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## **The Importance of Diverse Thinking**

### **Why the Santa Fe Institute Can Make You a Better Investor**

You must know the big ideas in the big disciplines and use them routinely—all of them, not just a few. Most people are trained in one model . . . and try to solve all problems in one way . . . This is a dumb way of handling problems.

Charlie Munger  
*Poor Charlie's Almanack*<sup>1</sup>



- Probably the question most frequently posed of us is: how does all of this non-traditional material help make you better investors?
- The logic of diversity provides individuals with a diversity of perspectives, heuristics, and interpretations to solve hard problems better than smart individuals with limited tools.
- Research shows foxes—people with a little knowledge of a lot of topics—make better predictions over time than hedgehogs—people who know one big thing.
- We provide some specific examples of where idea diversity offers a useful perspective from an investor's standpoint.

## A Wonk or You're Sunk?

From Bill Miller on down, LMCM is known as an organization “more like some sort of academic enclave or wonk house” than “a standard-issue money management firm.”<sup>2</sup> The investment team allocates time—through discussion, reading, and conferences—to topics typically considered outside the normal finance and investing realm. In particular, the Santa Fe Institute, a multi-disciplinary research institute dedicated to the study of complex systems, plays a prime role in stimulating our thinking.

All of this prompts what is probably the question most frequently posed of us: How does all of this stuff help make you better investors?

This essay will try to answer the question by looking at the theory of diversity, evidence of what it takes to consistently predict well, and some examples of how we use diverse ideas to view common investment problems.

We should start by acknowledging that delivering excess returns is a hard problem. Markets are complex; the business landscape is ever changing, information is abundant but often ambiguous, and fact and conjecture pass through a huge human psychological filter. The challenge is to gain insight, an edge others don't share.<sup>3</sup>

To state the obvious, it's unlikely you will gain insight if your inputs are identical to everyone else's. Many information sources—the popular business press, company disclosures, and analyst reports—are necessary but not sufficient for developing an edge. More important is interpreting the information in a way that's different, and better, than other investors. Gaining an edge requires a lot of work: reading, thinking, and intellectual independence.

The notion that diversity is good for business has become a cliché, and that's too bad. Understanding *when* and *why* diversity works (and that it doesn't always work) is as crucial as appreciating what it offers. So we'll start with a quick discussion of how diversity leads to a better ability to solve hard problems. Social scientists have now demonstrated diversity's value, showing it's no longer a soft concept but a real and powerful approach to problem solving.

## Winning the Sum-to-Fifteen Game

If you want to see the power of perspective, try playing the sum-to-fifteen game. Conceived by economist Herb Simon, the rules are simple. You lay nine cards, numbered one through nine, on a table face up. Two players alternate selecting cards with an objective to hold exactly three cards that add up to fifteen. If you've never played the game before, try it. Or offer to host it for some colleagues and watch carefully as they go back and forth.

The sum-to-fifteen game is moderately hard, because you need to keep in your head a running total of your numbers as well as those of your opponent. You also have to think offensively, getting three cards that add up to fifteen, as well as defensively, preventing your opponent from doing the same. Not infrequently, one person will win the game as their opponent gets tangled in the numbers.

Now we introduce a magic square that provides a perspective that makes the game much easier to play. Here is a magic square for this game:

8	3	4
1	5	9
6	7	2

Note the numbers sum to fifteen if you look at them vertically, horizontally, or diagonally. All of a sudden, the game becomes very easy: it's the childhood favorite, tic-tac-toe. Once you perceive

the game as tic-tac-toe, winning is much easier, a tie should be a worst case scenario, and losing is, well, inexcusable.

Scott Page's book, *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies*, describes the sum-to-fifteen game as part of a broader case of why diversity trumps ability under specific conditions.<sup>4</sup> Diversity has become a hot topic in recent years, but most of the discussion has surrounded social identity diversity—gender, race, ethnicity. Page carefully and rigorously shows how diverse perspectives, heuristics, and interpretations lead to better collective problem solving and prediction capabilities.

You can consider diversity on two levels. The first is for groups—teams, units, organizations. In this case, the individuals all contribute to diversity, and thinking about what each individual brings to the table and how they get along is essential. The second is on an individual level, or the diversity of your mental models. This addresses how many approaches you have to solve problems.<sup>5</sup>

In too-simple terms, diversity works because it provides lots of tools to solve a hard problem, increasing the likelihood one of the tools (or some tools in combination) will be effective. For any given problem, you *may* have the right tool in your head. But if your problems are hard and varied, and the number of tools at your disposal is limited, chances are you will struggle to find quality approaches to your problem.

