Thinking About Connections Between Places

A thousand fibers connect us. H. Melville
(Drafted 2009, mild update 2014)

This chapter is about organizing and representing geographic information by observing and evaluating spatial connections between locations. Unlike a geographic condition, which we defined as an observable fact about a specific location, a spatial connection always involves two or more locations.

An analysis of connections can start with a simple listing of other places that are linked to a given place. A more comprehensive study of spatial connections might include:

- identifying the **nature** of the link (is it a physical process, a seasonal migration, a trade link, a family tie, a political allegiance, a religious edict, or . . . ?)
- tracing the **route** or mode of the connection (is it a flowing stream, a surface road, a radio wave, a text message, a corporate link, or . . . ?)
- identifying **gates, barriers**, or other features that may facilitate or block the connection (does it follow a river valley, cross a mountain range, pass through a narrow strait, have to pay toll, require a transfer between several modes or carriers, or . . . ?), and
- describing the **structures** or other features that may be built to facilitate the connection (e.g., a public highway, a private courier service, an allocated portion of the radio spectrum, or . . . ?)
- analyzing the **traits** of each place that predispose it to be part of that particular connection (is one place chronically short of water, suffering from a crop disease, situated over a deposit of high-quality copper ore, able to make cell phones cheaply, or . . . ?).

You may rightly infer from this list that spatial connections can be physical (e.g., upstream or downstream), economic (linked by a railroad or pipeline), or familial, corporate, political, even religious. Moreover, connections can change as a result of many influences, including time of day, season, advertising, air pressure, political party in power, interest rate set by the Federal Reserve, proclamations of religious leaders, etc.

In short, the task of learning about spatial connections seems to be every bit as complex and memory-demanding as learning about spatial conditions. For that reason, it is both analytically and pedagogically useful to draw a distinction between <u>remembering</u> spatial connections and <u>thinking about</u> spatial connections. The process of storing and remembering information about spatial connections is important, but the sad fact is that an attempt to teach about connections between locations is vulnerable to the same pedagogical "diseases" that plague many ways of teaching about geographic conditions – list making, rote learning, and trivial assessing.

Spatial thinking to the rescue! - our basic assumption in this entire project is that a major goal of spatial thinking is to simplify the world and thus reduce its demands on our memory. We do that by organizing our observations and memories of spatial conditions <u>and</u> connections by using some "thought processes" that appear to be "hard-wired" into the human brain. Those processes are the subject of Essays 5 through 12, on the various modes of spatial thinking.

Before leaving this essay, however, we should also note that the ideas of conditions and connections often seem to "cooperate" in order to form a person's image of a place, much like the two blades of a scissors are more effective when used together than if they are taken apart and used separately. This "cooperation" is embodied in the geographer's use of the terms *site* and *situation* to describe complementary aspects of location (Gersmehl 2014, Chapter 2).

This duality has some important parallels in the vast body of psychological research about the interplay between landmarks and routes in personal orientation and navigation, a form of "mental cooperation" between different brain areas that has been documented in many animal species as well as human beings (for a summary, see Golledge et al. 1995).

The story of neodymium magnets
(an illustration of the scissors-like interaction of geographic conditions and connections)

To illustrate the interplay of geographic conditions and connections in a real-world setting (and to provide a forward link to the "core" eight essay in this project), let us look at a story that was in the financial news and Wall Street rumor mill at the time this essay was first drafted. Start by recalling a TV commercial – a panoramic view of windswept West Texas, as the background for a heartfelt message from T. Boone Pickens, well-known Texas oilman. In that message, he looked right at the camera and told Americans that oil is a finite resource. For that reason, he said, more drilling will not solve our energy problem, and investment in alternatives such as wind energy is a better strategy.

Having briefly investigated wind energy back when we owned a farm, we were intrigued by this privately-funded public-service commercial and curious about the trend in price of farm-scale wind-powered generators. A quick web search told us that generators today are both less expensive and seemingly more efficient and durable than in the late 1980s. A little more research uncovered a reason for the price trend – modern wind generators use light but strong magnets made out of an alloy of iron, neodymium, and boron. That "recipe" was discovered in the mid-1980s, a fact that might make neodymium magnets a good fairly-recent example of a fundamental principle of economic geography:

> *Any significant change in technology has the potential to make some places more valuable and thus reduce the relative value of other places*.

