Cryptographic City

Decoding the Smart Metropolis

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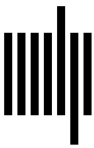

The MIT Press

5 A Thousand Insides

Aspects of the cryptographic city are hidden from view, with wild and untamed depths. The cyber wilderness is also dark and deep. "Welcome to the Dark Net, a wilderness where wars are fought and hackers roam," wrote security advocate William Langewiesche.[1] Notably, this cyber wilderness is of uncertain extent: "The deep web is deep because it cannot be accessed through ordinary search engines. Its size is uncertain, but it is believed to be larger than the surface net above it."[2] Digital portals such as Tor (The Onion Router; see torproject.org) allow you to "browse privately" and "explore freely" via multilayered encryption and "thousands of volunteer-run servers known as Tor relays."[3] The Tor Browser promises that no one can track your online activity or identify your location as you access online resources, including via anonymous peer-to-peer (P2P) networks. Computer users can transmit large files P2P, including pirated software and media, and do so undetected—hence the underground black market connotations, especially if cryptocurrencies are involved.

The dark web is also a site of imagining particularly for those who have not entered its portals. Inventive minds fill voids and uncharted spaces. In his book *Imaginary Cities* Darran Anderson observes: "When faced with the blank space on the map, we turn to the fantastical."[4] He's referring to the maps of early explorers. Imaginative storytellers filled in those parts beyond the reach of their surveys with peculiar inhabitants, ghosts, monsters, and unlikely riches. To early imaginaries, cities that were off the map were places "where the inhabitants are perpetually drunk, where men eat birds and ride around on stags, where marriages are arranged between ghosts, and the lord in his marble palace drinks wine from levitating goblets."[5]

The subterranean parts of cities have similar blank spaces filled in by speculative invention. That explains in part our curiosity about life

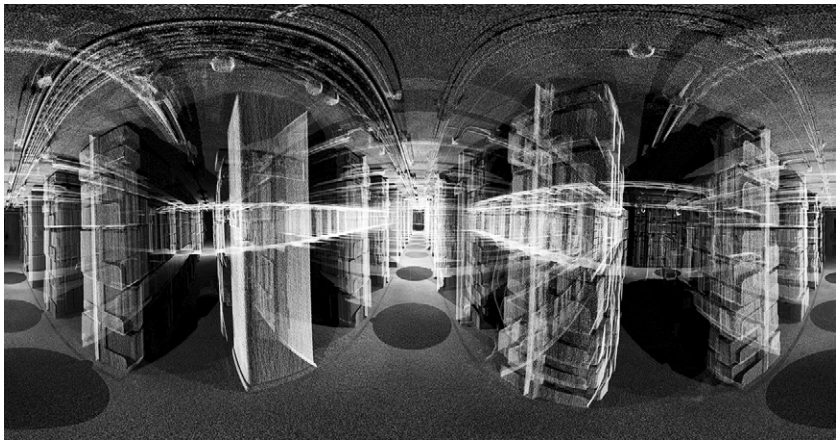

Figure 5.1
LiDAR scan of basement book stacks and services at the National Library of Scotland. *Source:* Asad Khan, https://www.theentropyproject.com.

underground, as identified by Paul Dobraszczyk, Carlos López Galviz, and Bradley Garrett in their book *Global Undergrounds*. Having worked the surface, urban scholars turn to mining the depths, invoking terms such as a *vertical turn* and "the politics of subterranea."[6] It is easy to associate such spaces with crime. After all, that's where you can move about undetected from the surface. Geoff Manaugh observes this in the case of burglary: "The world is riddled with shortcuts and secret passages—we just have to find them. It is a crime, but it also symbolizes that there are ways of navigating the world that we ourselves have yet to discover."[7] Such underground haunts can in fact be prosaic places. Old and new cities have underground garages, cellars, tunnels, storage (figure 5.1) passageways, services, and communication systems, many of which are unused and obsolete.