While Page provides real-world examples of diversity in action, his greatest contribution is the logic of diversity. He shows that when the conditions are right, diversity is not simply nice to have, but is necessary in order to find optimal solutions. His diversity trumps ability theorem is, as he writes, “no mere metaphor or cute empirical anecdote that may or may not be true ten years from now. It’s a logical truth.”<sup>6</sup>

The sum-to-fifteen game is a fun and accessible way to make a much larger point: the more ways you have to solve a problem, the more successful you’re likely to be. And if you have the identical tools as everyone else—the same business school education, TV channels, Wall Street research—you are very unlikely to gain insight.

## **Are You Foxy?**

While Page’s case for diversity is logically tight, you might ask whether there’s *actual* evidence for the value of diversity in tasks similar to what investors face: predicting the outcomes of complex systems. The answer is a resounding yes, and comes from Phil Tetlock’s remarkable research summarized in his book, *Expert Political Judgment*.<sup>7</sup> Every informed citizen should be aware of Tetlock’s findings.

Our society tends to hold experts in high esteem. We watch them on TV, seek their counsel, and defer to their advice. But how good are the predictions of experts, really? Tetlock asked nearly 300 experts to make literally tens of thousands of predictions over nearly two decades. These were difficult predictions related to political and economic outcomes—similar to the types of problems investors tackle.

The results were unimpressive. Expert forecasters improved little, if at all, on simple statistical models. Further, when Tetlock confronted the experts with their poor predicting acuity, they went about justifying their views just like everyone else does. Tetlock doesn’t describe in detail what happens when the expert opinions are aggregated, but his research certainly shows that ability, defined as expertise, does not lead to good predictions when the problems are hard.

Decomposing the data, Tetlock found that while expert predictions were poor overall, some were better than others. What mattered in predictive ability was not who the people were or what they believed, but rather *how* they thought. Using a metaphor from Archilochus (via Isaiah Berlin),

Tetlock segregated the experts into hedgehogs and foxes. Hedgehogs know one big thing, and extend the explanatory reach of that thing to everything they encounter. Foxes, in contrast, tend to know a little about a lot, and are not wedded to a single explanation for complex problems.

Two of Tetlock's discoveries are particularly relevant. The first is a correlation between media contact and poor predictions. Tetlock notes that "better-known forecasters—those more likely to be fêted by the media—were less calibrated than their lower-profile colleagues."<sup>8</sup> The research provides yet another reason to be wary of the radio and television talking heads.

Second, Tetlock found foxes tend to be better predictors than hedgehogs. He writes:

High scorers look like foxes: thinkers who know many small things (tricks of their trade), are skeptical of grand schemes, see explanation and prediction not as deductive exercises but rather exercises in flexible "ad hocery" that require stitching together diverse sources of information, and are rather diffident about their own forecasting prowess.<sup>9</sup>

Borrowing from Page's metaphor, we can say that hedgehogs have one power tool while foxes have many tools in their toolbox. Of course, hedgehogs solve certain problems brilliantly—they certainly get their 15 minutes of fame—but don't predict as well over time as the foxes do, especially as conditions change. Tetlock's research provides scholarly evidence of diversity's power.

Leadership research also offers conclusions supporting the significance of diversity. Scholars suggest the best way to forecast leadership success is to use a weighted combination of predictors. But one of these predictors, learning agility, stands above the rest as the best.<sup>10</sup>

Learning agility has many definitions, but generally includes critical thinking, an ability to examine a problem carefully and make fresh connections; eagerness to learn, a desire to gain new competencies in order to be effective; and coping with novelty, or an ability to perform effectively under first-time or different conditions.

We can now answer the "how does this stuff help you" question. Simply stated, cognitive diversity produces a large tool set to solve complex problems. If your tools are no different than everyone else's, you have no foundation for believing you can systematically outperform.

We now turn to a handful of practical examples of how Santa Fe Institute-inspired thinking has offered insight into an investing problem.