A better magnet is a significant change, for two reasons. A lighter generator means more electricity, because the generator can start with less wind. It also means lower cost, because the towers do not need to be as strong. At a continental scale, a decrease in generator cost should make windy places more valuable. To test that hypothesis about the effect of geographic conditions, you could look at per-capita income, unemployment rate, land value, and county tax revenues in some windy places where people have already installed the new technology – perhaps by looking at countries like Denmark, where people already get nearly 20% of their electricity from wind. In the United States, we might look at California, southwest Minnesota, west Texas, north-central Iowa, and so forth.

Our story, however, has a more detailed focus, because we were curious about <u>indirect</u> effects. Specifically, we wanted to know about neodymium, the mystery element in the magnet recipe. To be honest, we hadn't thought about "element number 60" for nearly half a century.

> Phil remembers a classroom activity that involved singing a song based on the periodic table of elements. It might be worth noting that he cannot remember the song itself; he only recalls that it wasn't very good music, and he disliked it, in the way that students often resent "educational activities" that seem to have no point other than rote memorization!

Neodymium, however, turns out to be critically important in hybrid cars, cell phones, iPods, and many other products as well as wind generators. Chemists classify it as a rare-earth element. "Rare," however, is a relative term – neodymium is roughly as abundant in the earth's crust as cobalt, which means it is nearly half as common as copper, about a third as abundant as nickel, but three times as common as lead, 30 times as plentiful as molybdenum, and a thousand times more common than gold. All of those other metals are already obviously important in world commerce, where they have been significant sources of money income for people in various places, often for thousands of years.

So, here's the question: where in the world do people get rich by producing neodymium?

This is where the story gets interesting. It so happens that a single mine in California was the world's largest producer until the 1960s (when people used small amounts of neodymium for purposes other than magnets). In the late 20th century, however, China took first place and now produces more than 95 percent of the world total. That is a simple geographic comparison (Essay 5), and the locations of producers and consumers also make a geographic connection between China and West Texas, in the form of a movement of neodymium from Chinese producers to Texas wind-generator builders.

What can we learn if we do some more spatial thinking about neodymium?

Metals like gold, copper, or silver tend to occur in small areas on a map, because they are found in layers, veins, or even nuggets in places where geologic forces tend to concentrate the metals. That clustered pattern (Essay 11) makes these metals relatively easy to mine. Neodymium, by contrast, is more dispersed, with trace amounts in many common rocks. Slightly richer deposits occur in a few places near the edges of specific geologic regions (Essay 6). Those deposits are caused by recent intrusions of granitic magma into layers of altered sedimentary rocks – a spatial association (Essay 12). Mineable deposits of rare earths have already been found in places with similar geology in Australia and Malawi (a global pattern, Essay 11 again). Based on that history, geologists are now exploring for rare-earth minerals in Brazil, Canada, Russia, and other analogous locations (Essay 10). The value of a mine in each of those places would depend on local conditions (Essay 3), the cost of transporting thousands of tons of metal oxides to refineries and markets (Essays 4 and 8), and the hierarchy of political jurisdictions around the mine (Essay 9). Finally, any successful mine will have an aura of influence on surrounding territory (Essay 6). Those influences include jobs and tax revenues, but also noise, congestion, and potentially hazardous release of radioactive elements.

In short, even a cursory look at the geography of neodymium involves applying all eight modes of spatial thinking that we will describe in this book. One plausible goal of this kind of inquiry is to make a spatial-financial model (Essay 14) that will tell investors whether a particular neodymium venture would be a good investment.

That is where the story gets really interesting. It turns out that in 2003 the China Iron and Steel Industry Trade Group bought about 40 percent of the Lynas Corporation, the company that runs a rare-earth mine in Australia (The Australian, September 25, 2003). That mine was one of only three neodymium sources outside of China, and China just made a bid to gain a controlling interest while we were writing this chapter (Business Day, July 6, 2009). Two years ago, in 2007, Lynas acquired the Kangankunde rare-earth deposit in Malawi (Mining Weekly, September 21, 2007).

