Complexity and Liberty: On Fortune, Social Engineering and Everything in Between

Nadav Shnerb

"Then I saw that wisdom excelleth folly, as far as light excelleth darkness. The wise man's eyes [are] in his head; but the fool walketh in darkness: and I myself perceived also that one event happeneth to them all. Then said I in my heart, As it happeneth to the fool, so it happeneth even to me; and why was I then more wise? Then I said in my heart, that this also [is] vanity." (Ecclesiastes 2:13-15)

Galileo's Laws, Machiavelli's Fortune

At the end of the 16th century Galileo Galilei gained renown worldwide for his contributions to science. In addition to his specific contributions to the principles of mechanics and astronomy, he is remembered as having helped entrench what is today known as the scientific method: reliance on empirical observations, disregard of prior prejudices and (as much as possible) the dogmas of the church and meticulous analysis of experiment results.

However, fifty years earlier a Florentine thinker preceded Galileo on all these counts. Niccolo Machiavelli was a diplomat and statesman in the service of his city, Florence, in a period when the Italian Renaissance was waning as the result of internal wars and foreign invasions. Machiavelli grew up in an Italy divided into various political units: principalities, republics and church states. In his formative years these various units entered into a free for all, in which the great powers of Spain and France also participated. The result was a Gordian knot made up of hundreds of negotiations, alliances, which were variously upheld and violated, and battles with differing results. This historical context provided a golden opportunity for a scientist seeking to discover the laws which govern reality by analyzing empirical data. For an extended period Machiavelli represented Florence in the courts of kings and the palaces of princes which provided him with first-hand information and impressions. His book, *The Prince*, presents various political principles which he deduced based on his observations.

The Prince is generally considered one of the cornerstones of modern political thought. Machiavelli rejects the great religious and philosophical traditions then prevalent, which saw the state and its political system as tools whose purpose is to provide opportunities for exceptionally talented men to travel the path of truth, whatever it may be. In light of his observations, Machiavelli concluded that these traditions rely on erroneous assumptions regarding human nature. The typical man is more egotistical and dishonest than was assumed by the ancients. More importantly, any attempt to change this state of affairs will not succeed. Machiavelli realized that the organization of human society has to be based on **exploitation** of these negative elements. This paved the way for the great political school associated with Hobbes, Locke and their compatriots, who broadened Machiavelli's ideas from the level of advice to princes to encompass organization of societies as a whole, thus establishing the ideological basis for modern regulated capitalism.

Nevertheless, the difference between Galileo and Machiavelli is well understood. Few would think of the latter as a "scientist", and the specific advice he gave to princes is not given the same validity as the principles of pendulum motion or the paths of Jupiter's moons discovered by Galileo. Why is this so?

The answer to this lies in one of the basic distinctions between natural and social sciences: the relative significance of randomness or what engineers call SNR – Signal to Noise Ratio.

Let us imagine an engineer trying to design a missile to hit a specific target. He takes into account the laws of mechanics, gravitational force, and effects of air resistance. Using this information he comes up with an equation describing the speed and location of the missile in relation to its launch site. With the help of this equation he predicts the impact point of the missile.

These elements (gravitation, friction etc.) are all constant and can be described by well defined equations. These factors are known as deterministic. However, other factors affect the movement of the missile as well, including whirlwinds, the odds of hitting a bird midflight causing a change in trajectory, and irregularities in the fuel supply to the engine. These are the random, or stochastic, factors affecting the missile's movement. Given a lack of precise data on the direction of the wind at every point of the missile's flight, and of knowledge concerning the flight paths of birds, these random events reduce the engineer's ability to correctly predict where the missile will land.

It is therefore clear that the ultimate question in engineering design is the quantitative ratio between the deterministic factors affecting the project and the random ones. Since a ballistic projectile fired at a target 100 meters away has a relatively small chance of encountering a gust of wind on its way to the target, the engineer's projections will be relatively accurate. The rocket will hit a specific point "give or take half a meter", where this half meter is the part of the projection dependent on random factors. When a missile is aimed at a more distant target the effect of the random factors also grows, causing the engineer to estimate the point of impact "give or take ten kilometers".[1] An extreme case of this is when a small piece of paper is thrown from the roof of a tall building on a stormy day. Even given complete knowledge of the laws of mechanics and of gravitational force there is no way to predict where the paper will fall even to a reasonable approximation. In this case the result is **entirely** (or almost entirely, as discussed below) controlled by randomness.[2] Predictions based on the laws of physics thus become worthless.

