The Many Facets of INFECTIVITY

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Infectivity—the word evokes mostly ominous connotations, especially in today's world of such potent foes as bird flu and AIDS. But put in the hands of the Santa Fe Institute, its facets beyond disease begin to emerge. During the Annual Business Network and Board of Trustees' Symposium in Santa Fe, participants looked at those many facets, ranging from disease to computer viruses to the spread of technology as an infectious process. "The idea was that, like robustness and innovation, infectivity could be a metaphor for a great deal that happens at SFI," said Researcher Doug Erwin, who helped plan the Symposium. As it began, SFI President Geoffrey West called the Institute a "safe haven" for such kinds of exploration for people coming from academic, business, and economic sectors.

The Infectiousness of Technology

Esther Dyson, SFI trustee and principal of EDventure (formerly with CNET Networks), discussed "Technology as a Vector for Infectious Ideas." She began with three questions: How do "social networks" infect people? How can technology help transmit ideas? And, how is information technology itself a new idea?

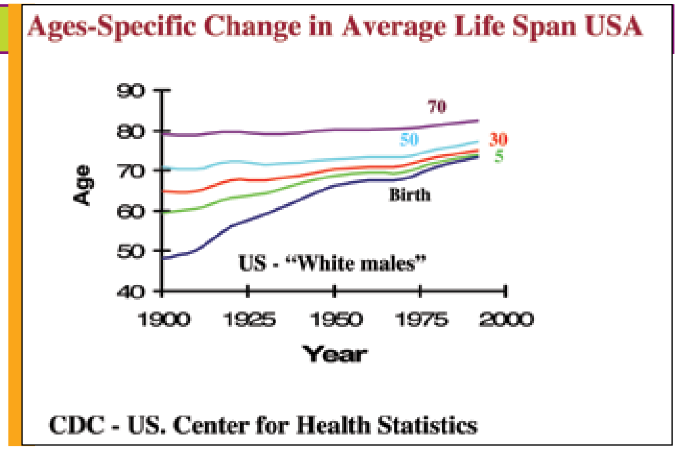
She explored the first question by pointing out that "Every business wants to be viral," meaning most companies want to "infect" people with their ideas or products. "But it's not easy," she said. People are busy, and they need to be attracted to things in order to give them their attention. Some effective modes that act as attractors are word-of-mouth communication (especially among friends), online widgets and buttons that direct people to other websites, interesting content that will hold attention, and endorsements from reputable sources. In the latter case, problems may arise if the endorsements become a devalued currency, which happens when endorsers hand them out too freely, or in return for cross-endorsements. Considering all this, she noted, social network infection is not quite like biological infection. It requires more work to attract, hook, and keep attention, because people can generally avoid infection if they want to.

Addressing her second question, how technology works as a vector for ideas, Dyson noted that information technology has dramatically changed how those in the developed world work, mostly because ideas spread so quickly now. Technology creates the means to make passive users active. It can be especially useful in the world of education. One example she cited is Fathom, a statistical software package that promotes exploration, investigation, and discovery. It doesn't simply "do" statistics; it lets users see how statistics (correlations, deviations, etc.) work. Technology is also used today in testing students to see most developed countries, and is essentially the same as that of Cuba," Levin said.

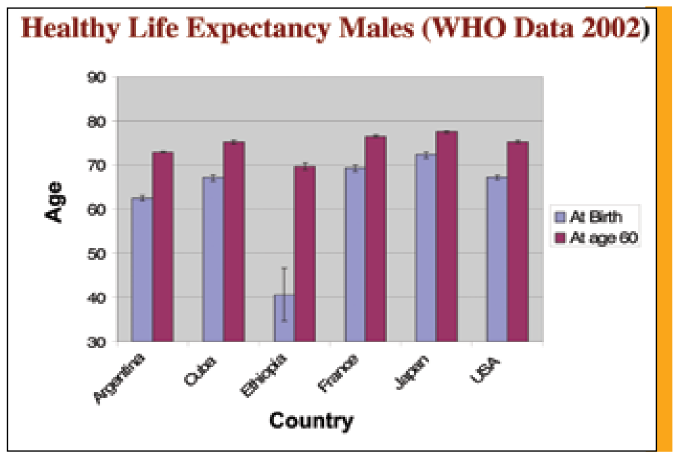
One somewhat unexpected cause of mortality today is hospital-acquired infections. Studies have shown a 36 percent increase in such infections between 1975 and 1995. Extrapolating from the results of the 2005 report of the Pennsylvania Health Care Cost Containment Council for the USA at large, there were more than 456,000 cases of hospital-acquired infections for an excess cost of hospitalization of approximately 70 billion dollars. The average term of hospitalization of patients without hospital-acquired infections in Pennsylvania was 4.5 days and with a mortality rate of 2.3 percent. The corresponding figures for patients with hospital-acquired infections were 20.6 days and 12.9 percent, respectively.