## **The Wisdom and Whims of the Collective**

The efficient market hypothesis has been one of the bedrocks of finance theory since the late 1960s. The hypothesis holds that security prices reflect all available information, and hence suggests no investor can systematically generate excess returns.<sup>11</sup> The overwhelming evidence, gathered over decades, indeed confirms that most active managers underperform passive indexes over time.<sup>12</sup>

Market efficiency is a very important topic for active investment managers. Without a clear understanding of how and why markets are efficient or inefficient, investors have no foundation for establishing an investment strategy. Still, very few investors think carefully about market efficiency, and most take inefficiency for granted.

There are three basic ways to get to market efficiency.<sup>13</sup> The first assumes that investors are rational, which means they correctly update their beliefs when new information is revealed and make appropriate choices given expected utility theory.<sup>14</sup> The second relaxes the assumption that all investors are rational, and instead hinges on a small set of rational investors who use

arbitrage to remove pricing errors. The final approach relies on the interaction and aggregation of many independent investors. This route to efficiency, colloquially known as the wisdom of crowds, is an example of a complex adaptive system.<sup>15</sup>

Nearly all of the models in finance emanate from one of the first two approaches. For example, mean-variance efficiency, where investors trade off risk and reward in a linear fashion, is based on investor rationality. If you've ever uttered alpha or beta in a non-disparaging way, you've used the rational agent approach. The arbitrage approach lies at the core of most options pricing models, including Black-Scholes. The rational agent and arbitrage models are the dominant tools in the financial economist's toolbox. The wisdom of crowds approach has received limited attention and, in some cases, complete dismissal.<sup>16</sup>

Scientists test a theory's validity by judging the plausibility of its assumptions and the accuracy of its predictions. By these measures, the rational agent and arbitrage models are wounded. In both cases, modelers assume the mechanism, investor rationality, which allows for the results. If common sense and experience are not enough, psychologists have conclusively demonstrated that investor behavior deviates meaningfully from the rational ideal.

More nettlesome, there are major gaps between the predictions these models generate and the results we see in markets. These tools have undoubtedly advanced our knowledge, and have the advantage of being mathematically tractable. But they remain severely limited in explaining the real world.

A consistent theme at the Santa Fe Institute since its founding has been the study of complex adaptive systems (CAS).<sup>17</sup> Santa Fe Institute scientists were early in identifying the salient features of these systems and considering the similarities and differences across disciplines. CAS tend to have common characteristics:

- Composed of individual agents (e.g., investors, ants, neurons) that have evolving decision rules.
- An aggregation mechanism (e.g., stock exchange, pheromone trails, synaptic connections) that captures the interaction between the agents.
- Emergence of a larger scale system that has features distinct from the sum of the parts (e.g., stock market, ant colony, mind).

One crucial feature of CAS is the lack of additivity: you can't understand the whole by adding up the parts. You can take most mechanical systems apart, identify the role of each piece, and reassemble the system. Cause and effect are transparent. Not so with CAS; the system emerges from the interaction of the individual agents. Just as you can't divine the dynamics of an ant colony by interviewing an ant, no individual investor can explain the stock market's workings.

Certain conditions must prevail for a CAS to solve a problem effectively, including agent diversity, a mechanism to aggregate information, and some incentive. Note these conditions fit closely with Page's framework. In market language, when these conditions prevail, markets tend to be efficient in the sense they reflect available information and do not offer opportunities for systematic excess returns.

Conversely, when one or more of the conditions are violated, markets can and do become inefficient. By far the most likely condition to be violated is diversity. Humans are natural imitators, and periodically investors synchronize their behavior in a way that leads to sharp excesses.<sup>18</sup> So this approach readily demonstrates efficiency regimes, based on specific conditions. Economists have confirmed these findings using agent-based models.<sup>19</sup>

Why is viewing the stock market as a complex adaptive system better than the other two approaches? First, the assumptions underlying the framework are much more realistic. The market has lots of diversity: long- and short-term horizons, fundamental and technical analysis,

growth and value bents. We need not assume *anyone* is rational, yet the approach comfortably accommodates rationality.

Second, although a CAS doesn't make specific predictions, the system behavior is consistent with what we see empirically in markets. One of the greatest challenges in standard finance theory is explaining the presence of large events—booms and crashes. Applying mean-variance statistics suggests the crash of 1987 was effectively impossible. In contrast, a CAS approach allows for episodic, large-scale moves.