I live in a street with a fifteen-meter-deep tunnel that for twenty-one years had a rail and cable system for hauling goods and passengers along its 1:27 gradient. When the cable system became obsolete, the tunnel was repurposed as an air raid shelter, and later as a mushroom farm. It is now sealed off. What's down below is difficult to see by peering through the substantial iron grille at its lower end. It is a hazardous place, and local authorities restrict access. The invisibility of underground facilities contributes to people's fascination with such hidden places. This particular tunnel

features in a novel by Alexander McCall Smith who expands the underground network to nonexistent side tunnels and access points to coal cellars and buildings across the city.[8]

Paulsay Dobraszczyk and colleagues write about the underground parts of the English city of Nottingham in similar fantastical terms: "Nottingham sits above a burrower's fantasy: labyrinths within labyrinths of private artificial caves carved from the region's sandstone. Stairways in the backs of pubs, old cellars below houses, the lower reaches of shopping centres and car parks—all butt up against this hidden world."[9] Even if it weren't true, according to Anderson, "all great imaginary cities merge the matter-of-fact with the surreal."[10] We would want to believe in the city's underground passageways whatever the reality.

In chapter 1 I aligned the architectural crypt with cryptography as a major touchpoint in the cryptographic city. Novelists and filmmakers invoke the underground to explore the unknown. I recall episode 3, season 8 of *Game of Thrones* called "The Long Night" (dir. Miguel Sapochnik, 2019). Those who couldn't fight or were too important to lose in battle were told to hide in the crypt of the capital for safety. Meanwhile those above ground battled the indomitable White Walkers and their army of the dead. You shouldn't hide in a crypt when the Night King, the leader of the White Walkers, marches on the city. As the Night King slowly raised his arms in the midst of battle those who just died in the battle—or those long dead in a crypt—rose up and continued the fight as his relentless zombie army.

People may fear what resides underground, but there's a primordial connection there. In his fictional history of Middle Eastern oil extraction, philosopher and novelist Reza Negarestani invites the reader to fear and revere what's underground: "Ungrounded and unreported histories of the Earth are full of passages, vents and soft tunnels mobilized and unlocked through participations with the Earth as a compositional entity. These histories are engineered by openings and that which crawls within them; every movement in these passages invigorates the ungrounding of the earth, engineering what makes Earth, Earth."[11] Such autochthonous references connect the underground with earth, origins, and life.

Crawling, oozing materials and creatures and protohuman troglodytes live underground. They become disgusting when they move above ground as if matter out of place.[12] In a collection of short stories gathered under the title *Labyrinths*, the novelist Jorge Luis Borges (1899–1986) described

such an encounter: "In the sand there were shallow pits; from these miserable holes (and from the niches) naked, gray-skinned, scraggly bearded men emerged. I thought I recognized them: they belonged to the bestial breed of the troglodytes, who infest the shores of the Arabian Gulf and the caverns of Ethiopia; I was not amazed that they could not speak and that they devoured serpents."[13]

Urban Labyrinth

Such underground spaces are not just voids and caverns, but also passageways with indeterminate connectivity. The labyrinth provides an appropriate architectural type with which to characterize underground places—invoking branched and looping passageways, dead-ends, losing your way, navigating hazards and with no external clues as to where you are or the scope and scale of the network. In chapter 1 I mentioned the labyrinth as a motif for secret societies, and a motif of cryptography.

As I will elaborate later in this chapter, the format of the labyrinth correlates with procedures for solving puzzles, including in video games and some of the computerized processes in the cryptographic city and in codebreaking. The philosopher and fiction writer Umberto Eco thinks that detective stories are like a labyrinth.[14] I would add, so is the challenge of trying out combinations on a lock, hacking, codebreaking, breaking and entering, as well as instituting and defying security systems. A labyrinth is also a means of organizing and reorganizing space.

Retractable queue barriers funnel tightly packed airport passengers in twisted but orderly lines. These security labyrinths manage large numbers of people within a confined space. They also keep people on the move, and unceremoniously herd compliant travelers into conformity. Under social distancing measures during the pandemic, these processionals became even more common as people queued to enter airport departure areas, museums, and supermarkets.

Umberto Eco identified three types of labyrinths. The most complicated type is *rhizomic*.[15] You get caught in loops. Eco refers to sets of complicated interconnecting passageways "where every path can be connected with every other one. It has no center, no periphery, no exit, because it is potentially infinite."[16] I think Eco means that the rhizomic labyrinth is the world as lived. You could think of a traditional market, a *souq*, in that way—the

common trope of the bazaar as organic, changing, multilevel, unplanned.[17] A tourist gets lost in the souq (and even wants to) to savor its sights, sounds, smells, and confusions—and to experience a kind of ludic vertigo.