The ratio between the deterministic and the random factors, or between rule governed behavior and noise, is the central characteristic of the difference between the natural and social sciences. This does not

---

[1] The following anecdote illustrates this point. The original motivation for the development of the H-bomb was the inaccuracy of ICBMs in the 1950s. Their long flights exposed them to random effects, which resulted in deviations of several kilometers from the target. The H-bomb was designed to explode with enough force to destroy the target even when the missile landed kilometers away.

[2] The deeper issue of the difference between random movements and deterministic movements lies outside the scope of this article. It could be argued that whirlwinds are nothing more than a specific type of movement of oxygen and nitrogen molecules. The path of each molecule can then be analyzed the same way as the trajectory of an artillery shell. For the purposes of this article it is enough to establish that it is not realistically possible to collect sufficient data for the analysis of whirlwinds. Since these factors cannot be predicted they must be treated as built-in uncertainties in the parameters determining the movement of the rocket.

have to do with the essence of either field; in a different world whirlwinds might be so fast and strong that scientists attempting to experimentally discover the laws of freefall will be doomed to failure. In yet another world people's reaction to stimuli could be so predictable that it would be entirely possible to easily formulate the laws governing the behavior of individuals and societies. However, in our world this is not the case. The natural sciences generally deal with problems in which randomness is not a major factor, while observations of society reveal substantial influence of unpredictable elements.

Surprisingly, Machiavelli, living towards the end of the Middle Ages, was sufficiently sophisticated to understand this effect. In the penultimate chapter of his book, which bears the title "What Fortune Can Effect in Human Affairs, And How to Withstand Her," he discusses precisely this point. He deliberates on how much weight it is proper to attribute to randomness and on the validity of his advice offered throughout the book given the possibility of unforeseen influences.

Machiavelli does not deny that occasionally "[o]ne can also see of two cautious men the one attain his end, the other fail…" and that at times "two men working differently bring about the same effect". He notes that "many men have had, and still have, the opinion that the affairs of the world are in such wise governed by fortune…and because of this they would have us believe that it is not necessary to labor much in affairs, but to let chance govern them…." Nevertheless, he himself argues that "Fortune is the arbiter of one-half of our actions, but that she still leaves us to direct the other half, or perhaps a little less." We see here yet more evidence of the man's genius: he appears to have been the first person to understand the importance of evaluating the ratio between signal and noise in modern science. Unfortunately, he chose to deal with research areas in which the influence of noise is too great to allow the clear formulation of laws based on observation alone.

From a modern perspective it can be said that Machiavelli's claim that random factors govern roughly half of the course of human events falls squarely in between the two major schools of political thought. Blaise Pascal pointed out in his book *Pensées* (162) that "Cleopatra's nose: had it been shorter the whole aspect of the world would have been altered"[3]. He can be seen as representative of the fatalistic approach which holds that the influence of randomness on human affairs is so great that there is no point at all in applied social research.

Naturally, not many social scientists accept Pascal's position, since this undermines the very foundations of their profession. Many economists, political scientists and even historians held that the effects of randomness in human affairs is negligible, thus making it possible and productive to formulate laws based on observations even in these fields. Karl Popper referred to this position as historicism, denouncing it as a basic fallacy with far-reaching political consequences. The following section attempts to clarify some of the technical aspects lying at the heart of the debate and to explain why physicists who deal with complex systems have anything to contribute to the discussion.

Between Pascal and Marx: Social Determinism and Democracy

Historical or social determinism are umbrella terms for a series of theories which assume that randomness does not play a large role in history or in determining the direction of a society's development. This makes it possible to discover laws which enable the prediction of the condition of a society in the future based on its state in the present, similar to an engineer predicting the impact point of a rocket. The success of the mechanical natural sciences, and primarily physics, played a large part in popularizing theories of this ilk. Marx, in his introduction to *Das Kapital*, provides a clear cut example of this type of thinking. He writes

[3] Blaise Pascal, *Pensees (Thoughts),* (Mobi Classics). Trans. W. F. Trotter. Mobile Reference, 2010.

that "it is the ultimate aim of this work, to lay bare the economic law of motion of modern society." Regardless of Marx's ambitions and whether or not he truly uncovered such laws, it is important to understand that he implicitly assumed determinism. In other words, he assumed randomness had a negligible influence on the dynamics of society. If Marx had assumed that social dynamics are the same as the dynamics of a piece of paper thrown from the roof of a building on a stormy day, he would have realized the dubious practical value of "discovering" the laws of social dynamics, just as the laws of gravitation become (almost) worthless when analyzing the movement of a piece of paper caught up in the storm winds.