Finally, the CAS approach specifies conditions, or circumstances, when markets are likely to get it right or wrong. A reasonable default assumption is the wisdom of crowds conditions prevail. But when diversity breakdowns occur, they can create attractive investment opportunities. Taking advantage of these opportunities, however, requires clearing both psychological and organizational hurdles, which most investors are unable to do.<sup>20</sup>

Understanding markets as a CAS provides a non-traditional but robust perspective.<sup>21</sup> The framework makes concrete conditions under which markets operate efficiently and when they break down. Since CAS are found in many domains, we have varying contexts to gain perspective and insight into how they work.

### **Connecting to Network Theory**

Many value investors, most notably Warren Buffett, disavow allocating capital to the technology sector because of the perceived lack of predictability.<sup>22</sup> Buffett has spoken persuasively about the importance of investors identifying and staying within their circle of competence, undoubtedly sound advice. But Buffett only claims that technology investing is not within *his* circle of competence, and leaves open the possibility some investors can have insight.

One intriguing feature of technology markets is while individual products tend to have short life cycles, some companies gather and maintain very high market shares. In many consumer-product markets, leading companies with strong competitive positions have market shares in the 30 to 50 percent range. Think Coca-Cola, Nike, and Anheuser Busch. In contrast, in some technology sectors the market shares are much more skewed; market leaders often have 90 percent or more of the market (Microsoft in operating systems, eBay in auctions). Is there a perspective that can help us understand why market shares differ so much?

One of the pillars of microeconomics is that competitive forces assure that a company's return on capital migrates back toward its cost of capital over time. Researchers have repeatedly documented decreasing returns.<sup>23</sup> Yet there have been and are cases of increasing returns.<sup>24</sup> While economists have recognized increasing returns for a long time—Adam Smith's pin factory is one early example—the concept was largely swept under the rug by mainstream economists until fairly recently.<sup>25</sup>

W. Brian Arthur, involved with the Santa Fe Institute from its early days, has been one of the more visible and vocal economists to highlight the importance of increasing returns.<sup>26</sup> Arthur's work has covered a number of areas, but increasing returns as a result of network effects has garnered the most attention. A network effect exists when the value of a good or service increases as more people use the good or service. A canonical example is a phone system; the more people with phones, the more valuable the whole network.

When network effects are strong, one network often emerges as dominant. Even though multiple networks often compete for leadership, positive feedback assures that one wins. Classic illustrations include the QWERTY keyboard, VHS in video cassettes, and Intel in microprocessors. A number of leading thinkers in network theory, including Duncan Watts, Mark Newman, and Steven Strogatz, are affiliated with the Santa Fe Institute.

Most investors are aware of network effects, but are far too casual in applying the concept. Specifically, three issues are central to employing network theories to investing. The first is a clear-cut understanding of network taxonomy, and in particular where network effects are likely to be robust. Investors often inappropriately invoke network effects.

Second is how network effects translate into the drivers of value creation: sales growth, margins, risk, and sustainable competitive advantage (the last being Buffett's prime concern). When network effects take hold, these value drivers combine to drive rising returns on invested capital and lower risk.

The final issue is network formation and diffusion, an area that draws heavily from epidemiology and sociology. An understanding of network formation allows investors to anticipate changes in growth rates better than the market does.<sup>27</sup>

A thorough understanding of network theory provides a set of perspectives that can help establish or enhance a circle of competence. Notably, most of what we learn in classrooms is classical economics based on supply and demand of physical goods, where diminishing returns holds sway.<sup>28</sup> Further, network theory is inherently multi-disciplinary, drawing on ideas from a host of fields.

## **The Power of Power Laws**

Our final example, power laws, is more speculative but promises to be a fascinating line of inquiry and source of possible insight in the next few years. A power law effectively represents a number of biological (animal mass and metabolic rate), physical (earthquake frequency and size), and social (city size and rank) relationships. Visually, a power law looks like a straight line from the upper left side to the lower right side of a chart, where the variables on the horizontal and vertical axes are plotted on a logarithmic scale.<sup>29</sup> To take earthquakes as an example, a power law implies you see small earthquakes frequently and large earthquakes infrequently.

Power laws show up in a number of realms important to investors, including firm sizes and stock price changes. But unlike some power laws in biology where the causal mechanisms have been worked out fairly well, no one knows how most social-system power laws come about.<sup>30</sup> What we do know is some of the theoretical mechanisms that generate power laws do not hold up to empirical scrutiny.<sup>31</sup>

How can an understanding of power laws help an investor? First, knowing that stock price changes follow a power law distribution can help reorient our understanding of risk. Most of finance theory, including risk models, is based on normal, bell-shaped distributions of price changes. A power law distribution suggests periodic, albeit infrequent price movements that are much larger than standard theory predicts. This fat-tail phenomenon is important for portfolio construction, leverage, and insurance.