One reason for such high occurrence rates today is that hospital populations include a greater fraction of patients that are immune-compromised due to age and underlying disease. Another factor is the use of more aggressive medical and surgical interventions, such as implanted foreign bodies and organ transplants. Yet another is the growing resistance to antibiotics due to antimicrobial use in hospitals and long-term care facilities. Also contributing to the problem is the failure of hospital personnel to follow basic infection control protocols, such as hand washing between patient contacts. "While there may be some controversy about the absolute magnitude of the morbidity, mortality, and economic burden of hospital-acquired infections in the U.S., it is clear that because of these infections, hospitals are a dangerous place to be, especially if you are sick," Levin said.

What can be done? First, Levin suggested that patients might want to wear buttons asking "Did you wash your hands?" a suggestion that sounds humorous but could have a strong impact. He also recommended forcing hospitals to fully disclose statistics of acquired infections; a "Consumers Report" might be created for hospitals and physicians that could be used as an economic incentive. Unfortunately, this might place critically ill and other patients that are more susceptible to infections at a disadvantage for admission to hospitals and/or care by established physicians.



This graph illustrates changes in life expectancy (for individuals of different ages—at birth, 5 years, 30 years, 50 years, and 70 years) from 1900 to 2000.



While medical expenditures in the U.S. exceed those of most other developed countries, our expected lifespan is less than that of most developed countries.

A key factor that needs to be addressed, he emphasized, is antibiotic resistance. In theory and practice, there is a direct relationship between the rate of antibiotic use and the frequency of resistance. "Although some may attempt to outlaw the teaching of evolution, it is not possible to prevent evolution from occurring," said Levin, adding a bit of levity to the hard fact that "The evolution of resistance is an anticipated outcome of antibiotic use, be that use prudent or profligate." However, because hospitals are potentially controlled environments, the frequency of antibiotic resistant bacteria in them can be lowered by the same procedures used to reduce the incidence of hospital-acquired infections. "Nevertheless," he said, "for economic and possibly scientific reasons, we are unlikely to be able to sustain, much less win, the

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antibiotic–resistance arms race."

Although the extent is unclear, pharmaceutical company innovations have almost certainly contributed to the increase in human life span over the past 25 years. Curiously, part of their contribution may be attributed to an interesting shift in their development focus. "Over the past 25 years there has been a change in the focus of the pharmaceutical industry from the sick to the well," Levin said. Today there is more emphasis on drugs that treat cholesterol, blood pressure, insecurity, menopause, sexual potency, senescence, and mental, social, and behavioral problems.

Levin foresees large shifts coming in the way we treat infections. "Sometime in the not-all-that-distant future, we will look back at the era of antimicrobial chemotherapy as a crude early post- 'germ theory' approach to the treatment of infectious disease," he said. Much of the morbidity and mortality of infections can be attributed to immune over-responses. He believes that the future of treatment of infections lies in controlling that over-response.

Finally, Levin addressed one possible source of mortality that he argued could eclipse all others: pandemic influenza. Looming behind this concern are the images of the 1918 flu pandemic that swept the globe, killing between 25 and 50 million people. Will we be better off now than we were then? "Yes and no," he suggested.

We now know the etiologic agent of influenza, a virus, which we didn't know in 1918 and a great deal more about the epidemiology of influenza and how to control it. We can make vaccines to reduce the likelihood of infection by that virus, albeit not so readily for a new influenza virus. We have antibiotics to control pneumonia and other secondary infections due to bacteria. We also have extensive communication networks for the flow of information between communities and the world at large. And, at least in the developed world, we don't have the extraordinary crowding conditions of wartime 1918: the barracks, troop ships, and trenches.

On the downside, there are approximately three times as many people living in the world now as there were in 1918, making social distancing all that more difficult. We now have airplanes moving potentially infectious people between cities and around the world at very high rates of speed. Although influenza has a relatively low infection rate—in a wholly susceptible population, on average, each infected person will only transmit the virus to two other people—it is transmitted before people are symptomatic, making quarantining difficult.