This dilemma has important implications for the theory of democracy. The father of sociology, Auguste Comte, who tried to establish a science that is wholly dedicated to the discovery of the laws determining the development of society, made this argument. Isaiah Berlin boiled his thinking down to the following question: "If we don't allow free thought in mathematics, why on earth should we allow it in morals and politics?"[4] This question is echoed in any theory espousing social determinism, and in fact, can be seen to underlie Plato's concept of the "Philosopher King". How can a system of government be based on the opinion of the masses while experts suggest other ideas?

This way of thinking embodies a powerful argument against the ideal of liberty which should be clarified. The general claim is that a certain level of expertise is necessary in order to express an opinion. When building a bridge, there is no point in putting the question of how much concrete should be used so that the bridge doesn't collapse up to a vote among the residents of the city. Everyone agrees that instead it is necessary to turn to an expert – in this case a bridge engineer – and get his professional opinion. This will allow the cost of the bridge to be calculated. Next, an expert will be consulted to determine the effect the bridge will have on the traffic patterns in the city. Once the cost and potential benefits of the bridge are known, only then are the city's residents approached to vote on whether or not the bridge should be built.

Comte argues that this last stage is foolish. If a bridge engineer and a traffic engineer were consulted in order to understand the cost and benefits, then now a social engineer should be brought in to make the final decision. A social engineer is an expert in social dynamics and can determine, for instance, how reducing the amount of time spent in traffic will result in the teachers arriving more refreshed to classes and thus help raise the level of instruction. He can then weigh this benefit against the aesthetic damage which will be caused to the public from the graffiti that will no doubt be sprayed on the bridge and other potential costs. If we were willing to surrender our freedom to obtain the benefit of the expert's engineering knowledge at the planning stage, why should we surrender the benefits derived from the social engineer's expertise in the final stage in favor of the right to vote on the final decision?

There are two popular answers to Comte's argument. The first is the **corrupt ruler** argument: in effect Comte's suggestion is to turn the social engineer into a dictator. But there is no guarantee that the engineer will continue to provide good advice. He could start making bad suggestions that would harm the public, for his own personal gain. The engineer, or the Philosopher King, may be the most qualified person to answer questions, but he is also human and, to quote Lord Acton, absolute power corrupts absolutely. Therefore, democracy is our guarantee against the corruption of rulers, and we are willing to pay the price of inefficiency which comes from forgoing governance by experts.

The second widely accepted answer relies on the **spirit of freedom**. The assumption is that human beings want to feel that they hold their fate in their own hands and that they determine their own path in life. They are not interested in a wise big brother telling them what to do even if he really does know better. They would rather make mistakes and pay the price for them then be ruled by another. Individuals and

[4] http://berlin.wolf.ox.ac.uk/lists/quotations/quotations_by_ib.html

communities have a deep psychological need for autonomy. They are willing to pay the price of giving up on experts' rule to gain the psychological satisfaction of having this need fulfilled.

However, these two arguments are of limited use when pitted against the need for a government of experts. After all, someone who doesn't follow his doctor's orders on a critical matter just to feel like a free man will not be viewed as particularly sane. The fear of corruption of the system – such as practitioners providing unnecessary treatments in order to increase their profits – is allayed by checks and balances within the healthcare system, and not by putting medical treatment to a vote. The defense of democracy against the argument of government by experts, or sophocracy, implicitly assumes that social scientists do not have the same type of expertise as their colleagues in the natural sciences since the laws of social dynamics have not yet been discovered. And even more importantly, randomness plays such a large part in determining the behavior of societies that even if such "Newtonian Laws" of politics were discovered, they would not do any good.[5]