Second, power laws suggest some underlying order in self-organizing systems. While we don't know how they come about, we have enough evidence they exist to make structural predictions about what the distributions will look like in the future. For example, with a reasonable forecast for growth, we can anticipate the distribution and size of firms in the U.S. Unfortunately, we don't know where individual companies will end up on the distribution.

Finally, the power law science provides insights into growth.<sup>32</sup> For instance, efficiency changes with size: the cells of a large mammal don't work as hard as those of a small mammal. Specialization also tends to increase with size, which is why large cities offer more culinary alternatives than small cities. Investors can apply these perspectives to companies as they move through a life cycle.

Power laws, much like complex adaptive systems, are striking in their ubiquity yet remain poorly understood in many contexts. As scientists develop theories to explain a broader range of power laws, investment insights are likely to follow.

### **Beliefs About Beliefs**

If diversity is both logically and empirically useful, why don't investors spend more time developing diverse perspectives? The first obvious answer is constant learning is a lot of work. In a time-pressed world, allocating time to ideas outside the world of business and finance is very challenging.

But difficulty is unlikely the ultimate answer, because the rewards for success are so high. The more likely culprit is based on belief formation and maintenance. While most investors work hard to input the relevant information, very few are introspective enough to question their own beliefs.<sup>33</sup> Why do I believe what I believe? Does the belief stand up to the evidence? These are uncomfortable, even unnatural, questions.

Once we've established a belief—most of which come from people around us—we are loathe to change it. Social psychologist Robert Cialdini offers two deep-seated reasons for this. First, consistency allows us to stop thinking about the issue—it gives us a mental break. Second, belief consistency allows us to avoid the consequence of reason—namely, that we have to change. The first allows us to stop thinking; the second allows us to avoid acting.<sup>34</sup>

The logic of diversity requires that we constantly develop new tools if we hope to be successful in consistently solving complex problems. Constant learning and open-mindedness are the best ways to achieve this goal, but are cumbersome and generally not innate tendencies. At LMCM, we try to embrace diversity so our investment process is as robust as it can be.