Navigating the rhizomic labyrinth's twists and turns requires detective work. As a writer of mystery fiction, Eco gravitated toward the detective story as a labyrinth. The world in which the detective operates "can be structured but is never structured definitively."[18] Who among us is not at some stage a detective: sifting evidence, interpreting, and exercising indirect, abstruse, and abductive inference within a confusing landscape.

Eco's second type of labyrinth has junctions along the route where you have to make choices. There are dead-ends, and you may have to backtrack. Navigating such a labyrinth requires trial and error. Sometimes the routes through cities and shopping plazas are like that, especially for the tourist or infrequent visitor.

For Eco, the third and simplest labyrinth is the kind that has a center, and a single, convoluted path leads eventually to it. The traveler may be confused and lose orientation, but you can't get lost there. A security maze at an airport is like that. Technically, it is a *unicursal* maze. The traditional unicursal maze has no forking paths but leads inevitably through a series of turns to its center.

Labyrinths exist underground but also as drawings or patterns in tiling. As a drawing or ornamental pattern, you imagine the lines are walls and trace your finger along the path. You eventually arrive at the center through a series of left and right turns. There's just one path through the intestines of this maze structure. An illustrator designing a maze for a child's puzzle book will start by drawing out a single path with twists and turns from the start to the finish—center or goal—perhaps laid over an organizing grid. Once that route is established then it's only necessary to add alternative paths, dead-ends, and looping paths to make it more difficult for readers to trace their way from start to finish. Mazes start unicursally, at least in their conception.

Nigel Pennick's seminal book on mazes and labyrinths provides a detailed compendium of major examples throughout history and their attendant derivations, narratives, myths, and theories.[19] According to Pennick, some traditions treated the labyrinthine path as a metaphor for life—from perdition to salvation: life's goal seems within your grasp only to be lost and found again along the journey. The unicursal maze's path as traced takes you close to the center, and then further away, only to return eventually to

the center. The path also serves as an image of the universe or macrocosm, in particular the movement of the sun as it passes over the four-cornered earth. The sun rises somewhere in the east and sets in the west, but it drifts over the months and seasons in a kind of spiral pattern, particularly pronounced in northern (or southern) latitudes. The maze traces this spiral motion as you follow it, but also as you try to draw the maze.

The unicursal maze provides a simplified diagram of this movement. You start with a square aligned notionally with the points on the compass. You draw arcs connecting points on either side of the square, but asymmetrically. Both the drawing of the maze and its traversal follow this kind of back-and-forth spiral path. In figure 5.2 I show the derivation of the unicursal maze with its origin in the ordinal cross and the four-square grid

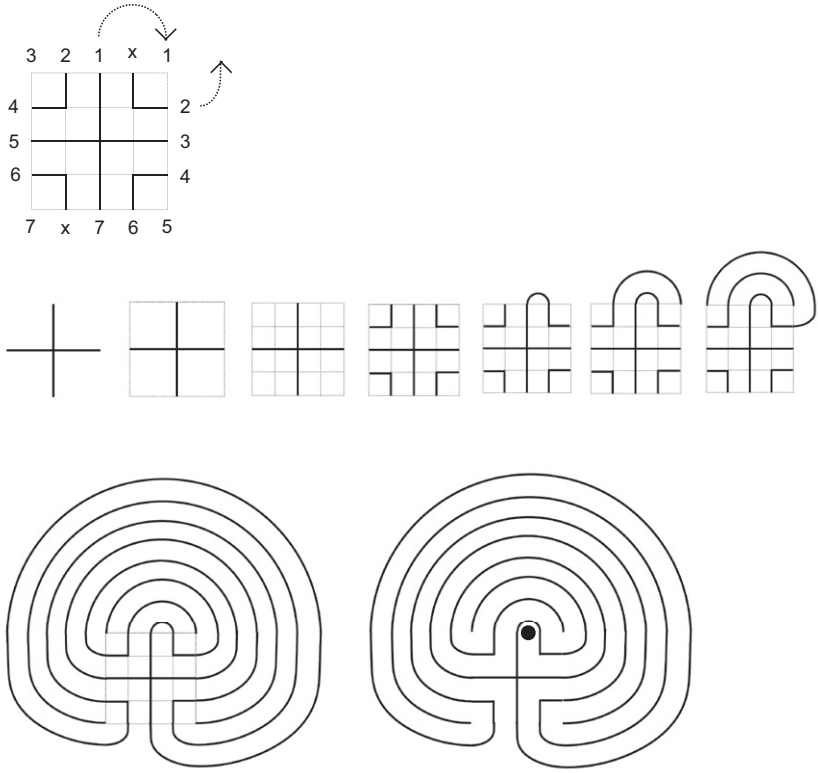

Figure 5.2
Derivation of the unicursal maze with its origin in the ordinal cross and the four-square grid (double tetractys). *Source:* Author.

