

CHAPTER 8

THE EPISTEMOLOGY OF ENTREPRENEURSHIP[☆]

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ABSTRACT

Entrepreneurs have two advantages over credentialed experts. They “know” less of what is false, and they (informally) know more of what is true. They know less of what is false because they are either ignorant of, or willing to ignore, the currently dominant theories. They know more of what is true by having more informal knowledge (whether local, tacit, or inchoate). Funding of projects by firms or governments will rely on expert judgments based on the currently dominant theory. So breakthrough innovations depend on innovative entrepreneurs being able to find funding independent of the insider incumbent institutions, usually self-funding.

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Experts and Epistemic Monopolies

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THE INNOVATIVE ENTREPRENEUR

The central question of economics is why some economies ignite and sustain growth, and others do not. This was the question with which Adam Smith (1976) started the discipline and still today Nobel Prize winner Robert Lucas has observed that ‘once you start thinking about economic growth, it is hard to think about anything else.’ Several economists (e.g., Aghion, 2002; Baumol, 2002; Caballero, 2008; DeLong & Summers, 2001; McCloskey, 2010; Mokyr, 1990; Schumpeter, 1950), though in a minority within the profession, hypothesize that the main source of economic growth is the process of creative destruction.

Schumpeter and others recognized that the primary agent of creative destruction is the innovative entrepreneur. It follows that if we seek to encourage innovation and economic growth, it is useful to explore more fully what is required for the innovative entrepreneur to succeed. I will argue that entrepreneurs have two epistemological advantages over credentialed experts. They “know” less of what is false, and they (informally) know more of what is true. They know less of what is false because they are either ignorant of, or willing to ignore, the currently dominant theories. They know more of what is true because they have more informal knowledge (whether local, serendipitous, tacit, or inchoate). Exploring what the entrepreneur knows and the implications for innovation, economic growth, and policy, is the subject matter of the epistemology of entrepreneurship.¹

ENTREPRENEURS ARE TYPICALLY NOT MASTERS OF CURRENT THEORY

Major breakthrough innovations almost always arise from individual entrepreneurs or small start-up firms, rather than from large incumbent firms (Baumol, 2005; Christensen & Raynor, 2003; Darby & Zucker, 2003; Gilder, 1993, p. 90; Klein, 1977). For example, William Baumol has documented (2005) that a very large number of “breakthrough” innovations have arisen from entrepreneurially based small firms, rather than the research and development labs of large incumbent corporations.

There may be multiple reasons for this. Christensen and Raynor’s account (2003) is based on their theory that disruptive innovations take a long time and much effort to develop, and initially do not generate sufficient profits to support a large incumbent firm’s infrastructure or to satisfy Wall Street’s expectations for the incumbent firm’s short-run performance.

Another reason is that the formalized decision procedures of large incumbent firms are well designed to incrementally improve the features, quality, and production process efficiency of already-known products, but are not well designed to bring a radically new breakthrough product into existence. Baumol (2005) and Gilder (1993, pp. 88–91), suggest that the reason is that the most far-reaching innovators are often attempting to do something that expert (conventionally well educated) opinion believes is highly unlikely (sometimes impossible) to accomplish. Baumol (2005) goes so far as to suggest that too much theoretical knowledge can be a disadvantage to the entrepreneur because it will discourage him, even when the theory is wrong, from attempting what the theory views as impossible.²

Baumol's initial hypothesis was that it is useful for an innovative entrepreneur to be ignorant of the currently dominant theory. Some examples fit the Baumol formulation; for example, Marconi was probably ignorant of the physics that suggested radio wave broadcast from Britain would not curve to be received in Canada. But other examples may not fit as well; for example, Venter was probably aware of the theory that suggested that his team's gene-sequencing methods would not work.

Scientist/philosopher C.S. Peirce is widely quoted as saying that true theory is what would be achieved after "infinite inquiry."³ This implies that what theory we have after *finite* inquiry falls short of truth and can be improved upon. Thus, both the improvement in theory and the achievement of practical technical progress depend on not allowing oneself to be overly constrained by the currently dominant theories. Avoiding the constraint can be accomplished in more than one way. Like Edison, or Ford, or Disney, or the Wright brothers, or Marconi, one can avoid higher education entirely. Or like Alexander Graham Bell, one can attend higher education, but not study the theories that would constrain one's innovation. "Bell ... knew very little about Faraday, electricity, or the telegraph" (Schwartz, 2004, p. 22). Or like Robert Metcalfe or Craig Venter, one can know the current theories, but not take them seriously enough to feel constrained by them. Robert Metcalfe has said "Ethernet works in practice but not in theory" (as quoted in Gilder, 2002, p. 81). He proceeded to make Ethernet work, much as Marconi proceeded to transmit across the Atlantic, Venter proceeded to sequence the genome, and Galileo proceeded to show that the earth, indeed, moved. For technology and science to advance, rebels must have the freedom and the means to show that the currently dominant theory is wrong.

My improved version of the Baumol hypothesis is that it is useful if an innovative entrepreneur does not hold the currently dominant theory

in too high regard. This more general version encompasses the case where the entrepreneur is ignorant, and also encompasses the case where the entrepreneur is aware of the dominant theory, but understands that dominant theories change and are subordinate to the evidence of experiment and practice.

The Baumol hypothesis is surprising and important enough to justify devoting some space to illustrative examples. Baumol (2005) himself presents examples of prominent breakthrough innovators who, by the standards of our time, and even by the standards of their own time, did not possess a high level of formal education.⁴ His specific examples (p. 34) are: “Watt, Whitney, Fulton, Morse, Edison, and the Wright brothers.”

Other examples could have included Henry Ford, whose formal education ended with an apprenticeship at age 16, and who explicitly said that ‘mechanics’ get ideas from machines, not from books (Brands, 1999, p. 96), or Walt Disney who was not college educated and directed “jibes” at college-educated employees (Barrier, 2007, pp. 213–214). Marconi’s pursuit of sending wireless telegraph signals across the Atlantic was done in the face of a contemporary theoretical physics that predicted the impossibility of the venture, due to the theoretical expectation that the waves would follow a straight line into space (Larson, 2006). Craig Venter’s entrepreneurial decoding of the human genome provides another relevant episode (Shreeve, 2004). A leading theorist “proved” the impossibility of a creative gene-sequencing technique. As a result, the government gene-sequencing team rejected the technique out of hand. It was Venter’s team that tried the technique and proved it could work.

Another example occurs in John Nye’s discussion (1991, p. 148) of the “revolutionary Float-process of glass-making.” He approvingly quotes from Barker’s study (1977, p. 203) that “The scientists, all too aware of the theoretical difficulties of what was being attempted, would not have set off in the first place ...” The (note this should be closing quotation mark) work was carried out by “young” engineers who had apparently been unaware of the theoretical difficulties. They succeeded “only after years of continuing failure and sustained financial loss” (Nye, 1991, p. 148).

A further possible example might be Jimmy Wales, the entrepreneur behind Wikipedia, who was hired by a Chicago investment firm because of his graduate degree in finance, but who concluded that the firm’s pricing practices had no theoretical foundation. Their pricing worked in practice, even if it did not work in theory. Lih (2009) suggests that Wales found this to be an important lesson that he used in the development of Wikipedia. Wales would not let theory rule out what might work in practice and he

would not exclude the uncredentialed as either consumers or producers of knowledge (Lih, 2009, p. 10).

