centuries trying to prove that anything like it was impossible, reef creatures have been *making* hyperbolic surfaces in the fibers of their being since the Silurian Age. The question of how humans might imitate this fleshy embodiment of a "pathological" geometry was no easy problem; in short, artisans had to learn how to embody hyperbolic math.

It turns out we can do so with crochet. Using a female-coded craft we can generate coraline frills and ruffles that follow the conformations of hyperbolic space, realizing in yarn an idea that shook mathematics to its core and helped lead Einstein to the general theory of relativity.[vii] The technique a crafter employs is to *increase* stitches. The more frequently one increases the more crenellated the form becomes, and by *varying* the rate of increase we can produce a whole taxonomy of crochet coral "creatures"—each of which may be understood as a data point in a virtual landscape of mathematical possibility (fig. 1).

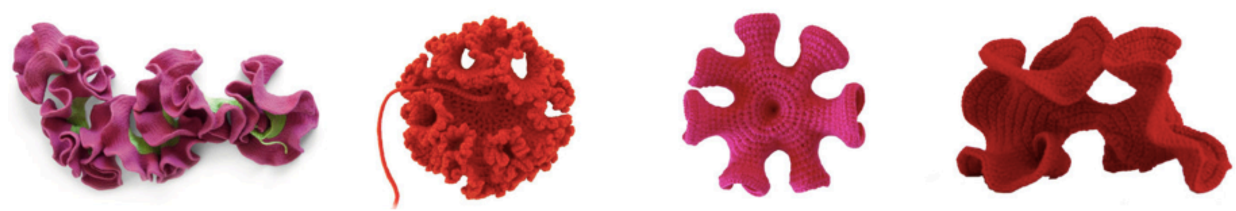


**Figure 1:** Various geometrically precise *hyperbolic crochet* coral creatures made Margaret Wertheim and Anitra Menning of the Institute For Figuring, 2006/2007. Image © Institute For Figuring

To create a hyperbolic form, one begins with a line of chain stitches, then iterates the algorithm: "Crochet 'n' stitches; increase one stitch; repeat." As we increase, the form begins to bend away from Euclidean flatness, taking on an ever more pronounced curvature: first one ruffle, then two, and so on. Working with hook and yarn, the crocheter creates a model of the *hyperbolic plane*, a surface characterized by mathematicians as the geometric opposite of a sphere. While the Euclidean plane is said to have *zero curvature* and the sphere *positive curvature*, the hyperbolic plane has *negative curvature*. It's a geometric analog of a negative number.[viii] Consonant with Smith's notion of vernacular natural history, this material making of non-Euclidean surfaces constitutes a form of *vernacular mathematics*—one that's been almost exclusively explored by women.

**The domestic frontiers of hyperbolic space**

The discovery of "hyperbolic crochet" is attributed to Cornell mathematician Daina Taimina, who created such models as pedagogical tools for college-level geometry classes.[ix] Taimina's brilliance was to identify how a humble craft could be employed to emulate a structure mathematicians had struggled to visualize for two hundred years. With crochet, she crafted models they could *see* and *feel* and manipulate in their hands. One can even stitch lines onto such surfaces to visually demonstrate bizarre properties of hyperbolic space, such as the angles of a triangle adding up to less than 180˚ and the circumference of a circle measuring more than 2πr.[x]

But if Taimina was the first to recognize the math embedded here she wasn't the first to construct such shapes—ladies crocheting doilies have been making hyperbolic surfaces for at least a hundred years. In the collection of doilies Christine and I own we have an exquisite piece of lacework from the nineteenth century with cascading layers of ever more crenellated hyperbolic frills. Also, a selection of 1940s pattern books for "ruffled doilies" features dozens of examples of hyperbolic edgings spelled out in stitch *algorithms* incorporating subroutines and other staples of computer-coding techniques. The "literate artisans" who wrote these patterns—and the women who reproduced the objects in their homes—had a clear understanding of how hyperbolic surfaces behave. Theirs was (and is) a mature form of material "knowledge making."

Thus, in parallel to the academic study of hyperbolic geometry going on in university math departments, wives and maids at home were also developing an understanding of non-Euclidean concepts and a rigorous language for describing such forms. Using what Smith calls "sensory tools of embodied experience," ladies crocheting doilies have long been exploring the frontiers of hyperbolic space.