(double tetractys). Pennick does not emphasize the grid in his derivation diagram,[20] but I think it makes sense to relate the narrative to Vitruvius's account of the layout of the Roman city. Each of the turns that make this a maze occur at the grid.

If you move your body along the path of the maze as a pattern on the ground, either inside a building, outside it, or under it, you are likely to feel dizzy. Hence, the maze is associated with a disordered state—vertigo. So far, I have used the terms *labyrinth* and *maze* interchangeably, and the OED gives them the same meaning. But *maze* is a North Germanic and Scandinavian variant of *mase*, which captures this idea of disorientation: "exhausting labour, nagging, . . . whim, fancy, idle chatter, . . . trouble, bother, . . . to bustle, fuss about, strive, slave away, reiterate, pester, beg, . . . to wear oneself out, . . . to toil, to idle, dawdle, . . . to bask, sun oneself."

My university installed a unicursal labyrinth of paving and gravel in a public park in the middle of the university grounds. It is more complicated than the maze in figure 5.2. During the pandemic lockdown period we were allowed to meet with students outside. I led a column of eighteen students on an impromptu walk tracing the route of the labyrinth. Without theoretical exposition, the most common student banter related to the repetitive and lengthy nature of the journey, and to feeling dizzy. As part of a column of people snaking along the winding path it was apparent that we oscillated into the center and out again until eventually settling on the center. There are no walls to this kind of labyrinth. The character of this space-filling movement had no function other than as a route for exercise and contemplation.

In English, to be amazed is to be bewildered, astonished, perplexed. So, the term *maze* is often associated with a puzzle, involving forking paths, but it also implies exhaustion from the labor and frustration of traversing the length of the path and negotiating all those turns. To reiterate, it is a state that can usefully be described as *vertigo*—a symptom of spinning your body around. In the words of Roger Caillois writing about play and games, such dizziness seeks "to momentarily destroy the stability of perception and inflict a kind of voluptuous panic upon an otherwise lucid mind."[21]

According to Pennick, some traditional dance moves follow the pattern of the unicursal maze, as if to amplify the vertigo effect, and to release the apparent chaos of the heavens. As I've indicated, the traditional unicursal maze structure has the square at its center with tightly packed passageways

in concentric rings around that. The concentric rings' maze structure provides a means of relating the fourfold construction of the microcosm, the earth, to the seven planets of the pre-Copernican universe, the seven notes of the octave, and the seven levels of heaven. After all, the method of maze construction delivers seven concentric arcs or circuits. According to another tradition, the center of the labyrinth would be occupied by a young maiden. Any suitor that could navigate the dizzying curves of the labyrinth without stepping off the path would be worthy of the ultimate face-to-face encounter.

To summarize, the maze is a potent metaphor for urban experience. It touches on some of the mythic origins of cities, the significance of the city center, the confusion of winding streets and lanes in old town centers, and the disorientation of encountering a place for the first time. It also contributes to a town's defenses, leading us closer to the purpose and practice of cryptography.

Maze Security

Like the code of a combination lock, the maze also served as a means of confounding access, as a rudimentary security system. The famous maze of Knossos was reputedly such a maze, impeding access to the mythical Minotaur and keeping the beast locked in. In any case, the winding paths would confuse entry and exit. For Pennick, according to this theory, the maze "is a means to arrest an intruder by means of confusion, whilst simultaneously it protects the centre from penetration by any intruder."[22] If there is a tower or summit at the center, then invaders are in full view while traversing the walled maze. They are vulnerable to archers or gunfire. The center also provides a rewarding overview outside the confusion and entrapment of the maze's pathways. The center realizes the aha moment of prospect and clarity, the reward for the tortuous journey required to get there. This unicursal maze has many variants, though it still retains a place as the model of all mazes. It turns up in ancient ornaments, coinage, graffiti, tiling, arrangements of stones, and in paving, as well as built structures and hedged gardens, not to mention secret society symbols and rituals as in Freemasonry. As a link back to the opening sentences in this chapter about a dark wilderness, the maze as an adjunct to a traditional formal garden would be called a *wilderness*, referencing the untamed, unknown, and hostile.