If entrepreneurial practice was less constrained by current theory, the expected result would be an increase in the efficacy of practice. But an added and paradoxical result would be the likely improvement of theory itself. The point can be illustrated by an example from the Aristotle discussion in Rosen's, *The Most Powerful Idea in the World* (2010, pp. 6–8). For 2,000 years scholars rejected out of hand the possibility of the existence of a vacuum because of Aristotle's deductive (tautological/sophistical) argument about the theoretical impossibility of a vacuum. This led both scholars and practitioners to ignore the work of the ancient engineer Heron in which a vacuum was accurately described. The logjam was only broken when some scientist/engineers succeeded in mechanically producing and proving a vacuum, most notably including Galileo's admirer Torricelli (Rosen, 2010, pp. 8–10). The point is not that innovators need to be ignorant of the scientific theories of their day, but that, if not ignorant, then they should at least view the theories with a healthy degree of skepticism. When practical innovators resisted allowing themselves to be constrained by the currently dominant Aristotelian theory, they achieved the results that undermined the dominant Aristotelian theory, which eventually helped produce an improved theory.

More recent examples can be adduced. I have already mentioned how Marconi's ignoring dominant theory led him to broadcast across the ocean, which eventually led to an improved theory. Burke recounts (1986, p. 315) how Planck's theory of radiation implied that background radiation from stars would be too weak to be detected – so for 30 years no one tried to detect it. Finally, a practical problem at Bell Labs with car radio background static (Burke, 1986, p. 315) (or in an alternative account (Burke, 1997, p. 199) a practical problem with luxury liner radio reception) led to detection of the radiation.⁵

Judging the soundness and generality of Baumol's claim has become more difficult because historical accounts of inventive and entrepreneurial success are apt to be biased in favor of a greater role for theoretical knowledge. Consider one extremely important example, the invention and entrepreneurial innovation of the steam engine. William Rosen (2010) explains that Newcomen has been given less than his due by academic historians because of his lack of academic credentials and connections. The adage that history is written by the victors is only one example of how historians can bias history in the direction of their own beliefs and interests. Historians are usually academics and they are predisposed to

believe that the work of other academics has been crucial during key advances.⁶

Even if historians can restrain their own prior beliefs, they face another obstacle to uncovering what happened. Those innovators who know the current scientific theories are also the ones most likely to document their own activities through letters, diaries, and the like. So, other things equal, their activities are likely to receive more emphasis from historians than are the activities of their more taciturn (and less theoretically informed) peers.

Besides these examples of major entrepreneurs who were lacking in theoretical or formal education, there is another body of relevant examples, consistent with Baumol's claim. It has increasingly been observed that the proportion of dyslexics among entrepreneurs in general (Logan, 2009), and innovative entrepreneurs in particular, is significantly higher than in the general population.⁷

Why are dyslexics overrepresented among innovative entrepreneurs? One reason sometimes given is that the dyslexic's academic disadvantage may force him to be more nimble and resourceful in other, more entrepreneurial, ways. Elsewhere (Diamond, 2010), I mention another reason: those, such as dyslexics, felons, and immigrants, who find other avenues for advancement closed off for them, may pursue entrepreneurship as one of the few remaining paths for improvement. Landes (1949), Nicholas (1999), and Stanley and Danko (1996) provide evidence that entrepreneurs prefer (at least for their children) the imagined security of professional sinecures. But sinecures are often acquired through standardized exams, and dyslexics tend not to excel at standardized exams. So some dyslexic entrepreneurs may become entrepreneurs, not entirely by choice, but because it is the only path open to them along which they may prosper.

But the relative *un*importance of theoretical knowledge in innovative entrepreneurship (the Baumol hypothesis) may also help explain why so many innovative entrepreneurs are dyslexics – what would be a barrier to the pursuit of many professions, may not be a barrier, and may even be an advantage, to the pursuit of entrepreneurship.⁸

To reiterate, my small elaboration of Baumol's view is that formal education becomes a constraint on innovation when it inculcates a theory and respect for the theory, to the extent that innovators do not try the experiments or technologies that would seem to violate the currently dominant theory. So, as with Bell, it would not be a disadvantage for an entrepreneur to be well educated in areas irrelevant to the attempted innovation. Some theoretical training might even be an advantage if it is combined with an attitude that appreciates the tentativeness of current

theory, and the subservience of current theory to experimentation and practice. But this may be hard to achieve in practice since the incentives and mental habits of those who spend their time studying and elaborating the current theory will naturally lead them to practice and value allegiance to the current theory. The goal would be to *use* theory, but not to *respect* it.

Consistent with this view, I further hypothesize that most of the use of science by entrepreneurs is opportunistic and mainly empirical. As a first step to grounding this additional hypothesis, I note here a few examples of the opportunistic use of science by entrepreneurs. One is the British entrepreneur John Wilkinson who loved iron, had himself buried in an iron casket, and more importantly, made the first iron boat. Many of his contemporaries wagered that it would sink, because they knew (common sense) that wood floats and iron sinks, when placed in water. But there is a scientific result written down by Archimedes and apparently understood by Wilkinson (from reading Archimedes, or from directly observing it himself) that an object will sink into water until it has displaced water equal to its weight. It is easy to design an iron boat so that this displacement occurs before the boat is deep enough into the water for the boat to sink. It was a big event, with a lot of people betting that the boat would sink; but it floated, leading to iron boats gradually replacing wood. (The casket story is mentioned in both Allitt, 2002 and Rosen, 2010; the rest is paraphrased from Allitt, 2002.)

A classic example of an entrepreneur making opportunistic use of science is Carnegie's use of a chemist to determine the iron content of ores:

We found ... a learned German, Dr. Fricke, and great secrets did the doctor open up to us. [Ore] from mines that had a high reputation was now found to contain ten, fifteen, and even twenty per cent less iron than it had been credited with. Mines that hitherto had a poor reputation we found to be now yielding superior ore. The good was bad and the bad was good, and everything was topsy-turvy. Nine-tenths of all the uncertainties of pig iron making were dispelled under the burning sun of chemical knowledge. (p. 246)

What fools we had been! But there was this consolation: we were not as great fools as our competitors ... Years after we had taken chemistry to guide (p. 247) us [they] said they could not afford to employ a chemist. Had they known the truth then, they would have known they could not afford to be without one. (Carnegie as quoted in Rosenberg & Birdzell, 1986, pp. 246–247)

Later, chemists helped vastly improve the durability of steel:

..., with their aid, the life of a rail increased from two years to ten, and the car weight it could bear from eight tons to seventy in the forty years between the Civil War and 1905. Only a very few new technologies have had equal significance. (Rosenberg & Birdzell, 1986, p. 247)

Another example of an entrepreneur's opportunistic use of science may be J. Paul Getty's report (1963) that he was one of the first to rely on the science of geology to help him decide where to drill. Note that geology, like chemistry at the time of Carnegie, is a highly empirical – not theoretical – science.

