CEREBRAL CITIES

In Christopher Nolan's 2001 film, *Memento*, a man who has lost the capacity for short-term memory has the basic facts of his story tattooed onto his body, his skin stretching the ink-stained blueprints of this memory palace. One curiosity of the film is that, despite remembering nothing else as he begins each day, this character somehow always knows where to go.

In that small logical lacuna lies a metaphor for the way we make our way in the world: less by a process of memory–a chain of remembered routes, places and directions–than by an instinctual drive present in all humans, even amnesiacs. Most of us live our daily lives without recourse to a map. Even those who are "bad with directions" know the particulars of their environs. We internalize the map; the map is us. But a map is a crude, even incorrect, analogy for understanding how we interpret and remember space, since a map is just a story told by someone else. After all, any given space (Main Street, a shopping mall, France, the Western Hemisphere) could yield a million different maps.

I was walking on lower Broadway in Manhattan one day when a man asked me how to get to Ground Zero. I stopped to think for a moment. In its initial atomic test incarnation, Ground Zero was an epicenter from which measurement proceeded outward, as distance from the blast; since 9/11, the phrase has a reversed geographical imperative, serving as a site of pilgrimage. Certain streets in Tribeca on the way to the former World Trade Center flashed into my head, as did nearby subway stops and buildings that bordered the site. I even briefly pictured the site itself–the viewing platforms, the steel and concrete "pile" of the towers' remains. But I couldn't articulate exactly how to get there, the successive streets one would need to take. I knew where I was and where it was but in between was a blank space. So I simply pointed south and said, "just head down Broadway, and it will eventually be off to your right. Not far."

A month later, I was canoeing with the naturalist Mark "Bird" Westall in the J.N. Darling National Wildlife Refuge on Sanibel Island, off Florida's Gulf Coast. As we piloted down countless channels in the swamp–each a tangle of brackish water and mangrove roots exposed like gnarled hands–a fellow passenger asked Westall how he knew where he was going. "How do you know where you live?" he asked after a few seconds. "This is my backyard."

In both these examples, a person had formed an internal awareness of a familiar environment, but was unable to render that knowledge into anything resembling a map. Psychologists and geographers use the term "cognitive map" to describe "long-term stored information about the relative location of objects and phenomena in the every-day physical environment." But "map" may be too tidy a metaphor. Barbara Tversky, a professor of cognitive studies at Stanford University, has suggested that "cognitive collage" may be a more fitting phrase. "In wayfinding, memory and judgment," she argues, "we make use of a multitude of information, not just remembered experiences or remembered maps of environments."[1]

My inability to provide detailed directions to the World Trade Center site might have been a consequence of the simple fact that the towers are no longer there. During my lifetime in New York, they had served as a ready visual reference, an irrefutable sign-post for Downtown. Much as Roland Barthes remarked of the Eiffel Tower, the only way *not* to see the World Trade Center towers was to be inside them. I had yet to create a memorable narrative of how to reach the abstracted site where the towers formerly stood.

Something else might also have been at work. Tim McNamara, a professor of cognitive psychology at Vanderbilt University, has conducted several studies of how people remember and interpret spatial relations among objects in their environment, and use that information to navigate. When asked to estimate the distance from a recognized landmark to another, more anonymous, building, and then vice versa, research subjects tend to estimate a smaller distance in the first case than in the second. McNamara accounts for this asymmetry with what he calls a "contextual scaling model":

> When people retrieve the location of the buildings, they activate in long-term memory what they know about that memory and what the neighboring buildings are in the space or on the map. A landmark activates a larger context—more things come to mind—and the actual space, the distance of the other objects that come to mind from that landmark, is greater than when they first think of a non-landmark.[2]

Just as our imaginary cognitive maps are subject to these asymmetries, so too is the most rigorous cartography subject to corruption by our perceptions of it. Given a choice between a world map showing North America incorrectly aligned with Europe, and a map that shows the true layout of the continents, respondents tend to choose the incorrect, symmetrical version. In a landmark 1956 study titled "The Graduated Circle: A Description, Analysis, and Evaluation of a Quantitative Map Symbol,"[3] the geographer J. J. Flannery noted that map readers consistently underestimated the size of circular depictions of urban areas—a typical cartographic

Barbara Tversky, "Structures of Mental Spaces: How People Think About Spaces." *Environment and Behavior*. Volume 35, issue no. 1. Pp. 66–80.