Returning to cities and their codes, as I've shown, the maze derives from the grid and is not so far removed from the contemporary city, its structures, twists, and security systems. We can think of the world as a labyrinth, but it's rare for clients to commission architects, landscape architects, engineers, and others to deliberately create spaces as labyrinths. For most purposes, actual labyrinths are monofunctional and highly inefficient when put to practical uses. They are all threshold, all circulation, at their best with nooks, statuary, benches, and landmarks along the way. They do not provide functional articulation, in other words, rooms with particular purposes. The nesting of passageways prevents views out, or daylight coming in except from above. They slow down transition and require you to negotiate space in a convoluted back-and-forth or circular manner. They obscure and confound navigation. But architects do incorporate lessons from the labyrinth, reference them, and respond to them.[23] The labyrinth serves as an extreme case of the city as system, where circulation takes over. It serves as a metaphor for the city, its infrastructures and communication networks, a theme requiring further investigation.

Cryptopolis

Let us return to the theme of the dark web with which I began this chapter. The idea of the labyrinth conjures up an internal and even a biological space. Elements that belong inside but appear on the outside strike us as grotesque, prime examples of what anthropologist Mary Douglas calls "matter out of place" that contribute to the sense of disgust.[24] Any butcher or spectator of a dissevered corpse would recognize the inner organic world of passages and tubes.[25]

The Persian word for labyrinth is *hezar'to* that translates as "a thousand insides."[26] The urban scholar Somaiyeh Falahat explores the implications of hezar'to as a potent metaphor of the city.[27] Reexamining some of the mazes I described, they appear as nested rooms within rooms—seven in the case of the classical unicursal maze. The passages as drawn resemble entrails—internal organs. Think of these insides as also inside the earth—a multiplicity of interiorities, a proposition that further informs cities and their networks.

Labyrinths occur most frequently under cities. I need hardly repeat the connection between cryptography and the underground crypt in a church

or castle (a hidden place) that houses the dead. Architects have certainly paid attention to memorials, monuments, tombs, vaults, mausoleums, and necropolises. The latter are simply cemeteries, though the term *necropolis*, or *nekropolis*, has come to mean something close to an abandoned and ruined city. *Nekropolis* is the final stage in the decline of a city, according to Lewis Mumford, where: "War and famine and disease rack both city and countryside. The physical towns become mere shells."[28]

As reported by Negarestani, the contemporary Iranian architect Mehrdad Iravanian extended the nekropolitan theme. He said, "In order to study architecture, one must first investigate necrocracy."[29] *Necropolis* is in the OED; but *necrocracy* is not. It implies a system of governance where people are ruled by someone who is dead, or perhaps indirectly in a city where people venerate the dead. Such ancestor worship is common enough in autocracies where the dead founder is represented in portraiture or statuary or embalmed in a crypt to inspire pilgrims. The book in which Negarestani quotes this is infused with themes of death. I have referred to his book a few times. He titled it *Cyclonopedia: Complicity with Anonymous Materials*, which among its other characteristics forms an unrelenting compendium, or unstructured encyclopedia of cryptic neologisms.

Negarestani's book is a work of fiction[30] and refers explicitly to code systems, ancient and modern, involving numerals, cuneiform and Arabic script, and geometrical diagrams. It also plays on themes of the crypt, with portmanteau terms such as *cryptogenic*, *crypto-fractal*, *cryptomilitary*, *crypting*, *decrypting*, *cryptological*, *crypto-nihilist*, *cryptospores*, *crypto-vermiform*, *crypto-bureaucratic*, and *cryptic outsidedness*. Cryptography stalks the pages of such literary and urban imaginaries.

Surveil, Ground, Return, and Recur

I have suggested that the maze serves as a metaphor for the city. Visitors lose themselves in the city's streets, corridors, and communication systems. Cities give the appearance of regularity, symmetry, and order, at least as viewed on a map. In his description of cities and places, Borges affirmed that a maze is a house "prodigal in symmetries,"[31] which I take to mean a surplus of symmetries. Probe deeper and you find the city underlaid and permeated by networks, circuits, dead-ends, and short circuits. The best mazes appear ordered and regular from the outside, with slight

twists and deviations that deliver the maze's contiguous tortuous space-filling pathways.