Smith's project to recognize the role of artisanal practices in scientific knowledge making could also be paralleled if we consider the history of mathematics, where age-old traditions of vernacular understanding have long been overlooked. One great exemplar is the body of Islamic tiling patterns in mosques and palaces throughout the Middle East and Spain.[xi] On the walls and ceilings of the Alhambra palace in Granada and other masterpieces of Islamic tessellated art, we find all the variations of tiling patterns formally categorized by European mathematicians in the nineteenth century. Thrillingly, medieval Islamic mosaicists also give us examples of *aperiodic* tiling, a *chaotic* version of tessellation that Western mathematicians didn't "discover" until the 1960s.[xii] And just as Islamic artisans working with material techniques long preceded academic mathematics in comprehending tiling, so African artisans discovered *fractals* hundreds of years before Western geometers. In his splendid book *African Fractals* (1999), mathematician Ron Eglash documents how craftspeople across that continent have been incorporating fractals into textile and ceramic designs, hairstyling, and even the layout of villages for perhaps a thousand years (fig. 2).[xiii] Many other indigenous design techniques could be cited.[xiv] Vernacular mathematics systems involving material practices are found throughout the world and have been too little acknowledged in both the "science" and "art" domains.

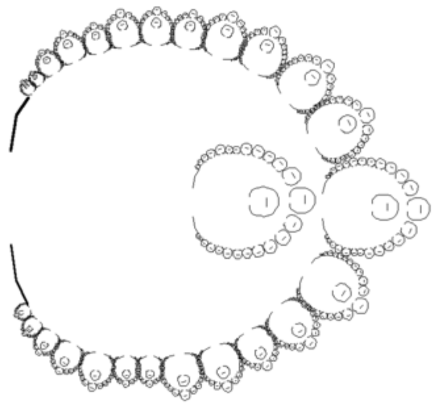


**Figure 2:** Fractal design for layout of a Ba-ila village in southern Zambia, by Ron Eglash, in *African Fractals* (2002).

**Crochet Codes and Crafty Cryptology**

Artisanal thread-based processes can also be seen to encompass a vernacular form of *coding*. Indeed, female crafters have been deploying the apparatus of codes and algorithms for centuries. Handicrafts such as knitting, crochet, basketry, and weaving were the original *digital* technologies—*technes* created by digits—and it is one of the ironies of the computer age that the "digital" has come to connote disembodiment and divorce from the material domain when the term derives from our fingers. History records this linkage in the punch cards of early computers, born out of cards created to automate looms.

Crochet actually deploys two distinct kinds of codes: one *graphical*, the other *lexical*. In the doily patterns here, we see examples of a *spatialized* code a crafter can enact with her fingers (fig. 3). Each mark or symbol represents a set of stitches to be performed, making these images visual algorithms.[xv] Beginning at the center and spiraling out, a crocheter performs the instructions the diagram describes using yarn as a medium to bring the algorithm into material form. Much as Smith's Renaissance artisans began to formalize their knowledge in written texts, so doily makers have developed a rich language for conveying the information to create intricate diatom-like objects.

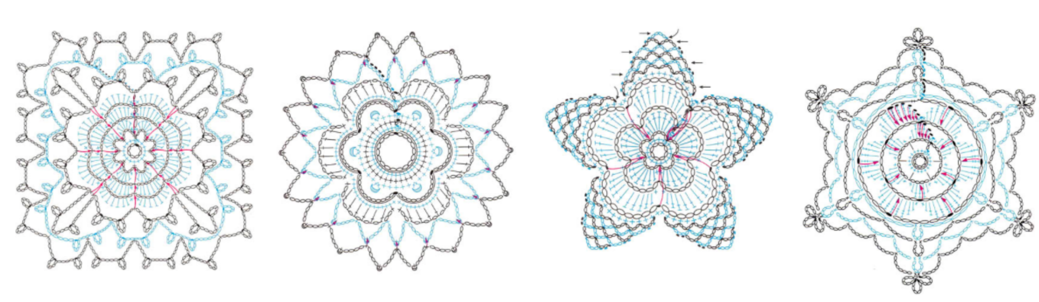
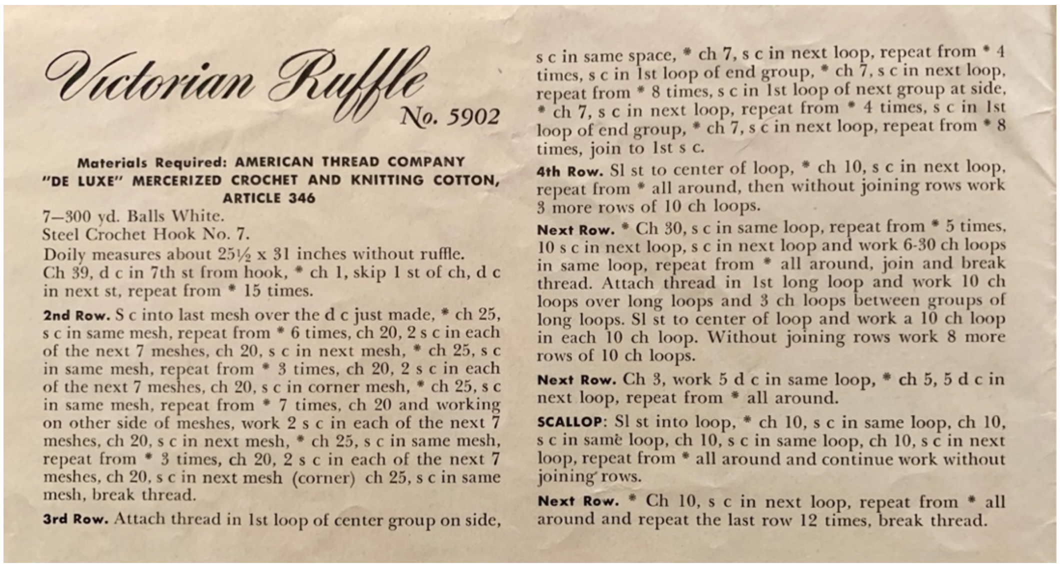