Baumol himself recognizes (2005, pp. 50–51) that the modern relationship between academia and entrepreneurship is probably more complicated than the simple version of Baumol's account allows. Those on the fringes of academia may make a contribution, especially in the United States where the size of academia may allow more nooks for the fringes to survive, and where the entrepreneurship of faculty seems generally to be more tolerated. Ray Kurzweil and Carver Mead (Gilder, 1990) may be examples of those on the fringes of the academy who have made major innovations.

Maybe the observations of Nelson (2008) and Rosenberg (2009) suggest a small partial answer to Baumol's puzzle (2005) on how to design higher education to advance innovative entrepreneurship. Nelson (2008, p. 5) praises "... the traditional openness of American Universities to entrepreneurial activity on the part of their researchers." Rosenberg's (2009) account of entrepreneurship in medical equipment is a complicated story. Closeness to universities matters. But advance has come from interdisciplinarity directed at solving a problem (getting a practical task done). The relevant university scientists were also often heavily involved in the businesses that applied the ideas (in the United States, but not elsewhere). Allowing professors to be entrepreneurial gives them incentives to apply their knowledge, and also gives them incentives to appreciate the value of the practical applicability of their theorizing. That is, not only are they advancing entrepreneurship, but they also may be advancing science.

SOME IMPORTANT VARIETIES OF NONTHEORETICAL OR PRE-THEORETICAL KNOWLEDGE

The great potato and memory chip entrepreneur J.R. Simplot kept a plaque on his desk that read: "*Nothing will ever be attempted if all possible objections must be first overcome.*"⁹ (Gilder, 1992b, pp. 23–24, italics in original). Sometimes the objections cannot be overcome because the entrepreneur's knowledge of how to overcome them is vague, or hard to

convincingly communicate. Or sometimes the objections cannot be overcome because the entrepreneur only has a confidence that she will learn how to overcome them, but do not yet possess the knowledge of how she will do so.

The second case often is based on a kind of knowledge: the knowledge from past experience of how oneself, or other entrepreneurs, have been able to overcome past objections through a trial-and-error process of entrepreneurial discovery. Perhaps this is the sort of knowledge that Brunelleschi had when he committed to building a dome bigger than had ever been built, and bigger than he initially knew how to build (see King, 2000). Another example might be how Disney made a commitment to Winkler to produce animated films, before Disney fully knew how he was going to do it (Gabler, 2006).¹⁰

But in this section, I mainly consider the first case, where the entrepreneur possesses some kind of unsystematic knowledge that is vague, or hard to communicate. Theoretical accounts of innovative entrepreneurs, as well as biographical and anecdotal accounts, often attribute to them informal knowledge not possessed by others. Rosenberg, for instance, writes (1994, p. 55) that the individual entrepreneurial act is based on “intuition” (as well as “charismatic leadership”).

An authoritative taxonomy of the kinds of informal knowledge would be useful, but may not yet be possible, as long as we continue to learn more about how we know and what we know.¹¹ So for present purposes I will make some rough distinctions, without claiming that my distinctions are final or authoritative. Broadly, there are two kinds of knowledge: formal knowledge (that is theoretical and codified) and informal knowledge. Many terms have been used to label types of informal knowledge, including: local, particular, unique,¹² serendipitous, tacit, fuzzy, inchoate, intuitive, unsystematic, vague,¹³ partial,¹⁴ insightful, foresight, hunch, epiphany, educated guess, etc.

Without arguing that it is an authoritative or complete taxonomy, I will mainly mention three kinds of sound, but hard to communicate, knowledge. The first kind is the local, particular knowledge that Hayek emphasized (1945), including as a subcategory, the serendipitous combining of knowledge and experiences. (See Burke’s books for many examples.) The second kind would be Polanyi’s tacit knowledge that, like knowing how to ride a bike, is hard to verbalize. (Many of Gladwell’s examples in *Blink* (2005) are of this kind.) The third kind would consist of the gradual, difficult clarification of initially inchoate intuitions. (See Foster & Kaplan, 2001; Johnson, 2008.)

LOCAL, PARTICULAR, AND SERENDIPITOUS KNOWLEDGE

Hayek's (1945) local, particular knowledge is knowledge that a person has by virtue of making observations or connections based on evidence or events in a particular time and place. Hayek's local knowledge of a particular time and place is not inherently hard to verbalize. Part of the problem with effectively communicating it is that there is so much of it, and each of us can retain and access only a small part.

Serendipitous discoveries can be viewed as a kind of Hayekian local particular knowledge. The word "serendipity" is derived from a story about three princes from "Serendip" which is the Persian word for Sri Lanka. Apparently they were not just Sri Lankans, but metaphorically they were Austrian Sri Lankans. "If you read between the lines, you'll notice that the princes were always traveling to interesting places and that they were always on the lookout for chance wisdom" (Schwartz, 2004, p. 63). They took advantage of the unexpected local knowledge that they encountered in their travels, and they were able to take advantage of that knowledge because they were alert to it.¹⁵ (See Kirzner (1973) for the importance of entrepreneurial alertness.)

Important examples of serendipity have been documented in several sources, including Flatow (1993), Meyers (2007), Root-Bernstein (1989), Root-Bernstein and Root-Bernstein (1997), and Merton (2006). The works of James Burke (e.g., *The Pinball Effect* 1997) also provide countless examples of inventions (e.g., vulcanized rubber) that resulted from serendipitous discoveries. Although many examples have been documented, there is good reason to believe that many more remain undocumented. In comments on Meyers' book, Dr. Robert Stanley (Editor of the *American Journal of Roentgenology*) has noted (Stanley, 2007) that: "In reading this book, I learned of the very common and recurring theme that the discoverers of major breakthroughs were often reluctant to reveal the chance events that led to their ultimate breakthrough." When an innovator attributes an innovation to serendipity, the innovator's credit for the innovation is likely to be reduced. As a result, we would expect first-hand reports to be biased in the direction of underreporting the importance of serendipity.

The innovation that results from serendipitous discoveries is often due partly to luck and partly to preparation. An example of the luck part is when complementary component inputs or technologies come together that make the breakthrough possible. Grove (1999) has emphasized the importance of

complementarities in innovation, and Burke's *Connections* book could be viewed as an energetic elaboration on the same theme. Burke specifically has some comments on how the successful inventor is often the one in the right place when several necessary component technologies become available. He gives the arc-lamp and Edison's phonograph as examples.¹⁶

Based on examples such as these, serendipity is often viewed simply as a form of good luck. And so, innovative entrepreneurs who have benefitted from serendipity have often been viewed as merely lucky. For example, Nye (1991) discusses famous, important entrepreneurs who failed, both before and after, their signature innovations. From these failures he infers that entrepreneurs are usually "lucky fools." Mokyr (2009, p. 353) summarizes Nye's view as credible, without fully endorsing it.