Also contributing to the downside of our prospects for controlling the next influenza pandemic are logistical problems of an unprecedented magnitude. Included among these are making and distributing enough vaccines and antiviral drugs and treating and caring for vast numbers of people who are ill. He noted that the amount of transmission and thus the magnitude of the pandemic could be greatly curtailed if people stayed at home, but the logistical support required for food, water, and electricity for months at a time do not exist and would be exceptionally difficult to arrange. Then there would be the fallout on the global economy, he noted, saying, "It's hard to imagine this fallout for a pandemic of the magnitude of that of the 1918 flu, much less prepare for it institutionally."

The conclusions are somewhat dismal, but that's Levin's point, to call attention to the challenges. Many people trust the government to inform and prepare for such outcomes, but even that, to Levin, offers little solace. "In general, representative democracy is not particularly amenable to planning for major disasters that have low annual probabilities of occurring, mostly due to the short duration of elected officials' terms in office," he said. His one bright note at the end, brought some hope. With an obvious bow to SFI, he quipped, "At least the mathematical modelers are on the case."

Why Do Superstars Have Long Tails?

P.J. Lamberson, research fellow in the Center for the Study of Complex Systems at the University of Michigan, discussed "Social Infectivity in Competitive Markets." He tackled the question "Why do distributions with superstars have long tails?" It's a reference to the question of why some products capture huge market shares, while at the same time, a wide variety of competing products continue to exist successfully, while capturing only small market shares. He modeled the problem, providing insights into how one might capture and hold a large market share.

The work harkens back to that of economist W. Brian Arthur, also present at the Symposium, who first posited the underlying mechanism of "increasing returns"—the tendency for that which is ahead to get farther ahead, and for that which loses advantage to lose further advantage. In Arthur's original model, a sequence of adopters with individual preferences choose between two technologies. The utility they receive from adopting one of the technologies increases with the number of previous adopters of that technology. Arthur was able to show that in this situation, one technology will completely dominate the market.

So, why then, in markets where increasing returns operate, do we see both superstar products and product diversity? For example, if increasing returns explains the market dominance of the iPod, why doesn't everyone buy one, eliminating the tail of the market share distribution altogether? One potential answer is individual preferences, but if everyone's choice is based solely on their individual preferences, why would one product become a superstar?

To answer these questions, Lamberson created a model extending Arthur's from two to many products. In it he combines individual preferences and increasing returns, and assumes that consumers only consider "nearby" products. That is, different consumers have different ranges of products that they are willing to consider, based on their personal preferences, and the choices of previous adopters only affect the utility of products within this range.

Using this model, he found that with no increasing returns all products captured roughly an equal market share as expected. With global increasing returns, as in Arthur's model, one product won 100 percent. However, when consumers consider only nearby products, the distribution of market shares follows a power law in which one product, the superstar, captures a commanding lead, but many more products capture smaller and smaller shares of the market. This is the distribution of market share observed in many industries that Lamberson had set out to explain.

Watching how market share developed in the model over time—after the introduction of the new technology—reveals the following factors, much like a horse race:

- Early on, it's difficult to tell who will win.
- To be the eventual winner, it seems to help to lead/get ahead early, which gives you an enthusiasm advantage.
- There are no guarantees—you can finish in the top ten even though you had a pretty low ranking early on.
- If you cannot be the market leader, then it's wise to differentiate your product from the market leader to capture more market share.

During discussion of the talk, W. Brian Arthur raised his hand. "Why didn't I do this 20 years ago?" he asked. "I was afraid that you *had* done this 20 years ago," Lamberson replied, laughter filling the room. The exchange offered an example of a seasoned researcher such as Arthur seeing his work utilized and expanded upon, accomplishing one of the goals of the Symposium, and of SFI. ◀

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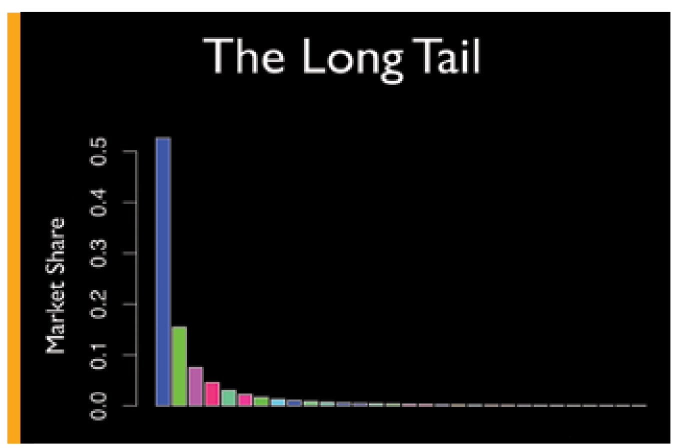

This power law distribution illustrates one product capturing a large market share, while a variety of competing products continue to exist successfully while capturing only small market shares.