In the middle of that flurry of international acquisitions, in 2005, a Chinese government-backed company tried to buy Unocal, an American oil company. American lawmakers were reported as concerned over its "ominous implications for national security -- in particular, the security of U.S. oil lifelines" (Washington Post, June 1, 2005). What seldom, if ever, got reported at that time was the fact that Unocal was also the owner of the Mountain Pass rare-earth mine, the only source of neodymium in the United States.

Fast forward a few years, and the story gets even more interesting. Congress passed a resolution requiring a study of the impacts of selling an major oil company to China. The Chinese group withdrew its offer, citing political complications. Another oil company, the Chevron Corporation, then bought Unocal. Then, in rapid succession, the sub-prime-mortgage market imploded; the stock market plummeted; some large banks collapsed; and Congress provided a financial bailout for several large banks, including Goldman-Sachs (a major New York investment bank). Meanwhile, in 2008, Chevron quietly sold the California neodymium mine to “a group of private investors.”

In sum, Congress is on record as opposing the sale of an oil company to China, on national security grounds, but it did nothing to prevent its sale to a private group that is not subject to the rules of public financial disclosure that apply to companies listed on the stock exchange. In this way, a geographical flow of a rare metal from China to West Texas is part of a far more complex set of geographical connections that also involve Washington, New York, Australia, Malawi, and California. One consequence of those connections was to remove from public scrutiny the only non-Chinese source of a very important resource, while the price was going up by more than 600 percent. No wonder the conspiracy theories abound!

As citizens, we have to admit that this story raises some concerns about the state of public knowledge, the value of public disclosure, and the use of public funds to bail out a financially strapped company that is simultaneously making a private deal to acquire an effective national monopoly over a strategically important resource (at least until geologists find new sources, which seems likely). In the meantime, as geographers, we find it deeply disturbing to reread newspaper and TV stories from that time and note how shallow and misguided the geographic analysis of the issue was. We repeat the italicized phrase from the beginning of this section:

> *Any significant change in technology has the potential to make some places more valuable and to reduce the value of other places*.

It does so by altering the conditions at various places and/or the connections between places. The neodymium story underscores the point that one of the most efficient ways to learn about those conditions and connections is to engage in some serious thinking about spatial patterns, associations, hierarchies, analogies, and so forth.

Footnote: Of course the stunning rise in price of neodymium had ripple effects – people have looked for new sources in many places, from Greenland to Kyrgyzstan, and the California mine is no longer a front-page news item. If I were still teaching economic geography, I would try to find a more up-to-date story.

But this is a project about spatial thinking, and the research that supports new ideas about how human brains perceive and process spatial information. Let’s get on with that story!

Research on Thinking about Spatial Connections

The research on thinking about spatial connections falls into three broad groups, none of which directly addresses the issue of discerning connections on maps.

The first category of research deals with personal wayfinding – the use of mental maps and environmental cues to help select a route for personal transportation from one place to another. One common goal of research was to find out whether prominent landmarks, visual scenes ("snapshots" of conditions), or routes (connections) take precedence in the human memory system (for reviews from different perspectives, see MacEachren 1992; Golledge et al. 1995; Mallot and Gillner 2000; McNamara and Shelton 2003; Tom and Denis 2004; Wolbers et al. 2004; Calton et al. 2008; Epstein 2008; Buckley et al. 2014). After decades of studies that are far too numerous to survey here, the answer to this apparently either-or question can apparently be paraphrased as "yes, at different times under different circumstances, and perhaps for different people under the same circumstances."

This rather wishy-washy conclusion still has significant implications for the design of educational materials. The implications, however, cannot take the form of a simple prescription for "a best practice" to teach about connections. On the contrary, the take-home message for teachers is that different students are likely to organize their mental maps of connections in different ways. It follows that the classroom environment, including tests, should be structured in ways that do not penalize individuals who prefer to organize their mental maps around landmarks, major connections, analogies with other places, or any other particular way of combining landmarks and routes.

In recent years, there have been a number of studies that tried to identify specific brain areas that are involved when people think about paths between places, One line of research uses the notion of a "visuo-spatial sketch-pad" as a way to describe mental processes (for a review, see Pickering et al. 2001). Another puts more emphasis on the idea that people routinely do a form of "path integration" by monitoring head direction and updating an internal array of place cells in the brain (see McNaughton et al. 2006). A third line of research looks at how the regions of primary brain activity seem to change as a person's knowledge of a particular environment increases (Wolbers et al. 2004).