Telephone conversation with author, 2003.

James J. Flannery, "The Graduated Circle: A Description, Analysis and Evaluation of a Quantitative Map Symbol." Ph.D. thesis, University of Wisconsin, 1956.

method of indicating city populations. Flannery's findings led to a change in standard cartography, such that the radii of graduated circles were scaled to 0.57 times the logarithm of their purported quantity—so as to compensate for the inherent distortion.

This speaks to the arbitrariness of mapping in general, since there is no correct size for a circle or dot on a map (and probably no standard amount by which such circles are underestimated); the marks on a map are just generalized abstractions, approximate ways of understanding the world. As a child, taking long car trips through the western states of America, I often imagined there would be "lines" when we crossed state boundaries, just as there are on a map. This might seem fanciful, but I'd suggest that much of our sense of large-scale spaces is conditioned by cartographic interpretation.

Maps are informed by our experience, location and condition. My personal map of New York (being based in Brooklyn) would probably be quite different from that of someone living in Washington Heights. Though today this observation may seem blandly intuitive, it was novel stuff in 1960 when the geographer Kevin Lynch wrote, in his now-classic book, *The Image of the City*:

> The creation of the environmental image is a two-way process between observer and observed. What he sees is based on exterior form, but how he interprets and organizes this, and how he directs his attention, in its turn affects what he sees. The human organism is highly adaptable and flexible, and different groups may have widely different images of the same outer reality.[4]

Lynch's argument was informed by the groundbreaking work of University of California psychologist Edward Chance Tolman, originator of the cognitive map theory. In his 1948 paper, "Cognitive Maps in Rats and Men," Tolman proposed that rats who were able to find food in a maze weren't simply reacting to a conditioned behavioral stimulus (e.g. "turn right for food"), but had generated a cognitive map of the overall environmental field.[5] Thus, when they began from a different starting point, they didn't simply "turn right" for the usual treat, but were able to "turn left," having generated an internal image of the entire maze.

"Despite a few remaining puzzles, it now seems unlikely there is any mystic 'instinct' of wayfinding," Lynch wrote in *The Image of the City*. "Rather it is a consistent use and organization of definite sensory cues from the external environment."[6]

Even with Lynch's insights, a vast puzzle remained: what is it that occurs in the internal environment when we find our way through the external environment? After all, maps and routes don't exist in themselves; they are simply projections onto a landscape that is, in itself, utterly abstract. The solution to this puzzle required

4. Kevin Lynch, *The Image of the City*. Cambridge: The MIT Press, 1960. p. 131.

5. Edward Tolman, "Cognitive Maps in Rats and Men," *Psychological Review*, 55, 1948. pp. 189–208.

6. Lynch, *op cit*, p. 3.

7. David \ Univer: Louis r 2002.

a technology not yet available in the early 1960s: a means of mapping the cognitive mapping apparatus itself.

Our man in *Memento*—our bleeder of memories—cannot remember people he met the day before, yet seems to possess intact some cognitive map of the larger environment in which he moves. He is said to suffer from anterograde amnesia, an extremely rare condition that prevents formation of short-term memory, but leaves memories formed before the damage and "procedural memory" (the ability to learn new skills) unimpaired. When the motel manager changes the narrator's room, he is unaware that he has been moved. But how does he even know how to get to the motel in the first place? Of all the memories tattooed onto his body, none are maps; we can only assume he knows this landscape intimately from his life before the accident. Without a map, navigation proceeds from memory: to move forward, one must look backwards. So how does our *Memento* hero remember where he is going? The answer, if there is one, lies in the mapping of another form of territory: the human brain.