However, it is a mistake to believe that the fruitfulness of serendipity is simply a product of luck. While no one would deny that luck plays a role in entrepreneurial success, there is evidence that luck is not the whole story. Gompers, Kovner, Lerner, and Scharfstein (2010) have shown that entrepreneurs who have succeeded in the past are more likely to succeed in the future. And they speculate that this success is due to some underlying knowledge or skills or traits of the successful entrepreneur.¹⁷

For example, it takes effort to be alert enough to see the unexpected. Hallinan discusses (2009) the evidence from psychology. If something is too unexpected, we commit the "looked but didn't see error," as illustrated with the experiment where a pedestrian was talking with a stranger, and two other people walk by with a door blocking the stranger. The stranger switches with one of the door carriers, and then resumes the conversation. Only a minority of the pedestrians realize that they are talking to another person (pp. 14–15 and 18–19). If something is outside of our interests or responsibilities, or experiences, we often visually "skim." We experience "change blindness," not seeing what is different from what we usually see (pp. 14–19). (For example, when proofing my own papers, I often "see" the word spelled as it should be spelled, rather than as I have actually spelled it.) If something is too hard to see, we eventually give up looking for it, which is called "the beer-in-the-refrigerator problem" (p. 21). So, successful entrepreneurs would be those with greater ability, or greater discipline, to be alert to seeing the dissonant or unexpected.¹⁸

Another reason that serendipity is not just a matter of luck is that it also takes effort to be able to *remember* the dissonant or unexpected, unless quickly written down or repeated. For example, McCloskey advocated, and Schumpeter exemplified, the desirability of always being ready to write

down quick notes on passing ideas or observations, to be sure they are not lost forever as they exit short-term memory (McCloskey, 1985; on Schumpeter's note-taking see: Allen, 1991, Vol. 1, pp. 16 and 28; Vol. 2, pp. 40 and 173). Otherwise, our long-term memories are likely to paper over the unexpected, and modify our memories to make them less dissonant with our prior beliefs. It also takes effort to see how the unexpected can be used. This may explain why innovative entrepreneurs are often impatient or dissatisfied (as claimed in Tom Peters' 2003; and as expressed in the title of David Sokol's book *Pleased but Not Satisfied*, 2007). Maybe those who find solutions are more likely to be those who are acutely aware of the problems.

And one can be dissatisfied. Tom Peters has emphasized (2003) that many entrepreneurs see plenty of room for improvements and are impatient for progress.¹⁹ It is a burden to carry around unsolved problems – how much more relaxing to simply accept whatever is. But with the burden comes a benefit, because the dissatisfaction keeps them alert to unexpected events or connections that might be useful to solve their problem. (See Tom Peters' examples (2003) of dissatisfied entrepreneurs; and the story in Evans' *They Made America* (2004) of truck driver Malcolm McLean having to wait to unload his rig at the docks and eventually becoming the innovative entrepreneur who standardized shipping containers.)

Louis Pasteur lectured in 1854 that: "Chance favors the prepared mind" (as quoted by Schwartz, 2004, pp. 64 and 216 from the *Oxford Dictionary of Quotations*). Besides being impatient with problems, how else can the entrepreneur prepare her mind for a serendipitous inspiration? In the case just discussed of new complementary inputs and technology, alertness helps. Broad knowledge and experience help. One can seek out times and places where there are diverse people, contexts, experiences, and projects. (Which is recommended in: Dyer, Gregersen, & Christensen, 2009; Koestler, 1964; Schwartz, 2004.) One can seek out the company of innovators (in cities where innovators gather, or classrooms where they teach, or web sites where they post, or books which they have written). Gilder emphasizes (1992b) that entrepreneurs are willing to learn. They listen carefully and with curiosity. Getty emphasizes (1963) how in his early years he spent a lot of time listening to wildcatters talk about their experiences in the oil fields.

If serendipity matters, then it is a matter of concern if funding does not support situations in which serendipity is likely to arise. Dr. Stanley in his review (2007) notes:

...., Dr. Meyers raises important fundamental questions about how the nation's research dollars are currently spent. In his concluding remarks, he emphasizes the need to foster

rather than stifle creativity and for the funders of research not to be so rigid and proscriptive in the way research studies are conducted and research dollars allocated.

Merton in his posthumous book on serendipity (2006, pp. 207–218) also notes that institutional funding pressures (whether from government, corporations, or the academy) may reduce the ability of the scientist to experience serendipity.

Even if we grant that luck may play a nontrivial role in serendipitous innovation, it may still be good policy to allow the innovator to keep the full reward from the successful innovation, so long as some of the success is due to hard work or judgment. If, as is likely, it will always be very hard to disentangle how much of the success is due to luck and how much to choices of the innovator, we may want to bend over backward to make sure that the innovator is fully rewarded for the part of the innovation that was due to choice. We would want to do this from a sense of justice, from a desire to provide ample incentives for future innovation, and from a desire to provide those who have shown good judgment with ample resources to allow them to pursue even more ambitious future innovation.

TACIT KNOWLEDGE

A good example of tacit knowledge occurs early on in Steven Johnson's *Mind Wide Open* (2004, pp. 37–40), although he does not identify it as such. He takes a test where he identifies people's emotional state based just on seeing their eyes. He is surprised that he only gets 5 wrong out of 36 (he had thought he would get half wrong). He cannot explain the mental process by which he does this. And when he tries to think about it explicitly, he is less sure of his judgments.

The standard example of what is meant by tacit knowledge is the knowledge of how to ride a bike. A bike-rider knows how to do it, but often is not able to clearly describe in words how it is done. And tellingly, the tacit knowledge is often acquired over an extended period, in a process that involves some trial and error.

This method of learning may have wide applicability. Malcolm Gladwell in *Blink* writes (2005, pp. 5–8) of how some experts, through long experience in their fields, develop an ability to make judgments with surprising speed and accuracy. For example, Frederico Zeri, Evelyn Harrison, Thomas Hoving, and Georgios Dontas were able to judge a statue as a fake, even

though application of the accepted theoretical criteria for authenticity had been judged by others to have been met (but it didn't 'look right' to the experienced experts).

In *Outliers* (2008), Gladwell discusses one of the premier entrepreneurs of our time, Bill Gates. In that account the young Gates had the key advantage of access to a computer when there were few computers to access. (Gates and his friend Paul Allen, snuck out of their parents' homes in the middle of the night to access unguarded computer terminals at the hospital at the nearby University of Washington.) Only a few locations had computers, and even fewer had computers that were available for hours of programming by a teenager. So in a sense, Gates' knowledge was local. But Gladwell emphasizes that part of what Gates gained came from the large number of hours that Gates was able to practice at programming. He was developing a tacit knowledge about what could be done, and how to do it most efficiently.

GRADUAL CLARIFICATION OF INITIALLY INCHOATE INTUITION

According to Greek mythology, the goddess of wisdom, Athena, emerged full-grown, well-armed, and beautiful from the head of Zeus (see, e.g., Bulfinch, 1979, pp. 7, 107, and 116).²⁰ Unfortunately in the real world, actual new ideas seldom emerge full-grown and beautiful. They often must be nourished for a time, sometimes a long time, during which they appear to many to be weaker and uglier than the currently dominant ideas. The noted philosopher of science, Imre Lakatos appreciated this, in his methodology of scientific research programs (1978). For him a "progressive" research program was one that, although initially flawed, had the promise of eventually being worked out to be better than the alternatives. Of course in the early stages the "rub" is how to decide, and who is to do the deciding, about which initially inferior and flawed program has "promise"?