## Endnotes

- <sup>1</sup> Peter D. Kaufman, ed., *Poor Charlie's Almanack* (Virginia Beach, VA: Donning Company, 2005).
- <sup>2</sup> Andy Serwer, "The Greatest Money Manager of Our Time," *Fortune*, November 15, 2006.
- <sup>3</sup> Ken Fisher, *The Only Three Questions That Count: Investing by Knowing What Others Don't* (New York: John Wiley & Sons, 2006).
- <sup>4</sup> Scott E. Page, *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies* (Princeton, NJ: Princeton University Press, 2007), 36-41.
- <sup>5</sup> See [http://www.tcd.ie/Psychology/Ruth\\_Byrne/mental\\_models/](http://www.tcd.ie/Psychology/Ruth_Byrne/mental_models/).
- <sup>6</sup> Page, 162.
- <sup>7</sup> Philip E. Tetlock, *Expert Political Judgment: How Good Is It? How Can We Know?* (Princeton, NJ: Princeton University Press, 2005).
- <sup>8</sup> *Ibid.*, 68.
- <sup>9</sup> *Ibid.*, 73-75.
- <sup>10</sup> William S. Frank, "High performance, potential don't always match," *Denver Business Journal*, November 25, 2005. See <http://www.bizjournals.com/denver/stories/2005/11/28/smallb2.html>.
- <sup>11</sup> Eugene F. Fama, "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance*, Vol. 25, 2, May 1970, 383-417; also Eugene F. Fama, "Efficient Capital Markets: II," *Journal of Finance*, Vol. 46, 5, December 1991, 1575-1617.
- <sup>12</sup> Burton G. Malkiel, "Reflections on the Efficient Market Hypothesis: 30 Years Later," *The Financial Review*, 40, 2005, 1-9.
- <sup>13</sup> Andrei Shleifer, *Inefficient Markets: An Introduction to Behavioral Finance* (Oxford, UK: Oxford University Press, 2000).
- <sup>14</sup> Nicholas Barberis and Richard Thaler, "A Survey of Behavioral Finance," in *The Handbook of The Economics of Finance*, Constantinides, Harris, and Stulz, eds. (Amsterdam: Elsevier, 2003), 1055.
- <sup>15</sup> James Surowiecki, *The Wisdom of Crowds* (New York: Doubleday and Company, 2004).
- <sup>16</sup> Shleifer, 12.
- <sup>17</sup> George A. Cowen, David Pines, and David Meltzer, eds. *Complexity: Metaphors, Models, and Reality* (Cambridge, MA: Perseus Books, 1994).
- <sup>18</sup> Michael J. Mauboussin, *More Than You Know: Finding Financial Wisdom in Unconventional Places* (New York: Columbia University Press, 2006), 77-81.
- <sup>19</sup> Blake LeBaron, "Financial Market Efficiency in a Coevolutionary Environment," *Proceedings of the Workshop on Simulation of Social Agents: Architectures and Institutions*, Argonne National Laboratory and University of Chicago, October 2000, Argonne 2001, 33-51.
- <sup>20</sup> Michael J. Mauboussin, "Contrarian Investing: The Psychology of Going Against the Crowd," *Mauboussin on Strategy*, March 8, 2005.
- <sup>21</sup> For a much more in-depth and technical discussion, see Michael J. Mauboussin, "Capital Ideas Revisited: the Prime Directive, Sharks, and The Wisdom of Crowds," *Mauboussin on Strategy*, March 30, 2005. Also, Mauboussin, "Capital Ideas Revisited—Part 2: Thoughts on Beating a Mostly-Efficient Stock Market," May 20, 2005.
- <sup>22</sup> Warren E. Buffett, "Annual Letter to Shareholders," *Berkshire Hathaway Annual Report*, 1999. See <http://www.berkshirehathaway.com/letters/1999htm.html>.
- <sup>23</sup> See Krishna G. Palepu, Paul M. Healy and Victor L. Bernard, *Business Analysis and Valuation* (Cincinnati, OH: Southwestern College Publishing, 2000), 10-6; Pankaj Ghemawat, *Commitment: The Dynamic of Strategy* (New York: The Free Press, 1991), 82; Bartley J. Madden, *CFROI Valuation* (Oxford, UK: Butterworth-Heinemann, 1999); and Michael J. Mauboussin, Alexander Schay, and Patrick McCarthy, "Competitive Advantage Period: At the Intersection of Finance and Competitive Strategy," *Frontiers of Finance, Credit Suisse First Boston Equity Research*, October 4, 2001.
- <sup>24</sup> We count at least five senses of the term "increasing returns." First is the notion that knowledge begets knowledge. Second is standard economies of scale. Third is the benefit from the universal learning curve. Fourth is the benefit from network effects. And fifth is the benefit from international trade.
- <sup>25</sup> For an excellent account of the history of increasing returns see David Warsh, *Knowledge and the Wealth of Nations: A Story of Economic Discovery* (New York: W.W. Norton, 2006).

<sup>26</sup> For a non-technical discussion, see W. Brian Arthur, "Increasing Returns and the New World of Business," *Harvard Business Review*, July-August 1996, 101-109. For a more technical discussion, see W. Brian Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor, MI: University of Michigan Press, 1994).

<sup>27</sup> Michael J. Mauboussin, "Exploring Network Economics," *Mauboussin on Strategy*, October 11, 2004.

<sup>28</sup> Carl Shapiro and Hal R. Varian, *Information Rules: A Strategic Guide to the Network Economy* (Boston: Harvard Business School Press, 1999).

<sup>29</sup> See [http://en.wikipedia.org/wiki/Power\\_law](http://en.wikipedia.org/wiki/Power_law). Also, Mauboussin (2006), 193-198.

<sup>30</sup> John Whitfield, *In the Beat of a Heart: Life, Energy, and the Unity of Nature* (New York: Joseph Henry Press, 2006).

<sup>31</sup> Michael Batty, "Rank Clocks," *Nature*, vol. 444, November 30, 2006, 592-596.

<sup>32</sup> John Tyler Bonner, *Why Size Matters* (Princeton, NJ: Princeton University Press, 2006).

<sup>33</sup> Lewis Wolpert, *Six Impossible Things Before Breakfast: The Evolutionary Origins of Belief* (New York: W.W. Norton, 2007).

<sup>34</sup> Robert B. Cialdini, *Influence: The Psychology of Persuasion* (New York: William Morrow, 1993).

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