There are many similarities between cities and mazes. Here are some other threads connecting them that is relevant to a city's defenses. First is surveillance. The unicursal labyrinth has a center. Following the model of the city as a fort on a hill, that center provides a vantage point. The labyrinth presents as an instrument of surveillance and control. Unlike that leitmotif of the surveillance society, the circular panopticon,[32] the labyrinth assumes movement by those under the gaze of the central tower. In a labyrinth, those under surveillance are not passive but approach the tower, the center. The tower assumes a defensive position. Under this spatial power structure, the journey represents an ascent to a position of control and advantage. By emphasizing movement, the maze metaphor varies the idea of the surveillance society and the city as a site of surveillance. We are being watched while on the move. The all-seeing eye tracks our movements.

The labyrinth in some respects makes maximum use of its enclosing spaces. All of the space is occupied by its passageways. The center of the maze is like the top of a hill. That's where you are rewarded with a view. The center provides the aha moment, where confusion gives way to clarity; enclosure gives way to prospect.

Second, the maze accords with strategies to position the city, any city and its elements, in a relationship with both the heavens and the earth. The classical unicursal maze is derived from the basic architectural grid. In so far as the city is a maze, it participates in ancient legacies relating the city to the microcosm and the macrocosm as I've indicated.

Borges conflated the maze and a residence in a fanciful description in his short story "The Aleph": "In the palace that I imperfectly explored, the architecture had no purpose. There were corridors that led nowhere, unreachably high windows, grandly dramatic doors that opened onto monklike cells or empty shafts, incredible upside-down staircases with upside-down treads and balustrades."[33] Borges echoes this paradoxical thesis in relation to his infinite, labyrinthine Library of Babel: "The Library is a sphere whose exact center is any one of its hexagons and whose circumference is inaccessible."[34] And by library he means "the universe."[35]

Third, the maze speaks to the theme of excursion and return, the practice of the pilgrim, traveler and tourist entering into and departing from the city. A unicursal maze extends the journey from the edge to the center

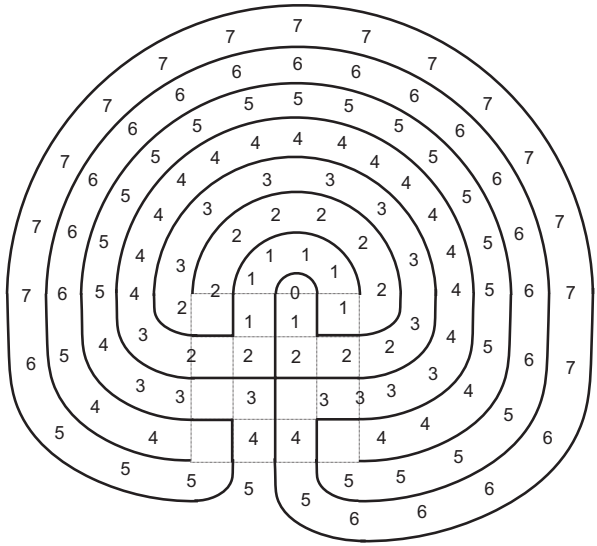

Figure 5.3
Circuits to the center through the maze numbered as steps. *Source:* Author.

in a way that brings you closer at times and then moves you further away. Without that characteristic, the path may as well follow an ascending spiral, which can also be derived from the originary grid—but a spiral is not a maze. The near and far, to-and-fro movement of the classical unicursal maze contributes to the character of the maze journey. For some traditions this movement toward and away from the goal models aspects of life's journey, or any aspirational, hopeful, or dreaded goal-directed experience.[36] Figure 5.3 shows progress around the unicursal maze. The numbers indicate distance in terms of rings from the center. The graph in figure 5.4 shows the journey as an ever-diminishing oscillation toward the center.[37]

Think of the security maze at a crowded airport or the line of students following the university's landscape maze: the encounter and re-encounter with others in line as you loop back and forth toward the goal. Such inadvertent encounters with others are a feature of any maze journey as circulation routes, and people, brush against each other. That reflects the casual and occasional sociability of the city.