Steven Johnson discusses (2008, p. 74) how intellectual progress often comes from fragments of thoughts, remembered and nurtured, sometimes over long periods of time. He gives Joseph Priestley as an example, suggesting that Priestley's work environment and research habits combined to allow him to take the initial fragments of great ideas and to nurture and sustain them over time. One of those habits was to take notes when ideas arrive, so as not to forget them. Johnson observes that modern corporations are not likely to have sufficiently long time horizons to nurture or reward thought processes that take several years.

Einstein once said “If I had 20 days to solve a problem, I would take 19 days to define it” (as quoted by Berkun, 2007, p. 127). Einstein’s observation implies that many important problems are not well defined during the majority of the time that it takes to solve them. Perkins has discussed (2001, pp. 9–10 and 84–85) five steps that he believes are characteristic of much “breakthrough thinking,” the first of which is “the long search.” Richard Posner’s aging book (1995) has emphasized that while some sorts of ability depend more on raw brain power, others depend more on the right sorts of experiences, properly processed.

The gestation/incubation process has been sufficiently noted to be the subject of advice on how to think effectively. Bertrand Russell suggested thinking hard about a problem and then letting it gestate (Russell, 1961, p. 64, 1963, p. 211). Deirdre McCloskey (1985) suggested carrying around a stack of 4 by 6 cards to jot down thoughts and later organize and re-organize them.²¹ In Allen’s two-volume Schumpeter biography (1991), there is a nice passage about a couple of students at Harvard seeing Schumpeter chat with a neighbor, after which he stood at his doorstep and wrote a note to himself – they saw it as one more peculiarity of the old professor. Elsewhere in that book it is noted that sometimes Schumpeter would stop in the middle of a lecture, take out a piece of scratch paper, and make a note to himself. (At least as of early 2006, one could still find many of Schumpeter’s scribbled notes in the Harvard Schumpeter archive.)

It is common to observe that eventually-great innovations do not emerge full-grown. For example, Höyssä and Hyysalo (2009) identify a “fog of innovation” due to the constraints and opportunities that will be faced during the process of innovation. Gilder more vividly observes that “... the ark of reason sails in turbulent and fog-bound seas” (1993, p. 45). Foster and Kaplan (2001, pp. 118–119) emphasize that the most important phase of the creative process is the “incubation period.” They quote Newton on this. The inability to plan for a long incubation period is one of the main disadvantages of incumbent, mainstream institutions (companies) versus entrepreneurial start-up firms. A plausible account of many entrepreneurial success stories suggests that entrepreneurs who are eventually successful often pursue initially inchoate ideas, through a long period of gestation (Collins, 2001; Gilder, 1984; Gladwell, 2008; Johnson, 2008). Baumol (1993) lists “persistence” as one of the characteristics of entrepreneurs.

Others have made similar observations. Jim Collins in *Good to Great* discusses the long gestation of many innovative companies’ ideas. Nucor, for example, did not just arrive overnight as a full-blown epiphany, as the business press would have you believe. Instead, “Nucor began turning the

flywheel” (Collins, 2001, p. 177). Nucor’s innovations were slowly and gradually nurtured. Morita discusses (1986, p. 79) how the visit to his office of a colleague named Ibuka, speaking of his desire to be able to listen to personal music, helped clarify and solidify an idea Morita “had been mulling ... over for some time.” The idea eventually became the Sony Walkman. The rise of Nucor and the Sony Walkman are illustrations that the epiphany account is generally less true, and the gradual progress and clarification account is generally more true.

Schwartz (2004) describes what the entrepreneur does as “reframing possibilities.” Sometimes, as with Alexander Graham Bell, this reframing takes a long time. All the science that ended up getting used in the telephone innovation had been around for decades. But it took Bell to reframe the possibilities in a process that was not linear, and that took time²² (Schwartz, 2004, pp. 21–25).

It often takes time for experiments to yield fruit, for the inchoate to become choate, and for the serendipitous event to happen. When skills are necessary, it also often takes time for an individual to become sufficiently highly skilled. In *Talent is Overrated* (2008), Colvin says that the key to excellence is deliberate practice, and he also makes the point that it is not in the interest of the managers of incumbent firms to encourage, or even allow, employees to spend time in deliberate practicing. The key reason is that the benefits of deliberate practice, when they occur, are long term, and there is no reason to think that the employee will still be with the firm when the benefits arrive. In the slow gestation of skills, just as in the slow gestation of ideas, the firm has too little knowledge about whom to invest in (the knowledge is uncertain, and asymmetric) and too little incentive to invest (since they cannot enforce long-term commitments from the employee).

So apparently there is a long gestation not only for ideas, but also for the skills to make the ideas happen. And since incumbent corporations do not have long-term horizons, or long-term commitments from workers, they have a disadvantage at creating long-term breakthroughs.

INNOVATION IS OFTEN ENHANCED BY RAPID, FREQUENT EXPERIMENTATION

We have seen that sometimes breakthrough innovations benefit from the kind of persistent long-term gestation process that can change the inchoate into the clearer cut. Incumbent firms (and governments) typically have neither the knowledge nor the incentives to support such a process.

Paradoxically, incumbent institutions also typically lack the knowledge and incentives to support a much faster and more experimental process of improvisation. The fundamental problem for the incumbents is the same in both cases. When there is either slow gestation or fast improvisation, the incumbents have difficulty articulating the time frame and likelihood of success. And they must be able to articulate, so that they can defend their decisions to boards and stockholders (in the case of incumbent firms) or to committees and taxpayers (in the case of governments). In the previous section, I discussed slow gestation. In this section, I discuss fast improvisation.

Some forms of experimentation are well suited to the university or corporate lab. For example, the classical controlled experiment is a frequent method of the sciences. More broadly “experimentation” can refer to any trial-and-error method designed to find out what works. Some of the trial-and-error methods well suited to corporate labs might include testing substances for drug efficacy, or new compounds for strength, conductivity, and the like. In such cases, past similar trials have yielded data on the costs and benefits of the research. To use the Knightian distinction, the activity is risky, but not uncertain (Knight, 1965). The probabilities are known, and hence the research process can be managed and optimized.

In other cases, where some new breakthrough is being pursued, the experiments take place more in the realm of uncertainty than risk. Here success is an unknown function of intuition, luck, and persistence.²³ To contrast this second type of experiment with controlled experiments, Bhidé (2000, pp. 15–16, 2008, 2009, p. 21) labels it “improvisation.” In discussing improvisation he quotes (2000) an unnamed entrepreneur as saying that the activity of the entrepreneur is more like “jumping from rock to rock up a stream rather than constructing the Golden Gate Bridge from a detailed blueprint” (p. 18). When I discuss experimentation in the rest of this section, I usually mean something closer to Bhidé’s improvisation, than to the expert scientist’s controlled experiment. (Sometimes the trial-and-error improvisation process also is described as “tinkering” as, for example, when Brands (1999, p. 95) applies the word to Henry Ford.)

Stan Metcalfe has gone so far as to suggest (2004, p. 158) that the “central dynamic of modern capitalism” is its “experimental nature.” Gilder (1984, pp. 252–254, 1993, pp. 34–38) proposed that innovative entrepreneurs are engaged in an experimental knowledge collection process, akin to Popperian hypothesis testing (Popper, 1959). One immediate implication is that even failed ventures increase knowledge in a socially useful way. (In the same spirit, see McGrath & MacMillan’s, 2009).