The advancement of functional brain scanning techniques over the past decade has yielded vast troves of new information about how the brain undertakes processes such as memory and navigation. After decades of observing from above how rats and men move through mazes (as it were), the focus has shifted to studying what happens in the brain as one works one's way through a maze, or a city. The cartographic metaphor is frequently invoked as these brain atlases are generated. "Just as maps of the Earth locate continents, mountain ranges and nations," said one neurobiologist, "our cortical maps will show the locations of the brain's structures and functional subdivisions."[7]

Perhaps thanks to its somewhat topographical appearance—a wrinkled, hemispheric mass of contours and regions—mapmaking of the brain has a venerable history, dating back at least to Egyptian papyrus relics, of circa 2500 B.C. At the end of the 19th Century, experiments with electrical shocks and intentional brain lesions produced evidence that particular regions of the brain were associated with certain behaviors. Much as ancient navigators were granted namesake islands and continents, two areas of the brain are still named after the 19th-Century neurologists who discovered them, Pierre Broca and Carl Wernicke: respectively, the frontal lobe of the left hemisphere, and an area stretching across the back of the temporal lobe, bordering the parietal lobe. Both of these areas related to speech actions, though neither is anywhere near the speech areas identified by the preeminent phrenologist Franz Gall. Broca discovered his area in a patient who, having suffered a stroke, couldn't speak, but was otherwise normal. After the patient's death, an autopsy revealed a massive lesion in what became known as "Broca's area." In 1957, a pair of neurologists noted the case of H.M., a patient who had received bilateral lesions of a section of his brain to relieve severe epilepsy. After the procedure, H.M. found

7 David Van Essen, quoted in University of Washington at St. Louis news release, October 29, 2002.

he couldn't remember things that had happened since the surgery; he later compared his condition to being permanently in a state of having just been awakened. Much of the damage to H.M.'s brain involved the hippocampus, which, after more than a century of study, has been fully charted as the locus of memory and spatial navigation. (This is also the fate of our man in *Memento*, whose accident has led to some damage of the hippocampal region.)

Where neuroscience once relied on a procession of the maimed and the dead for insights into the brain's operations, now the penetrating but harmless incursions of PET and Magnetic Resonance Imaging (MRI) produce real-time pictures of brain function rather than brain failure. Like a heat-sensitive map showing human activity in a landscape, responses in the brain can be watched, live, via MRI as they play out in reaction to activities, emotions and conditions. And one of the endeavors brain mapping has begun to unpack in breathtaking detail is the process of mapping itself: how we move about in the world.

Behavioral psychologists have long noted gender differences in the process of wayfinding: women are generally said to rely on landmarks and things such as street names, while men employ geometric and distance cues. A study at the University of Ulm in Germany, led by Manfred Spitzer, investigated the neural underpinnings of this difference. Subjects wired to MRI scanners worked their way through a computer maze using buttons to navigate toward an unknown exit. Certain walls were color coded to serve as landmarks. In all subjects, as expected, the hippocampus—the presumed site of the cognitive map—was the general locus of MRI activity. But in men (who were generally faster at exiting the maze), increased activity in the left hippocampus was noted, while in females an increase was seen in the right parietal and right prefrontal cortex. Presenting their findings in the journal *Nature*, the researchers noted that "[T]his distinct functional anatomy of spatial cognition in women versus men may be related to differences in the processing of spatial information."[8]

But locating general regions in the brain that are activated in men or women as they undertake wayfinding has not answered the question of how we actually navigate. Russell Epstein and Nancy Kanwisher, researchers in the Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology, have documented a region within the parahippocampal cortex that showed more intensified brain activity when subjects viewed large-scale environments such as rooms, streets or landscapes than when they viewed images of objects or faces. Epstein and Kanwisher dubbed this the "parahippocampal place area" (PPA)—an area of the brain that lit up when a place was viewed.[9] What might the purpose of such an area be? Could it be a memory bank of sorts that matches a scene to a stored equivalent somewhere in the hippocampus? Apparently not: in subsequent experiments, the MIT researchers found no difference in

. Georg Grön, Arthur P. Wunderlich, Manfred Spitzer, Reinhard Tomczak, and Matthias W. Riepe, "Brain activation during human navigation: gender-different neural networks as substrate of performance." *Nature*, April 2000, 3:4, pp. 404–408.

. R. Epstein, A. Harris, D. Stanley and N. Kanwisher, "The parahippocampal place area: Recognition, Navigation, or Encoding?" *Neuron*, 23:1999, pp. 115–125.