**Figure 3:** Diagrammatic crochet doily patterns. Images courtesy Sarah Simons.

In addition to this visual code, crochet instructions can be conveyed by an *alphabetic* code, with each stitch type described by groups of letters: “ch” for chain, “sc” for single crochet, “dc” for double crochet, and so on. This dialect of the digits is another way of representing patterns, as in the image below showing the stitch pattern for a ruffled doily (fig. 4).



*Victorian Ruffle* No. 5902

**Materials Required: AMERICAN THREAD COMPANY "DE LUXE" MERCERIZED CROCHET AND KNITTING COTTON, ARTICLE 346**

7—300 yd. Balls White.
Steel Crochet Hook No. 7.
Doily measures about 25½ x 31 inches without ruffle.
Ch 39, d c in 7th st from hook, * ch 1, skip 1 st of ch, d c in next st, repeat from * 15 times.

**2nd Row.** S c into last mesh over the d c just made, * ch 25, s c in same mesh, repeat from * 6 times, ch 20, 2 s c in each of the next 7 meshes, ch 20, s c in next mesh, * ch 25, s c in same mesh, repeat from * 3 times, ch 20, 2 s c in each of the next 7 meshes, ch 20, s c in corner mesh, * ch 25, s c in same mesh, repeat from * 7 times, ch 20 and working on other side of meshes, work 2 s c in each of the next 7 meshes, ch 20, s c in next mesh, * ch 25, s c in same mesh, repeat from * 3 times, ch 20, 2 s c in each of the next 7 meshes, ch 20, s c in next mesh (corner) ch 25, s c in same mesh, break thread.

**3rd Row.** Attach thread in 1st loop of center group on side, s c in same space, * ch 7, s c in next loop, repeat from * 4 times, s c in 1st loop of end group, * ch 7, s c in next loop, repeat from * 8 times, s c in 1st loop of next group at side, * ch 7, s c in next loop, repeat from * 4 times, s c in 1st loop of end group, * ch 7, s c in next loop, repeat from * 8 times, join to 1st s c.

**4th Row.** Sl st to center of loop, * ch 10, s c in next loop, repeat from * all around, then without joining rows work 3 more rows of 10 ch loops.

**Next Row.** * Ch 30, s c in same loop, repeat from * 5 times, 10 s c in next loop, s c in next loop and work 6-30 ch loops in same loop, repeat from * all around, join and break thread. Attach thread in 1st long loop and work 10 ch loops over long loops and 3 ch loops between groups of long loops. Sl st to center of loop and work a 10 ch loop in each 10 ch loop. Without joining rows work 8 more rows of 10 ch loops.

**Next Row.** Ch 3, work 5 d c in same loop, * ch 5, 5 d c in next loop, repeat from * all around.

**SCALLOP:** Sl st into loop, * ch 10, s c in same loop, ch 10, s c in same loop, ch 10, s c in same loop, ch 10, s c in next loop, repeat from * all around and continue work without joining rows.

**Next Row.** * Ch 10, s c in next loop, repeat from * all around and repeat the last row 12 times, break thread.

**Figure 4:** Doily pattern, from the pamphlet *Ruffled Doiles and the Pansy Doily*,
Star Book (The American Thread Company). no. 59, 1948

Alphabetic patterns such as this are a craft equivalent of computer programs. Both employ a coded lexicon to indicate specific steps, and both utilize “subroutines,” small programs-within-programs that get called on as repeats. (Subroutines in the pattern above are indicated by the * symbol.) Yet for all the power of alphabetic crochet patterns, the graphical variety has added virtues. In the pattern above, it is hard to imagine the object being created until it emerges in your hands. Who but an expert crafter would recognize the remarkable form seen below in Figure 5 as the result of such a code?