This insight has an interesting parallel in the field of economics and investment. In the world we live in almost any social prediction can be converted into economic profit. If I foresee the strengthening of the Ultra Orthodox Jewish community then I will invest in a hat factory, if I think the country is heading towards a patriotic revival then I'll begin producing flags and if I believe people will become vegetarians then I will withdraw my investments in the meat industry. In many cases, economic forecasting is simply social forecasting on a micro level. Traders examine the fluctuations of the stock market and attempt to deduce the psychological state of investors. They then use this assessment as a basis for their buying and selling. This process is known as technical analysis. Another common method is to examine in depth the performance of a company and of the market in which it operates in order to determine whether it is being run properly and how its competitors are faring. This method is also known as fundamental analysis. In both cases forecasting is being conducted based at least partially on claims regarding future social dynamics.

Some people manage to carry out these investments very successfully. For instance, the billionaire Warren Buffet is viewed as a wizard of fundamental analysis, examining companies in depth, buying the ones that will have the greatest pay-off and making a large fortune. Most people today hand over their pensions and savings to various financial managers and investment consultants, who while perhaps not as talented as Buffet, and therefore less accurate in their predictions, are still viewed as enough better than a layman that it is worthwhile to work with them and pay them significant commissions. Could these people perhaps be the true social engineers? Should we believe the experts who predict the laws of social dynamics and replace Karl Marx with Warren Buffet?

Professor Burton Malkiel of Princeton University, in his book *A Random Walk Down Wall Street*, claims that we shouldn't. There is nobody in the world who knows how to predict the future fluctuations of the stock market or what the price of coffee will be two years from now. The randomness factor is too great. An economist can invest time and effort, read a company's balance sheet and realize that it is being poorly run and that its competitors are wiping the floor with it and that it doesn't stand a chance. But it could turn out tomorrow that the company's offices are located in a developing section of the city and its value skyrockets. What will happen to an established insurance company if a powerful hurricane strikes New York or Philadelphia?[6] Malkiel and his colleagues checked the returns which fund managers and other

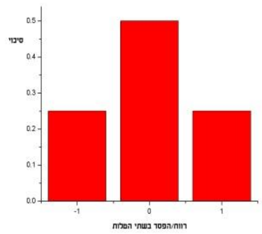
[5] Friedrich Hayek's book *The Road to Serfdom* brings home this point exactly. He develops several main threads of an argument which deal with the impossibility of large-scale government planning and recommend a social order formed "from the bottom up" via the activity of the free market. This article presents some mathematical aspects of these observations.

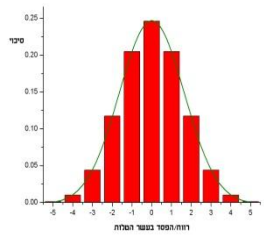
[6] It's worth noting that insurance companies do actually put a price on the likelihood of such an occurrence. A certain percentage of each insurance premium goes towards covering the risk of a mega-

financial wizards gain against the rise of the average index of the stock exchange, and discovered a simple fact: no-one manages to beat the index for long. At the end of the day, the profit derived from sophisticated investments is identical, over the long run, to the profit derived from buying bonds linked to the general index of the stock exchange. The thousands of dollars annually paid in commissions to the managers of pension funds are a pure waste of money.[7]

As for Warren Buffet, nobody can deny that he has made billions off of his investments. Can it be that there is no essential difference between him and an inexperienced person playing the market? The short answer is that there is indeed no difference. However, in order to fully comprehend this answer an explanation of the mathematics of randomness is necessary.

Pareto's Error





A coin toss is a prototypical random event. Assuming that the coin is balanced, there is a 50% chance of getting heads and a 50% chance of getting tails. For the purposes of discussion this can be views as a gamble: if the coin shows tails a dollar is won, and if it shows heads a dollar is paid. If the gamble is made twice there is a 25% chance of winning two dollars (the odds that the coin will land tails side up twice in a row), a 25% chance of losing two dollars, and a 50% chance (for either heads-tails or tails-heads results) of neither winning nor losing anything.