10. *ibid.*, p. 12

11. Eleanor A. J. Frackow D. Frith, "F around Lo the Right Drivers." *Neuroscie* 1997, vol.

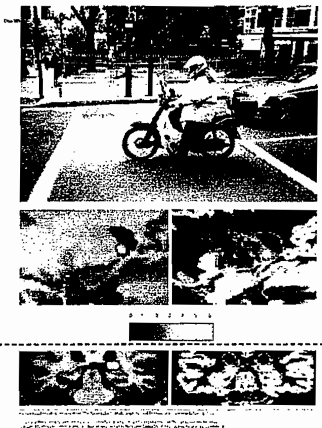
12. *ibid*, p. 71

subjects' responses to places they had previously seen as compared with places they had never seen. They were then shown photos of "places" and objects constructed from Lego blocks; although the former were clearly unreal places that could never have been visited, the subjects' responses were still higher to these faux Lego places than to the Lego objects.

The Lego experiment seemed to dispel the notion that the PPA might be a route-planning mechanism to places stored in the cognitive maps. As the researchers noted, "the lack of a familarity effect for scenes further demonstrates that the PPA is very unlikely to play a direct role in planning routes to distant locations, since one cannot plan routes from locations one does not know."[10] Was the PPA's function simply to encode new place information? This thesis seemed to yield the strongest results: brain activity was found to be higher in that region when subjects viewed a succession of novel place scenes, as opposed to viewing a series of identical scenes. In previous case studies of patients who had lost the ability to recognize places, damage was thought to have occurred in the general parahippocampal cortex. But the MIT study hinted that the problem might lie in a more specialized zone since, in these subjects, the PPA did not seem to serve any recognition function.

Perhaps this was mapping at its most fundamental: the simple processing of spatial information, all spaces being equal. Nomads excepted, this is not how most of us lead our lives. We inhabit places we know well, full of familiar scenes. Into what dusky regions of the brain does this spatial information settle? A landmark study of London taxi drivers undertaken by researchers at University College London's Wellcome Department of Cognitive Neurology revealed stunning insights into this process.[11]

Experienced taxi drivers who had fully grasped *The Knowledge* (as the encyclopedic memorization of London's street system is famously known) were asked to give the shortest route between two points without the aid of a map. Functional MRI mapping recorded their brain activity as they articulated the routes, and a surge in activity of the right hippocampus was observed. To determine whether this was an act of memory recall like any other, the taxi drivers were also asked to recall plot sequences of well known films they had seen. The researchers found that "the network of brain regions showing increased activation during semantic topographical memory retrieval are entirely different from those activated during non-topographical semantic memory."[12]



Territory maps

The taxi drivers were also asked to describe several famous landmarks outside London that they had never visited. This

10. *ibid.*, p. 121.

11. Eleanor A. Maguire, Richard S. J. Frackowiak, and Christopher D. Frith, "Recalling Routes around London: Activation of the Right Hippocampus in Taxi Drivers." *The Journal of Neuroscience*, September 15, 1997, vol. 17.

12. *ibid*, p. 7106.

triggered activity in many of the same brain regions as the recalling of routes (the occipitotemporal regions, posterior cingulate gyrus, medial parietal areas, and parahippocampal gyrus), leading the researchers to deduce that certain areas of the brain are primed for topographical information. One key difference was that the right hippocampus itself was only triggered *during* the route navigation.

These complex findings seem to refute the existence of a single cognitive map in humans. (When asked the way to Ground Zero, did my ability to recall landmarks supersede my large-scale spatial navigation capabilities?) A later study by the Wellcome researchers came to an even more striking conclusion. Structural MRIs of the brains of long-time London taxi drivers were compared with those of a non-taxi-driving control group. The researchers found that the volume of the posterior hippocampi of the taxi drivers was larger than in the control subjects, and that the discrepancy in volume correlated roughly to the time they had spent as taxi drivers. In other words, the brain showed "plasticity" in response to environmental stimulation: it had literally grown as the taxi drivers' knowledge of London's streets had grown. "Our results suggest that the 'mental map' of the city is stored in the posterior hippocampus and is accommodated by an increase in tissue volume,"[13] the Wellcome team reported. Having studied maps and learned routes once so assiduously in order to enter their trade, the taxi drivers had themselves been changed by *The Knowledge*. They were no longer reading maps; the maps had remade them. The city of London was more legible to them than it would be to the average person, but this was not due to some attribute of the city itself; rather, it was due to a physical change on the part of the taxi drivers themselves.