Experiments that yield the most unexpected results are most informative, but are also the least likely to be funded by the government, the banks, or even the venture capitalists. As a result, at the crucial early stages, it will be necessary for an entrepreneur to be self-financed. The self-financing character of entrepreneurship has implications for a variety of government policies. (More will be said on this in the next section.) Society benefits from entrepreneurial experiments being undertaken at the entrepreneurs' expense. This would be true even if the source of entrepreneurial hypothesis is random (Mokyr, 2009, p. 353; Nye, 1991). But it would be even more true to the extent that the entrepreneurial hypothesis is due to informal knowledge that is classically local (Hayek, 1945), serendipitous (Burke, 1978, 1997), tacit (Endres & Woods, 2010; Langlois, 2003; Polanyi, 1966), or inchoate (Foster & Kaplan, 2001).

Consider two alternative models for the process of generating knowledge. The first "posts" knowledge claims slowly, only after they have been carefully screened by experts. The second "posts" knowledge claims quickly, and then weeds out false claims over time. Peer-reviewed journals follow the first model, and Wikipedia follows the second. The usual belief is that knowledge generation under the first model will be slow and costly, but the knowledge will be reliable. And the usual belief is that knowledge generation under the second model will be fast and cheap, but the knowledge will be highly unreliable.

However, the usual belief is currently under challenge, for instance by Anderson (2006), who suggests that Wikipedia produces much more knowledge, that errors are usually quickly eliminated, and that overall and on-average the error rate is very low. According to George Gilder's description (2002), a similar process takes place in the Ethernet. Ethernet packets of information are fast and cheap, but error-prone. However, the Ethernet's enormous redundancy and error-correction capability result in extremely accurate messages.²⁴

A historical example of how faster trials and errors might speed innovation appears in Thomas Hager's *The Demon Under the Microscope* (2007), where he writes of how during WWI Gerard Domagk was able to observe in a couple of years more surgeries than many surgeons observe in their whole careers. Much can be learned in such an environment. A similar example would be Alexis Carrel (sic), the Nobel Prize winner, who developed his techniques for suturing arteries during WWI (Friedman, 2007).

The point is not to praise war, but to note that war creates an environment where medical innovators are not highly regulated, and so where

innovators are freer to experiment and learn. And it also presents an environment in which there are many cases, and so induction, and experimentation may be more fruitfully applied. In medicine, the issue would then be how to ethically emulate the constructive, creative aspects of the war environment. Perhaps it would be an environment in which patients give informed consent and in which they otherwise have no hope, and so are better off with fast or experimental care, than with no care at all?²⁵ Fortunately the costs of error are usually not so high outside of medicine, and so more rapid experimentation can be advocated in most entrepreneurial venues, without raising the difficult ethical issues that occur with medical experiments.

Rosenberg and Birdzell (1986) argue that the primacy of evidence over theory is a key reason for the economic success of the West. Before Galileo, the dominant theory had an account of how solid objects fall. But Galileo's experiments proved that theory wrong. Rosenberg and Birdzell argue that the explanatory power of Galileo's methods established the primacy of experiment and evidence, over theory. Paradoxically, focusing more on experiment and less on theory may actually be the fastest way to improve theory. The reason is that fast experiment may be the best way to reveal the flaws in current theory, and to correct the flaws.

Experiments that yield the most unexpected results are most informative, but are also the least likely to be funded by the government, the banks, or even the venture capitalists. There are two main reasons. The first is the difficulty in judging which innovative entrepreneurs are likely to succeed. The second is that success often takes a long and variable time, and the institutions are looking for quicker results. As a result, at the crucial early stages, it will be necessary for an entrepreneur to be self-financed.

FINANCING ENTREPRENEURIAL INNOVATION

More generally, when an entrepreneur's knowledge is of any of the informal kinds, especially when it goes against current theory or beliefs, it will be intrinsically hard to convince others of the plausibility of the plan, and so the plan will need to be self-financed. Conventional bodies of experts, whether government or corporate, will refuse to fund entrepreneurial ventures that are inconsistent with current systematic knowledge (the accepted wisdom, usually based on current theories). This is so even though, when they succeed, we learn more from such ventures than we do from more conventionally mundane (safe) ventures.²⁶

In the crucial early stages of sending wireless telegraph signals across the Atlantic, Marconi's efforts were largely self-financed by himself, his friends, and his family (Larson, 2006). At the early stages of adding sound to his cartoons, when Walt Disney was unable to obtain financing from banks, he talked relatives into loaning him the crucial funds (Gabler, 2006, pp. 82 and 131). George Eastman used his life-savings to finance his photo-developing business (Burke, 1997, p. 36). Baumol (2005) has argued for the generality of these sorts of cases.

Financing an innovative entrepreneur's later ventures may come from banks and venture capitalists. But the entrepreneur's big challenge is to acquire the capital for the first success. Venture capital is sometimes thought to be an important alternative to self-financing, but as Amar Bhidé notes (2000, pp. xiv–xv), venture capital firms usually look to fund firms with well-constructed business plans – firms, in other words, that can quickly make the transition from start-up to corporation. He suggests that though these may be important firms, they are relatively few in number and unlikely to be the ones that bring us breakthrough innovations.

The sometimes long-gestation period for breakthrough innovations might provide the basis for an additional reason for the importance of allowing for the self-financing of entrepreneurs. Corporations are not particularly good at measuring, rewarding, and incentivizing, contributions that are initially vague and uncertain, and that require multiple years for fruition. As evidence, consider the quarterly and annual goals and performance reviews, common in businesses. (The “accountability” movement in academia has moved academia in this direction as well.)

David Sokol (the former CEO of MidAmerican Energy) and Robert Slezak (the former CFO of Ameritrade) both have talked²⁷ of the constraining effects of companies having to meet Wall Street's expectations for the quarterly and annual numbers for revenue and profits. My memory is that Sokol gave this as one of the reasons for (and benefits from) his taking MidAmerican Energy private. In a similar vein, Christensen and Raynor (2003) wrote about Wall Street's “growth imperative.”

It might be argued that self-financing is not so crucial because successful innovative entrepreneurs can be identified by a unique set of traits. Venture capitalists, or even banks, could then fund those who have the traits, even if the venture capitalists and banks do not share the knowledge on which the entrepreneurial innovation is based. The main problem with this approach is that the traits that are identified as belonging to innovative entrepreneurs are usually attached to particular individuals only *after* they have succeeded. Smick (2008, pp. 69–70) writes of how surprised he was at

the early frat-house demeanor of trader Paul Jones; and he generalizes to suggest that Jones is like his fellow-risk-takers, the entrepreneurs who are “outside the mainstream” (pp. 70–71) and thereby do not initially look like future successes. Gilder paints (1990, 1992b) a similar picture.

You might ask: why could not venture capitalists or banks simply invest in those outside the mainstream? But just because most entrepreneurs are rough-hewn outsiders, it does not follow that most rough-hewn outsiders are promising entrepreneurs. In that case financiers might look for more specific characteristics. For example, charismatic leadership is often identified as a key trait of innovative entrepreneurs. But “leadership” is only bestowed on someone after she has led her enterprise to the successful innovation. The “leadership” label arrives too late to help with financing the initial success.