What if this is done a hundred times? In the best case scenario – where the coin comes out tails all one hundred times –a hundred dollars will be won, but this is obviously incredibly rare, as is the scenario of losing a hundred dollars. The graph on the right presents the odds for a specific result, for two results and ten results. This

---

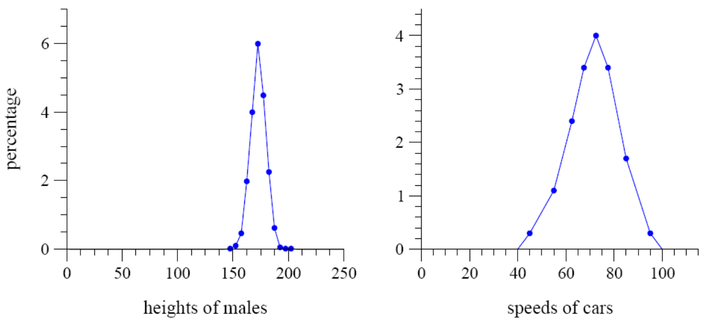
earthquake or hurricane the likes of which have never been seen before. But for the insurance company to make a profit it needs an actuarial assessment of the odds of such an event. It turns out, of course, that where there are buyers there are also sellers. At a scientific conference I once met the representative of a London office which provides insurance companies with numbers which are supposed to express the odds of a monstrous hurricane occurring. In her lecture she also spelled out the ridiculous methods they use to arrive at these numbers; without going into detail I can guarantee that consulting with a fortune teller is far more rational (as well as cheaper).

[7] The manner in which Malkiel's argument is presented here is not entirely accurate. The hypothesis he supports is called the "efficient market hypothesis" which argues that due to the large number of players in the market, and the fact that what one person knows everybody knows, there is no chance of getting a "free lunch" on the stock market. This is the same logic by which there is no chance of finding someone who will sell you his house for half its worth even though it has no physical defect or ownership dispute. The metaphor of the piece of paper on a stormy day hints in the opposite direction: markets are entirely inefficient, because five minutes from now a revolution could take place in Saudi Arabia and bring down indices worldwide.

But the ostensible contradiction is actually not so problematic. The efficient market argument states that it is not possible to take advantage of widely known, unambiguous pieces of information (the economical equivalent of the deterministic laws in physics) which can bring clear short-term benefit, because these facts are accessible to all the players. While the trajectory of an electron under magnetic field is independent of our knowledge about the theory of electromagnetism, the stock market will fall tomorrow if a known theory of its dynamics predicts a collapse in the next week, so the feedback effect that is built into the dynamics renders most of the deterministic theories useless. What remains is a collection of uncorrelated random events. This information loses its value very quickly, and therefore long-term forecasts attained through sophisticated methods are effectively worthless.

illustrates that as the number of results increases, a typical bell curve results. The peak of the curve, which corresponds to the most likely result, for this game is at zero (for every toss of a coin the odds of winning and losing are identical). The further away it is from the average value, the odds of getting that result grow smaller so that the majority of possible results cluster around the average. This bell curve (seen here as a green line) is called a Gaussian, names for Friedrich Gauss, the mathematician who popularized it.

The most important theorem in probability theory is the **Central Limit Theorem** and goes something like this: if a given situation determined by the sum of many small random events – as in the case of a hundred coin tosses, where the total profit/loss is the sum of the results of all of the tosses, each of which is random – then the distribution of probabilities for this situation will **always** take the form of a bell curve. Regardless of whether we toss a coin, play roulette, throw a die or generate random numbers using a computer, the distribution will remain the same. The nature of the microscopic processes that determined the outcome is not important. It is sufficient to know that many random factors join together to ensure that the result will be Gaussian.