The Wellcome study raises the fascinating question of what structural MRIs might show for other urban navigators. How might they be different for the police officer concerned less with expedient routes than with a thematic geography informed by frequency of criminal behavior? Or for the homeless person, whose cognitive map is determined by the need to find a safe place to bed down for the night? How might they appear for the historic preservationist, to whom city streets present a wealth of architectural detail and historical narratives?

A walk down a street is usually more than just navigation; it is a trip through memories. In *Remembrance of Things Past*, Proust elegiacally suggested that our memories are themselves fused, as if overlays, onto some already existing place map:

> For even though our life be a roving one, our memory is sedentary and, no matter how ceaselessly we may rush about, our recollections, riveted to the places from which we tear ourselves away, continued to lead their stay-at-home existence there, like

13. Eleanor A. Maguire, David Gadian, Ingrid Johnsrude, Catriona Good, John Ashburner, Richard Frackowiak, and Christopher Frith, "Navigation-related structural change in the hippocampi of taxi drivers." *Proceedings of the National Academy of Sciences*, April 11, 2000, Vol. 97, no. 8, p. 4402.

14. Marcel Pro *Things Pa* Moncrieff Kilmartin. 1957, p. 3.

15. John McC Recall," *N* 2003, pp. 2

> the temporary friends a traveler makes in town and has to abandon when he leaves because it is there that they, who do not go away, will end their journey and their lives, as if he were still there, by the church, before the door, under the trees of the promenade.[14]

If streets are memories, it seems only appropriate that memories should inhabit place-like realms ("Memory Lane" turns out to be quite an apposite figure of speech). Eleanor Maguire of the Wellcome Institute articulated such a notion in another study of memory champions: winners of contests designed to test the ability to recall lists of things. They employed a mental walk technique, or created a memory palace (as described by the Greek poet Simonides in 477 B.C.), literally placing objects to be remembered in a route-like succession, or as a sequence of rooms in an imagined architectural space.

But MRI research has shown that these activities—despite their map-like nature and shared home in the brain—both involve quite different chains of activity and minute differences in brain geography, which are only just being theorized. Those who study memory no longer refer to simple filing cabinet metaphors in understanding how the brain transfers information from short-term memory to longer-term storage. New research suggests that the "retrieval" of memories is a dynamic process in which a memory itself is susceptible to change. In the process of memory reconsolidation (as it is called), memories are fluid things invoked to serve the present or in reaction to it. "The dogma was that once a memory trace has been consolidated, it is permanent," McGill University researcher Karim Nader told *New Scientist*. "But here it was pliable, subject to interference in exactly the same way as a brand new experience."[15] Memories—like maps—change us, and we change them as we recall them. The hero of *Memento* understood this well:

> Memory's unreliable ... Memory's not perfect. It's not even that good. Ask the police; eyewitness testimony is unreliable ... Memory can change the shape of a room or the color of a car. It's an interpretation, not a record. Memories can be changed or distorted, and they're irrelevant if you have the facts.

Cartography, whether external or internal, is no less fluid. As one cartographer put it, "most cognitive maps not only fail to reflect all the details of the environment they represent, but they also have systematic errors caused by the processes that encode them into memory."

On a corner of lower Broadway in Manhattan, after dispensing less-than-definitive directions to a lost stranger, I had to stop for a moment to remember where I was going.

[14] Marcel Proust, *Remembrance of Things Past*. Trans. C.K. Scott Moncrieff and Terence Kilmartin. New York: Penguin, 1957, p. 3.

[15] John McCrone, "Not-so Total Recall," *New Scientist*, May 3, 2003, pp. 26–29.

> the temporary friends a traveler makes in town and has to abandon when he leaves because it is there that they, who do not go away, will end their journey and their lives, as if he were still there, by the church, before the door, under the trees of the promenade.[14]

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