On this point, recall the earlier discussion of how Jim Collins berates (2001) the business press for creating the impression that entrepreneurial successes burst suddenly on the scene. Collins shows instead that the reality is that the success is usually the result of long, intense effort. For example, Nucor was ignored during the many years of its initial growth and struggle. Only later was it recognized by the experts as a success, and its founder identified as a leader.²⁸

Even within firms, it is notoriously difficult to judge the likely success of an innovative project. Edwin Mansfield found that even *after* the fact (Beardsley & Mansfield, 1978), let alone in advance (Mansfield, Wagner, & Schnee, 1971), it is sometimes very hard to measure the success of a technological project. At a Berkshire Hathaway annual meeting several years ago, I heard Bill Gates’ friend Warren Buffett say that he rarely invests in technological companies because he finds it extremely hard to forecast which ones will turn out to be successful. (He finds it easier to forecast that people will keep drinking Coke, and eating Dairy Queen Blizzards.)

The problem with incumbent firms, venture capitalists, banks, and governments failing to fund innovative breakthrough entrepreneurs is not primarily a problem of irresponsibility or even of lack of appreciation of the innovative entrepreneur. The primary problem is that these institutions have a fiduciary responsibility to do due diligence – in the case of the incumbent firms, venture capitalists, or banks, on behalf of the stockholders; in the case of the government, on behalf of the taxpayer. And the more fundamental the potential breakthrough innovation, the less these incumbent institutions will know which would-be innovative entrepreneur is likely to succeed.²⁹

Does anyone know? Well to some extent, the innovative entrepreneurs themselves know: they have access to their own informal knowledge. And

since they know, self-financing will remain the most efficient and the most morally defensible form of financing.

When incumbent corporations, venture capitalists, banks, or governments decide, they usually do what is safe and politically defensible to current constituents (Wall Street or voters), which is to follow current theory. The entrepreneurial system takes advantage of the inchoate individual knowledge that exists, but is not yet theoretically defensible, and allows that knowledge to percolate to success.

Blaug (1998) and Casson (1982, 2003) have argued that the more innovative the innovation, the less likely the entrepreneur will be able to convince mainstream funders of the promise of the venture, and the more likely that the venture will need to be self-financed, if it is to move forward. As Casson (1982, 2003) has observed, though the entrepreneurial and capitalist functions may in principle be distinguishable, in practice they will almost always occur together, especially in the higher levels of innovative entrepreneurship.

CONCLUSIONS

Academically marginal entrepreneurs created most of the major breakthrough innovations of capitalism's past two centuries. Many such entrepreneurs lacked higher education, but "academically marginal" also includes those who were educated outside the academic establishment, or who innovated outside their area of academic training, or who rebelled against the academic establishment. The source of the entrepreneurs' successful innovations may sometimes have been partly luck, but often is luck mixed with forms of knowledge that are less articulate and formalized than the knowledge of the academy. Such knowledge can be called "informal knowledge."

Such knowledge can be local, or tacit, or initially inchoate. Although such knowledge can be hard to articulate, its existence and soundness can be established, largely by the greater success those who possess such knowledge have in situations where the knowledge would be useful. (Those who have the tacit knowledge of bike riding don't fall over as often when they try to ride a bike.)

To increase efficiency and reduce principal/agent problems, large organizations such as corporations and governments have systematic decision processes that involve forms and committees and explicit criteria. Such decision processes cannot easily accommodate informal knowledge.

If they try to fund based on informal knowledge, they will run up against two problems. One of these is the problem of distinguishing project proposers who possess genuine informal knowledge from those who merely claim to possess informal knowledge. (Think Khrushchev funding Lysenko.) The other is the problem of incumbent interests who lobby and bribe funders to induce them *not* to fund potentially disruptive innovators.

In future work, the implications of the epistemology of entrepreneurship can be drawn out for a variety of theoretical and practical issues. One example is that the epistemology of entrepreneurship reduces the likelihood that it will ever be possible to routinize breakthrough innovations, so that Schumpeter (1950) need not worry about the eventual obsolescence of the entrepreneur. Another example would be that the systematically pessimistic forecasting bias of economists (and other social scientists) can be understood because their academic forecasts tend to take account only of academically certified knowledge.³⁰ Such academics do not foresee the effects of nonacademic knowledge and entrepreneurial processes.

The epistemology of entrepreneurship that I have sketched also has implications for optimal tax policies related to income, inheritance, and capital gains (Gompers & Lerner, 1998; Holtz-Eakin, Joulfaian, & Rosen, 1994a, 1994b). Specifically a case can be made for lower marginal income tax rates, lower capital gains tax rates, and lower inheritance tax rates. The case is framed, not in terms of entrepreneurial incentives, not in terms of meritocratic justice, but rather in terms of productive efficiency.³¹ If more individual entrepreneurs have the means to self-finance their ambitious innovations themselves, or within their families, then we will learn more, faster, about what works, and what is true. The result would be more breakthrough innovations, faster economic growth, and higher standards of living. If the cases of Marconi, Metcalfe, and Venter are any guide, we may even expect positive spillover effects for the advance of theoretical science.

NOTES

1. I am not aware of any scholars who have made use of the phrase “epistemology of entrepreneurship.” Some of what Mokyr (2002) discusses might be considered relevant, though he is concerned with the relationship of two kinds of what I am calling formal or articulate knowledge. He wants to understand the relationship between articulate propositional scientific knowledge and articulate technical knowledge of how to get something done.

2. To avoid leaving a misleading impression of Baumol’s position, I should note that Baumol believes that knowledge of the current theories is an important enabler

of the incremental innovations that typically occur in incumbent firms and large industrial labs. And Baumol (2005; and especially 2010, pp. 32–33) believes that the cumulative benefits of incremental innovations can be very large, although they are far from being a substitute for the breakthrough innovations that typically arise from entrepreneurs and small start-ups.

3. See, for example, Margolis (1998, pp. 553–554).

4. In Jonathan Foreman's interview with British philosopher and historian Paul Johnson, Foreman reports that Johnson "... believes that Churchill benefited from never having gone to college: 'He never learned any of the bad intellectual habits you can pick up at university, and it explains the extraordinary freshness with which he came to all sorts of things, especially English literature.'" (Foreman and Foreman quoting Johnson in Foreman (2009, p. D6).)

5. High theory may sometimes be like the lead goose in Frank Knight's V-formation. When the flock changes course, the lead goose hurries to catch up so as again to be in the "lead" position.

6. Similarly, note that more academic chaired professorships and university budgets are supported by corporations, than by hungry, outsider entrepreneurs. So is it a surprise that most of the curriculum of business schools addresses the needs and interests of corporations instead of those of entrepreneurs?