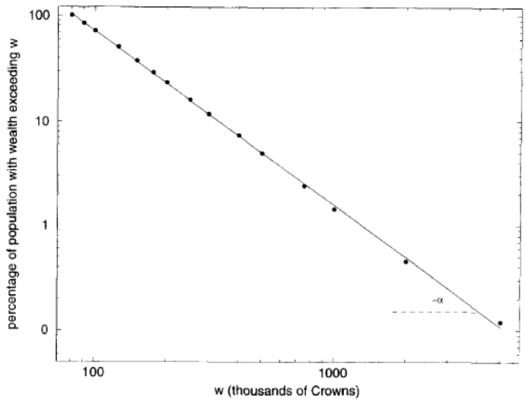


The graph on the left gives the distribution of the height of American men. A person's height is determined, in the absence of nutritional deficiencies, primarily by genetic factors. As opposed to eye color, for instance, which is determined by a single gene, height is determined by a large number of genes; any one of these can be inherited by a child from his parents with a given probability. A person lucky enough to get many of the genes which contribute to stature ends up being particularly tall, while someone who receives few of them ends up being short. Scientists today do not know the identity of these genes, the distribution of each of them in the population, or the mechanisms they use. Nevertheless it can still be argued that, since final height is determined by the sum of a number of random processes, the result must be, according to the Central Limit Theorem, a bell curve around an average. This is in fact the case in reality. The graph on the right shows the odds of finding a car going at a given speed (in kilometers per hour). Here the process is more complex as the speed is affected not only by the driver's random caprices but also by traffic laws, conditions of the road and the behavior of other drivers. The curve is still fairly bell-like.

The width of the bell curve in the graph of heights also has significance. The overwhelming majority of the population is located more or less within 15 cm of the average height; this is called a standard deviation, or σ. In Gaussian statistics, the odds of getting a result which deviates from the average by four to five standard deviations (namely adult males taller than approximately 2.4 meters or shorter than around 1.2 meters) are incredibly small, and for all practical purposes it can be assumed that there is no one taller than 4 meters (approximately 15 standard deviations from the average).

This result – an implementation of the Central Limit Theorem – shows that the claim made above needs fine-tuning. Above a dichotomy was presented between those searching for social laws like Marx and those who believe everything to be random such as Pascal. The Central Limit Theorem demonstrates that **even those who hold that everything that is random are proposing a rule**: they propose that society is controlled by the mathematics of randomness, and that examination of social or human phenomena as an accumulation of small decisions, or of many people, will yield bell-curve shaped results. These predictions are indeed borne out in reality: in the graph above of the distribution of the speed of vehicles on the freeway, the distribution is affected, as mentioned above, by many small factors including the individual's driving habits and the density of traffic. The result is indeed quite similar to a Gaussian distribution.

The first person to see the value of examining the hypothesis of randomness of human society against the data was the well-known Italian economist, Vilfredo Pareto. Pareto examined the basic index for human welfare: wealth, as measured by the amount of money had per person. If the advocates of randomness are correct, and success or failure in business is truly unpredictable, then presumably the sum total of a man's wealth, which was accumulated as a result of a long series of small, random successes and failures, will be distributed in a bell curve.



Pareto collected data from a number of human societies and various historical periods and was amazed at the patterns he found, such as the one illustrated by the figure on the right. This graph is not taken directly from Pareto, but rather from a modern study by Levi and Solomon[8]. It displays the distribution of wealth among the Norwegian population: the *y*-axis gives the odds of being a person of assets in excess of *x* thousand kroner (the currency of Norway), and the *x*-axis gives the wealth (amount of assets) in kroner (note that this is a logarithmic graph). It turns out that the distribution of wealth bears no resemblance to a bell curve. It is extremely **wide**: eighty percent of the people have assets of around two hundred thousand kroner, ten percent have over half a million kroner, and one percent have more than four million kroner!

In fact, this conclusion could have been reached even without Pareto's experiment, using simple logic. While the average salary in the US market is approximately 40000 dollars per year, it is not unusual to find people who make 60000. This means that the width of the distribution curve is around 20 thousand dollars. If it had been a bell curve then the odds of finding someone making 300000 thousand a year would be the same as the odds of finding someone who is 3.70 meters tall, or practically zero. But such people do exist. It is therefore clear that the distribution of wealth or income in the population does not obey the iron-clad laws of random events.

Pareto's discovery of this distribution of wealth and income (now known as a power law) convinced him that it is not possible that the rules of randomness govern the accumulation of wealth. He found the emerging picture to be very bleak. On the left side of the curve which he discovered are the masses who earn very little and live in poverty, while on the right are the select few, the rich and powerful. He figured that if they were not elevated to their advantageous position through a series of random events, then the cause must be differences in talent and ability. The rich must be smarter, pushier, more talented or more devious than the rest of the population, which must be what brought them to their superior positions. Pareto thought that his discovery forced the horrifying conclusion that democracy is a fraud, and society is actually controlled by various hidden mechanisms of power in a vast self-preserving conspiracy of the wealthy to keep the downtrodden trapped in their untenable situations. This observation led Pareto to support a different, undemocratic regime in which, he hoped, the government would be sufficiently powerful that it would be able to free the private sector from the binds of the conspiracy of the wealthy few. He became one of the most prominent supporters of Italian Fascism, and Mussolini's propaganda machine made considerable use of his name and teachings. [Pareto died a year after the Fascists came to