Yet another body of research looks at the influence of perceived environmental structure on "behavior" in a virtual environment (a computer world – see Jansen-Osmann et al. 2007). Finally, there is a sizeable body of recent research that documents a rather remarkable capacity of some parts of even middle-aged human brains to expand physically, by adding neurons, in order to accommodate additional information about spatial connections (one key early study was Maguire et al. 2000; for a popular review, see Schwartz and Begley 2002). This suggests that a targeted program of remedial work can actually help expand a student's brain capacity for learning additional information about geographic connections in the real world. Students should therefore be encouraged, for example, to draw connections on blank world and continental maps while reading news stories about events in other places (lines of ownership or control that stretch from China to Australia and then on to Malawi, in the case of neodymium!)

At the same time, students should try to make verbal descriptions of the connections they observe. Each time they mention a connection between two places and find those places on a map, they are reinforcing their mental maps of the locations themselves. That activity, in turn, provides a more solid base for interpreting the next news story.

The second category of related research deals with the visual perception of movement between places. If anything, this research has an even tighter focus on the personal rather than geographical scale. Relevant studies range from scanner-based attempts to find the neural basis for motion perception to a theoretical analysis of the process of mentally "computing" a motion trajectory in a one-earth-gravity environment with one-earth-atmosphere of air resistance, in order to catch a baseball in the outfield (Bremmer et al 2001; Dessing et al. 2005).

Given its focus on relatively small spaces, one might be tempted to ignore this work entirely, except for the fact that motion perception is one key to successful interpretation of virtual environments and animated maps, which in turn have become important ways to communicate about connections between places. We will leave this subject for a later chapter and another book; suffice it here to note that we have been involved in making animated maps for more than 20 years, for topics that range from seismic waves and nutrient cycles to capital flows and the spread of historical empires (see www.aag.org for descriptions of the ARGUS and ARGWorld projects, or the CD that is included in *Teaching Geography* from Guilford Press). During the time we were working on those projects, we made several attempts to find research that might offer guidance in the design of those maps (see Gersmehl 1990; Peterson 1995; Mayer and Moreno 2002; Tversky et al. 2002; Harrower 2003, 2004; Griffin et al. 2006; Lobben 2008). As the technology matures and animated maps become easier to make, the designers of such maps should pay more serious attention to the expanding body of research now being done by brain-scanning neuroscientists and eye-tracking vision scientists.

The third category of related research deals with the mathematical analysis of connectivity, defined as the measure of the number of direct links between places, divided by the number of places that could be connected. Also called graph theory, this research has had many fruitful applications in fields that range from traffic forecasting and internet analysis to wildlife biology (for an overview of the math, see Arlinghaus et al. 2001 or Godsil and Royle 2001; for a few examples that show the range of applications, see Bunn et al. 2000; Urban and Keitt 2001; Malecki 2002; Taylor et al. 2002; Derudder and Taylor 2005; Derudder and Witlox 2008). As with the issue of raster vs. vector encoding of locational information (described in Chapter 2), the technical research on spatial connectivity is mostly beyond the scope of this book. The exception to that statement is the fact that their findings can provide ways to measure spatial connections in an "objective" way for comparison with the subjective findings of psychologists or neuroscientists.

Before we leave this essay and go on to the essays about the eight neurologically distinct modes of spatial thinking, we should make sure that the distinction is clear between two meanings of the phrase "spatial connection." In the abstract sense of the term, a spatial connection is any kind of link between two separate locations. In its concrete sense, however, a spatial connection is an entity that exists on the landscape – a river, road, powerline, and so forth. As such, it can be perceived and analyzed through the same sensory systems that we use to observe conditions in a place. An abstract spatial connection, by contrast, can be examined only in our heads or through indirect measurements and symbolic representations. Much of the research that we will examine in the next eight essays will be more relevant for thinking about conditions and concrete spatial connections, rather than abstract links. One miracle of the human brain, however, is that it can shift so easily from thinking about concrete conditions and connections to abstract or even imaginary ones. That facility is one reason why psychological research about spatial thinking is often ambiguous or even contradictory – researchers often find it difficult to control for such shifts between different meanings of the same terms!

With that, let us go on to consider eight different ways of thinking about geographic conditions and connections.

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