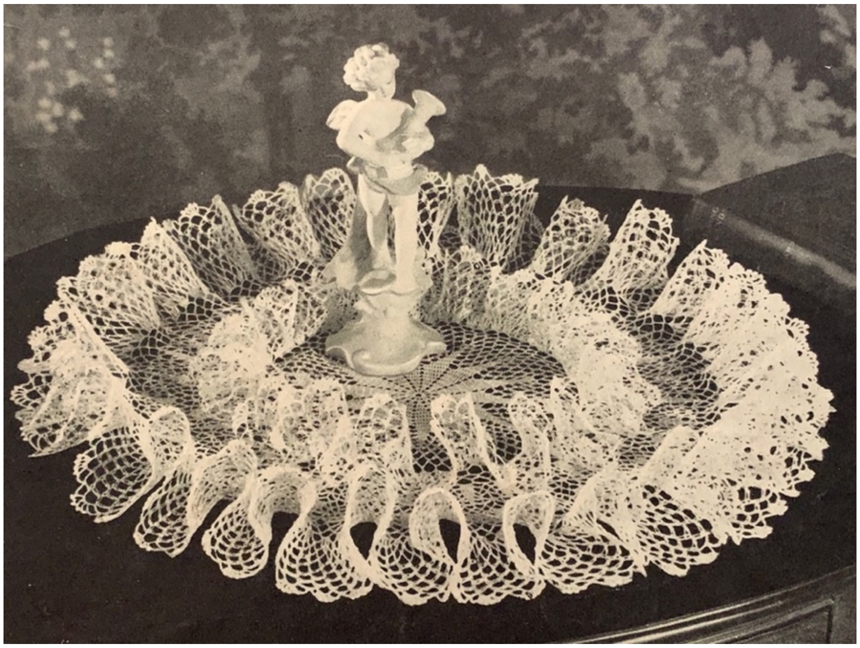


**Figure 5.** Hyperbolic doily crafted from a pattern in *Ruffled Doiles and the Pansy Doily*

With a *diagrammatic* pattern like those in Figure 3, one knows in advance the configuration it will produce because the graphics represent a one-to-one correspondence with the structural components of the finished form. The pioneering mathematician and logician Charles Sanders Peirce referred to such images as "icons," and to him *iconicity* was the highest form of signification.[xvi] Peirce believed practitioners of all sciences, including math, should strive to develop iconic notations for representing knowledge, and he famously created graphical systems to describe the logic underlying computing. He took inspiration from electrical circuit diagrams and chemical diagrams (Figure. 6), both of which lay out their component parts in a similar fashion to doily patterns. In all these cases, diagrams serve to make visible a logic of spatial relations—a literal *topo-logy*—thereby becoming tools to think with.

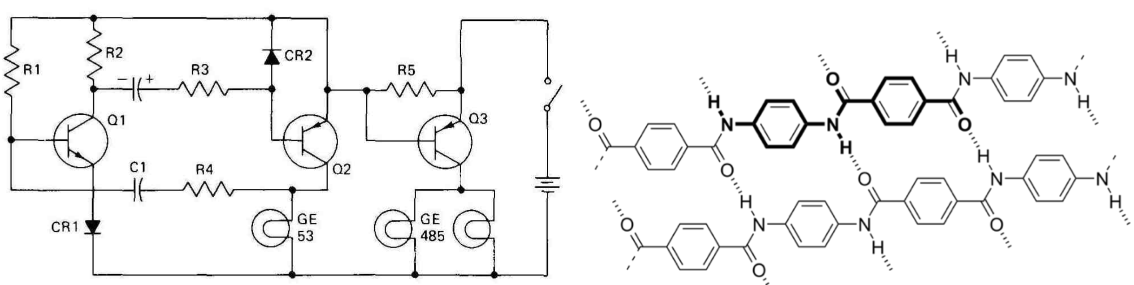



**Figure 6:** Diagrams of an electrical circuit (left), and the chemical structure of Kevlar (right).
Images courtesy Wikipedia commons

**Iterate, deviate, innovate**

Life itself instantiates a code; the code of DNA in the heart of living cells. And again, we find here a natural process that we crochet reef artisans strive to emulate.