Fourth, to elaborate on the idea of a city as a series of nested containers, the cryptographic city is also a *recursive* city. Recursion simply means return. So, a recursive city could be a city that you return to, or that encourages or

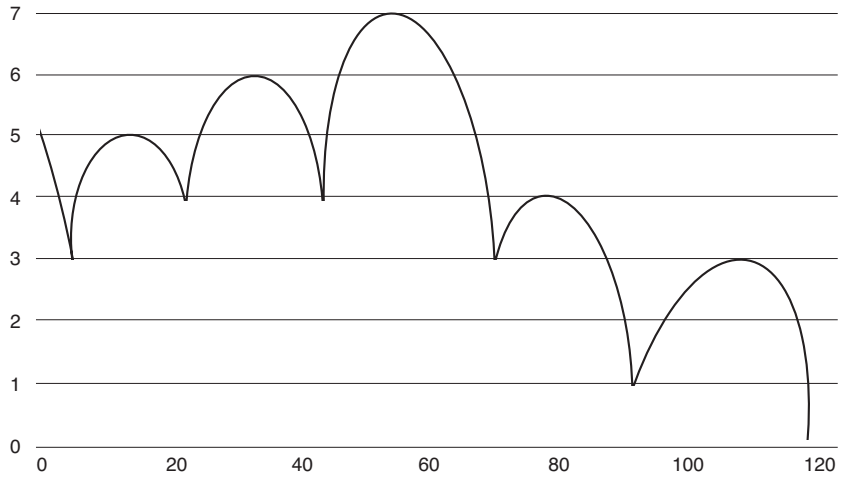

Figure 5.4
Graph of circuit numbers at each step in the progress to the center of the maze showing the to-and-fro movement. The x-axis shows steps on the journey. The y-axis shows the notional distance from the center. *Source:* Author.

requires you to keep coming back—like your hometown or a site of pilgrimage. The metaphor of near and far, of excursion and return applies in many city contexts. Where there is repetition, it's likely there's also recursion—a series of returns. The return may be to a different component that you treat the same as the whole, or the same but at a different scale—for example, a neighborhood grid sits within a district grid that is within a city grid. Recursion applies to geometry, shapes, forms, and arrangements in space, as well as rhythms, sounds, and music. So, the physical aspects of a city fall under the influence not only of repetition, but also of recursion.

In their 2007 book chapter "Imagining the Recursive City" Michael Batty and Andrew Hudson-Smith explain how we can think of the city in terms of recursive structures: "In cities for example, evidence of recursion might be seen in the physical patterns of its development where certain modules repeat themselves in different places, at different times, evidence enough of similar processes at work."[38] They also maintain that recursion shows up in social activity and behavioral patterns: "The way populations in cities behave in space and time, the way individuals, groups, institutions organize their activities, the way economic and social functions determine modes of living and work can all show evidence of such patterning."[39]

In summary, the metaphor of the city as a maze addresses surveillance, positioning within the cosmos, the to-and-fro nature of urban experience, and recursion—the city as a "thousand insides."

Unraveling the City

I find recursion helpful to understanding navigation through a maze, and through the city. It also helps in further understanding the cryptographic dimensions of the city. I have already alluded to navigating city streets as finding your way through a maze.

Douglas Hofstadter and Daniel Dennett's famous 1979 book *Gödel, Escher, Bach: An Eternal Golden Braid* provided a source of fascination for early generations of coders, design theorists, and composers. The authors made much of the cognitive significance, if not paradoxes, of recursion. Think of the M. C. Escher drawing of a hand drawing a hand drawing itself: "The concept is very general. (Stories inside stories, movies inside movies, paintings inside paintings, Russian dolls inside Russian dolls (even parenthetical comments inside parenthetical comments!)–these are just a few of the charms of recursion.)"[40]

Recursion has a precise meaning to mathematicians and computer programmers. There are routines that repeat a procedure over and over, perhaps with variation. That is *iteration*. Hence, a looped routine will draw a series of rectangles to replicate a city grid on a display screen. Recursion is more cunning than iteration. It allows the programmer to define a procedure in terms of the procedure itself. Recursion is particularly useful in algorithms that do navigation and search. Thanks to navigation apps like Google Maps, we take for granted the hidden procedures that find the best route by car from Arbroath to Hampton Court.