7. Casson (2006) distinguishes between "high-level" and "low-level" entrepreneurs. The high-level includes Schumpeter's innovators. The low-level includes the self-employed, private contractors, and small shop proprietors. Since such entrepreneurs make a contribution, and since the label "low-level" may sound pejorative, I prefer to call them "free agent entrepreneurs" and to call the other group the "innovative entrepreneurs." Lists of sometimes-alleged prominent examples of dyslexics among innovative entrepreneurs include: Richard Branson (Virgin Enterprises); Henry Ford (Ford Motor Company); William Hewlett (Hewlett-Packard); Paul J. Orfalea, (Kinko's); Charles Schwab (Charles Schwab & Co., Inc.); Ted Turner (Turner Broadcasting Systems); Craig McCaw (McCaw Cellular); Ingvar Kamprad (IKEA); Steve Jobs (Apple); William Wrigley, Jr. (Wrigley); David Neeleman (JetBlue Airways); Tommy Hilfiger (Hilfiger Clothing); F.W. Woolworth (Woolworths); Walt Disney (The Walt Disney Company); John T. Chambers (Cisco Systems); Thomas J. Watson, Jr. (IBM); Thomas Edison (General Electric); Alexander Graham Bell (Bell Telephone). (This is a tentative list – I currently have reliable documentation for some, but not all of the names on the list. Partial sources: Morris, Munoz, & Neering, 2002; Orfalea, 2007.)

8. An anonymous referee plausibly speculated that much of what I write about the relationship of dyslexics to entrepreneurship may also be true of the relationship of persons with Asperger's to entrepreneurship. Cowen (2009) has amply illustrated cognitive traits of many autistic persons that might be useful in innovative entrepreneurship, e.g., that they are more likely to see the cognitively dissonant. By e-mail, Cowen shared with me two sources (Grandin & Duffy, 2004; Lazar, 2006) that support the speculation that persons with Asperger's may often succeed as what I am calling "free agent entrepreneurs." But when I asked him if he was aware of any papers on a relation between autistics and innovative entrepreneurs, he responded "The paper still needs to be written." (e-mail received Septembr 2, 2011).

9. After some additional search, I found that the original source of this quotation is: Samuel Johnson (1889, Chapter 6).

10. Japanese transistor engineer Kikuchi said (see Gilder, 1990, p. 137) that it was an enormous advantage to know that someone else had solved a problem, even without knowing their solution, because that provided the knowledge that the problem was indeed solvable.

11. A thoughtful start toward a taxonomy has been provided by Oğuz (2010), who tries hard to make some useful clarifying distinctions of different forms of noncodified knowledge, within the context of Hayek's life work.

12. "The entrepreneur believes that the totality of the information available to him, in respect of some decision, is unique" (Casson, 2003, p. 13).

13. Keynes is widely credited, in print and on the web, with having said "it is better to be vaguely right than precisely wrong", but I have not located anyone yet who gives the details. In fact, an aside in Harcourt and Riach (1997, p. 108) suggests that the quote, while applicable to Keynes' view of method, was in fact first stated by Wildon Carr and was applied to Keynes by Gerald Shove. Similar sentiments to that expressed in the quote also have been expressed by Mayer (1993) and by Klaes (2004).

14. Metcalfe (2004, p. 159) cites Ripsas as saying that entrepreneurs depend on "partial knowledge" (but I am not sure if this phrase is Metcalfe's or Ripsas').

15. Serendipitous alertness can sometimes result in an inspiration or epiphany. Thomas Edison is often quoted as having said that 'invention is 1% inspiration and 99% perspiration.' But inspiration or epiphany does occur. Stashower (2002, p. 23) provides one example of how, after mowing hay on the family farm, the horizontal rows of hay inspired a young Philo Farnsworth to see a solution to the problem of electronic scanning for his television invention.

16. An interesting, but more complicated, example (not in either the Grove or the Burke books) is the butterfly keyboard input to the laptop computer. It was technologically brilliant, and it worked, but it died because of advances in the noncomplementary input of the LCD screen. When large LCDs had been expensive, consumers preferred a laptop with a small footprint, which the expandable butterfly keyboard made practical. But when LCDs became much cheaper, consumers preferred the larger screen, even if that meant giving up the smaller footprint. (For background on the butterfly keyboard, see Hays, 1995.)

17. Incidentally, although past success is a weak predictor of future success, past failure only predicts a chance of success equal to a novice entrepreneur – a past failure takes the entrepreneur back to the starting line.

18. An illustration of these issues arose during a key period of the research life of Oswald Avery who eventually identified DNA as the genetic material. Avery worked hard on a plausible hypothesis. But even he, that most conscientious of empirical scientists, did not immediately "see" the unexpected result. At first he criticized the soundness of the scientist whose experiments revealed it. Then Avery's scientific work was paralyzed for six months; he left the lab suffering from Graves' disease, which was probably due to stress. In the end, he returned to the lab and began the slow laborious process of using the unexpected result to solve a huge problem: the biology of the genetic code, eventually leading to the identification of DNA as the genetic material. (This account is from Barry, 2005, pp. 421–422.)

19. Munévar (2009) even suggests that exposure to serendipity is a primary rationale for manned space travel.

20. The aptness of the Athena myth has been appreciated by many, including Mokyř, *The Gifts of Athena* (1990).

21. In recent years, Microsoft's OneNote program may be a partial substitute for McCloskey's note cards.

22. The strength of this example depends on there being an adequate response to Shulman's (2008) case against Bell's being the bona fide inventor of the telephone.

23. William Rosen has suggested that some experimental success may also depend on what he calls, quoting Charles Bell, "the intelligent hand" (Rosen, 2010, pp. 36–38).

24. Another physical analogy to the Wikipedia process might be the mutation of RNA-based viruses as described in John Barry's *Influenza* book (2005). Because RNA-based viruses can mutate more quickly than DNA-based viruses, they can more quickly evade human immune system adaptations, and hence increase their ability to survive.

25. Another possibility would lie in the greater integration of veterinary and human medicine to the mutual benefit of both. A recent example involves a Cushing's disease that is common in dogs, but uncommon in humans. Some medical researchers have been treating dogs, both to help the dogs and to learn lessons that might be useful in treating humans (Bhanoo, 2010).

26. Kealey (1996, pp. 86–89) for science, and Cowen (2000, p. 136) more generally, have argued that amateurs are more likely to be creative and pursue big ideas. Kealey suggests that being self-funded allows amateurs to pursue projects that are riskier, or have longer gestation. Cowen suggests that amateurs can take greater risks because failure will cause them less damage to their reputation (since they usually have less reputation to lose in the first place).

27. Each spoke separately on two different occasions to sessions of the Executive MBA class that I used to teach at UNO.

28. After receiving the label "leader", outside funding may be easier to find. I once had the opportunity to ask billionaire Walter Scott about some technological reservations that George Gilder had expressed in *Telecosm* (2002) to some aspects of the Level 3 business plan, in which Scott had heavily invested. Scott answered: he didn't know technology, he knew Jim Crowe. (Crowe is the founder and as of this writing, still CEO of Level 3.) At the time of the founding of Level 3, Crowe was widely perceived as having a success under his belt, in the founding and sale of MFS to WorldCom in 1997. Later, after WorldCom was seen to be a house of cards, having founded a firm that was bought by WorldCom, was no longer a sure sign of success.

29. As distinguished evolutionary biologist Leigh Van Valen put it: "It can be hard to tell a crank from an unfamiliar gear" (as quoted in Martin, 2010).

30. The pessimistic forecasting bias of academics has been documented by Fogel (2004 and 2005).

31. Gilder (1992a) rejects justifying entrepreneurial wealth as an *incentive* for innovation, and embraces justifying entrepreneurial wealth as an *enabler* of further innovation.

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