Among the virtues of DNA is its propensity for *imperfect* reproduction. When a cell holding DNA replicates, malfunctions can occur; here or there a DNA "letter" may be changed, perhaps one is deleted or a new one gets added. Such "mistakes" are essential for the process of evolution, for if DNA always replicated perfectly life would lock into a groove with no new creations. Deviations at the molecular level cause mutations at the physiological level, leading ultimately to taxonomic *variety* and the whole plethora of living things.

Here, as well, we crochet makers imitate nature. Every person who comes to the project begins with a simple seed that they can gradually evolve, through deviation, into more complex forms. Each crochet coral "reefer" starts with the kernel of the basic hyperbolic algorithm given above—yet perfect hyperbolic forms (like perfect spheres) are the antithesis of living things, which are never quite regular, never geometrically precise. It is this move into "imperfection" that sparks the *Crochet Reef* project to life, hefting it from the domain of pure math into a kind of fiberized organicism.[xvii] After learning the basic technique, every crafter is free to inject their own deviations: to add to the code or change it here and there, mimicking the DNA deviations of organic evolution.

We too *queer* the code. "Iterate, deviate, innovate" has been the motto of our project. What is it *you* can imagine that no one else has done before? Each maker is free to invent new shoots on the crochet "tree of life," new wooly "organisms" whose multiplicity imitates the diversity of living beings. By emulating the accreted variation of earthly organisms, our crochet reef community has accreted a library of floofy formations and brought into being an ever-evolving taxonomy of crochet coral "species." Working with codes played out through fibers, we reefers together craft an imitation of life—a visionary yarn-based ecology and true "material imaginary."

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[i] Pamela H. Smith, *Ways of Making and Knowing: The Material Culture of Empirical Knowledge* (Ann Arbor: University of Michigan Press, 2014), Dust-cover. flap copy? back cover? front cover? [or maybe delete cover reference and just cite source…]

[ii] Smith, from slides delivered during a closed Zoom lecture at the National Gallery of Art, Washington, DC, April 6, 2014.

[iii] Smith, *Ways of Making and Knowing*, Dust-cover. ditto questions above

[iv] Smith, *From Lived Experience to the Written Word: Reconstructing Practical Knowledge in the Early Modern World* (Chicago: The University of Chicago Press, 2022).

[v] Smith, slides from National Gallery of Art lecture.

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[vi] Delger Erdenasanaa. "Ocean Heat Has Shattered Records for More Than a Year. What's Happening?" *The New York Times*, April 10, 2024, https://www.nytimes.com/2024/04/10/climate/ocean-heat-records.html (accessed May 1, 2024).

[vii] The discovery of hyperbolic geometry opened the door to a wider exploration of geometric possibility and led Bernard Riemann to develop a generalized description of geometric surfaces or "manifolds." This Riemannian geometry underlies the general theory of relativity that describes the curving structure of space-time.

[viii] Margaret Wertheim, *A Field Guide to Hyperbolic Space* (Los Angeles: Institute for Figuring Press, 2005).

[ix] Daina Taimina created her first hyperbolic crochet model in 1993, inspired by a paper model created by William Thurston. Thurston's model was difficult to make and hard to manipulate; Taimina realized she could generate the same effect with yarn, making for a pliable, manipulatable surface.

[x] Taimina, *Crocheting Adventures with Hyperbolic Planes: Tactile Mathematics, Art and Craft for all to Explore*, 2nd. ed. (Boca Raton, FL: CRC Press, 2018).

[xi] Jean-Marc Castéra, *Arabesques: Decorative Art in Morocco* (Courbevoie, France: ACR Edition, 1999).

[xii] Metin Arik, "Mathematical Mosaics, Islamic Art and Quasicrystals," talk given at Crystallography for the Next Generation conference, Hassan II Academy of Science and Technology, Rabat, Morocco, April 23, 2015, https://www.iycr2014.org/__data/assets/pdf_file/0016/111706/Session2_Arik.pdf (accessed May 22, 2024).

[xiii] Ron Eglash, *African Fractals: Modern Computing and Indigenous Design* (New Brunswick, NJ: Rutgers University Press, 1999).

[xiv] For example, Polynesian sand drawings, Celtic and Chinese knots, and Indian paisley.

[xv] I am indebted to *Crochet Coral Reef* contributor Sarah Simons from the Center for Land Use Interpretation for these images of doily patterns from old crochet pattern books.

[xvi] Albert Atkin, *Pierce's Theory of Signs*, in Edward N. Zalta and Uri Nodelman, eds.. The Stanford Encyclopedia of Philosophy, 2010.

[xvii] *Value and Transformation of Corals: Christine and Margaret Wertheim*, exh. cat. (Baden-Baden, Germany: Museum Frieder Burda; and Cologne: Wienand Verlag, 2022).