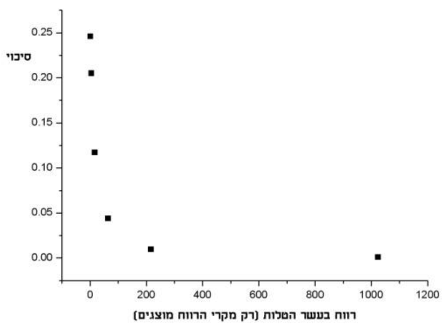
[8] Levy, M., Solomon, S., 1997. New Evidence for the Power-Law Distribution of Wealth. *Physica. A* 242, 90–94.

power, so it's hard to say what his opinion would have been on the social order which was instated in Mussolini's Italy].

However, Pareto was wrong. In technical terms he discovered that the distribution is too wide to be explained by the Central Limit Theorem, leading him to conclude that it could not be the result of a random process. However, he didn't take into account another important type of randomness: **a multiplicative random process**.

What is a multiplicative process? In the coin toss game mentioned previously, a dollar was gained in the case of tails coming up, and lost in the case of heads, each occurring with a probability of 50%. This model of gambling does not accurately reflect the reality of investment in the stock market. There the prospective gains or losses are not of a set amount of money, but rather of a percentage of the amount invested. A simplistic model of this stipulates that each stock either doubles its value or decreases it by half every year, at random. Similar to the coin toss, this is a symmetric process, meaning that the odds of winning are identical to those of losing, meaning that the odds of any given result (e.g. six wins out of ten attempts) are identical in the game of investment in the stock market as in the coin toss. However, the proceeds are distributed differently.

In the coin toss ten wins in a row resulted in a ten dollar gain. In the stock market game, on the other hand, ten wins multiply the initial investment by $2^{10} = 1024$. Twenty consecutive wins multiply the capital by about a million, while twenty consecutive losses reduce the investment to a millionth of its original value. As shown in the figure on the right, the distribution is now extremely wide; while a Gaussian distribution gave odds very near to zero for a profit of five, here there is still a fair chance of making a profit of 200, and in general there is some chance (albeit small) of getting very large numbers.



This is essentially the claim made by modern economists (Burton Malkiel as well as Nassim Taleb in his best-selling book *Fooled by Randomness*) in light of Warren Buffet and his peers. The activity of a single investor can be modeled simplistically by a system in which every year he either doubles his capital or loses half of it. This means that one of every two investors will in any given year be fortunate enough to double his capital, but half of those will the following year lose everything they gained. Thus, a lucky quarter of the investors will have quadrupled their investment over two years. If this game is continued, it will turn out that approximately one out of every million investors will have twenty consecutive winning years, multiplying his capital a millionfold. **Because there are millions of investors, the statistics predict that there will indeed be such a man**. This man, Professor Nassim Taleb writes, might be named Warren Buffet. He's not necessarily smarter or more talented or a shrewder financier than the other players in the market, some of whom have lost it all. He is simply luckier.

Quality Evaluation in Conditions of Randomness: Is Mr. Jones Exceptionally Productive?

The discovery described above, that a multiplicative random process can produce a very wide distribution of results in an entirely neutral process (i.e., where all the players have the same skills), raises a profound fundamental question with consequences reaching far beyond politics and economics. People tend to evaluate quality based on results: if someone buys ten different pairs of pants and wears them more or less the same amount, he will conclude, justifiably, that the ones that wore out in the shortest time are made of relatively inferior cloth, and those which lasted for many years and still look as good as new are made from particularly durable materials. The equation is simple: success, which for pants is measured in durability, is identified with quality. In other words, the assumption is that if someone or something succeeds – leads a long life, reproduces, rules a country, wins a war – then it is a sign that he has a certain positive trait, which can be called "fitness", which makes him more fit for the task at which he succeeded. This way of thinking seems to us almost axiomatic: Napoleon's winning many battles is seen as an indication that he was a gifted military commander and Julius Caesar's seizing political power is taken to be proof that he was a brilliant statesman. The fossils of 300 million year old cockroaches prove the exceptional durability of this species. The constant citation of John Doe's articles in the scientific literature must mean he is a prominent scientist.