Here is a human example of recursion in navigation. Sometimes when someone asks for directions to the railway station, it's helpful to say, "Go to the end of this street, then ask someone there for directions." You are saying: "Go to point A, which is on the network of possible points on the way, and apply the same procedure you did here, which was to ask someone." To get to where you are going, you need to do what you are doing now. More precisely, to go from A to B, select from a set of nodes adjacent to A in the network and go from there. A computer program doesn't usually need to ask for directions but will have a coded form of the city network at

its disposal and the recursive definition will search all the possible connections to find the most direct route, recursively.

Most computer programming languages of any power support recursion. Some specialized platforms such as Prolog and Lisp are structured around the idea of recursion. They are designed to keep track of nodes and pathways and are able to backtrack on dead-ends or abortive loops. Hofstadter and Dennett philosophize around such processes in a section of their book they call "Pushing, Popping, and Stacks."[41]

With deeply nested recursion it's hard to get back on track. You can get lost in the city, but also lost while telling a story or writing a book. People tell stories and construct arguments with subplots and digressions. It is fine for stories to wander. But for coherence we expect the storyteller to return to the main point, to rewind the string they just unraveled back into a neat ball, which is the challenge I'm presented with in this chapter, to bring the narrative back to cryptography.

As a digression within a nest of digressions it's interesting to recall that the anonymous Tor Browser as mentioned previously stands for "The onion router" as its relay nodes serve "to encrypt and privatize your data, layer by layer—like an onion"[42] as a series of nested parentheses.

Hofstadter and Dennett write about stories as nested digressions.[43] In a friendly conversation, consultation, or interview the interlocutors may help one another get back on topic by attempting to close off each other's various trailing brackets, or of the progress of the entire conversation. It gets complicated. If the nested parentheticals go too deep then it's hard for both the speaker and the listener to recover, to return to the top or outer-level bracket: nested stories bracketed within stories—as "a thousand insides." Hofstadter and Dennett understand such stories as stacks: "the terms 'push', 'pop', and 'stack' all come from the visual image of cafeteria trays in a stack. There is usually some sort of spring underneath which tends to keep the topmost tray at a constant height, more or less. So when you push a tray onto the stack, it sinks a little-and when you remove a tray from the stack, the stack pops up a little."[44] The customer can only take the top tray.

Stacks are not unique to cafeterias. My browser software maintains a stack of interlinked websites I've visited. Hitting the return arrow button takes me back down the stack. The undo function on most text- and image-processing apps does something similar. A stack is a way for the software to keep track of a series of nested (recursive) computer events.

As I will examine in chapter 7, the stack provides a way of explaining how data gets chained together in the cryptographic "blockchain" as a process in securely transacting digital money. The stack is also a useful metaphor for understanding the spatial organization of cities. Builders stack elements on top of one another, like bricks stored on a construction site. You can't get to the bricks at the bottom of the stack until the bricks above are removed. Though less mobile, urban layers are stacked and accreted on top of one another over time, even down to archaeological strata. Such strata are not as neat as cafeteria trays. It is easy to undercut the order of a stack of bricks, or tunnel through the layers of a city—as it is to circumvent the bracketed elements of a narrative and leave them dangling (to mix metaphors). Precise, algorithmic stacks are the way that computer programs manage navigation through recursive algorithms. A stack is a data table that keeps track of the stages in a recursive process.

Many programming platforms use stack-like data structures to accommodate recursion, and hence provide the means of searching a problem space, such as the best route through the city, that is, exploring a tree of decision points, a branching labyrinth. In chapter 7 I will elaborate on the *blockchain* as a way of securing data, which is a table of data accreted in a stack-like way but is designed so that is impossible to "unstack."

In so far as cities exhibit recursion, they also display characteristics of the stack.[45] Stories are an essential part of our experience of the city. Each nested plot event provides a context for the one nested within it, which in turn informs the events outside the bracketed subnarrative. That accords with the leitmotif of excursion and return I've already mentioned that is popular in theories about play, tourism, and interpretation according to philosopher Joel Weinsheimer: "Essential to play is the freedom of movement to and fro, back and forth, up and down the field—the repeated circular movement of excursion and return that is under control of neither the individual players nor referees but belongs to the playing of the game."[46]

The cryptographic city is recursive, meaning it is a place that invites return—through travel, narration, recollection, and imagination. But the return is never a simple algorithmic return, as in a recursive algorithm. The traveler is transformed in the process, and the city is transformed, like the meanings accrued by nested parentheticals in an engaging story or coherent speech. To simplify, if a city is a labyrinth in its patterns, stories, and recursive processes, then it is also in part cryptographic.

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