However, this is not necessarily the case. The problems in this way of thinking can be illustrated by comparing the case of the pants from above to drinking glasses. Pants which last for a long time can be inferred to be made of better material. But the same is not true for drinking glasses. A glass does not break because it has accumulated wear and tear over its lifetime, but as the result of a single random event such as being dropped in the sink or by being accidentally knocked off the table. If ten glasses are bought and six months later only half of them remain, it would be ridiculous to attribute a unique durability to the remaining five. The pants which survived were the more fit ones but the glasses that survived are just lucky. This can also be framed in terms of life expectancy of the objects. The life expectancy of year-old pants is shorter than that of a brand new pair; by contrast, a glass that survived a year in the kitchen has exactly the same life expectancy as that of one which was just bought since it is not the wear and tear that kills the glass but rather a random event.

Therefore, the case of the pants can be described using Darwinian terms of "survival of the fittest", while the glasses can be thought about in terms of "survival of the luckiest". When this is examined mathematically we see that there is a characteristic difference between the two cases. It would not be at all surprising to find differences of tenfold or even a hundredfold in comparing the life expectancy of pants made of inferior cloth to a pair of durable jeans. For glasses, however, the random nature of their end ensures that the odds of finding a glass that has survived five times longer than average is very small (How many glasses are have left from the set you bought after your wedding? If you've been married more than a couple of years the answer is usually zero). Does this difference between pants and glasses not allow us to distinguish between the fit and the lucky? Perhaps this will help pinpoint when success indicates fitness using statistics gathered on many people, species or objects.

This is a repetition of the argument that led to Pareto's error. It seems that the statistics provide a test which distinguishes fitness from luck by the distribution of the results. If the distribution is narrow (the results are not very different from one another) then it may be luck, but of the results differ from each other by orders of magnitude then it may be indicative of real differences in quality. As in the case of Pareto, this is an erroneous argument, due to the existence of multiplicative processes.

A wonderful example of this is the statistics of surnames. According to the results of the latest US census more than one percent of the American population, some three million people, proudly bear the name Smith. Similar numbers characterize the distribution of the other most popular surnames; millions of people are named Davis, Johnson, Williams, etc. In contrast, in the US there are four million surnames which are only borne by a single person! Out of six million different surnames, only 150,000 belong to clans of more than a hundred individuals. These numbers show a pattern similar to that seen by Pareto for the distribution of wealth and assets: a few very large tribes, a multitude of small groups, with differences of six orders of magnitude (a millionfold) between the largest and the smallest. This author's surname, Shnerb, twenty years ago belonged to only two families in Israel (though there has been resurgence in recent years, mostly due to my own heroic efforts). Pareto's approach would have forced the conclusion that surnames which are more common came to be that way due to the higher fitness or quality of their bearers. In this case it would mean that the Smiths and the Johnsons have more children than the Shnerbs and the other low frequency surnamed families, but nobody seriously believes this. There must be some other explanation for the distribution.

This problem has a long history, beginning with one of the fathers of modern statistics, Sir Francis Galton. To answer the question posed above requires only that proof that the relevant process is a multiplicative random process. This is not difficult to see. if each person in a given family has a random number of sons (assuming the society under discussion follows the tradition by which the son inherits the family name and passes it on to his male progeny) then the total number of children with a that surname is proportional to the size of the family, and this remains the case whether it increases or shrinks. A family that starts out with a thousand individuals will have, for example, either 900 or 1100 people after one next generation while a family of a million individuals will number between nine hundred thousand and a million and a hundred thousand in the next generation. The size of the generational jump is proportional to the size of the family, and larger families jump farther than smaller ones. This is characteristic of multiplicative processes, and as explained above, will indeed show a very wide distribution of results.

The presence of multiplicative processes in the system makes it very difficult to judge quality based on the results. Huge numerical differences can accumulate between people and tribes whose talents and quality are identical. But such multiplicative processes can be found everywhere. Some examples are the following:

1. **Book Sales**: Bestsellers are generally thought to have some quality that caused their popularity (even if those with literary snobs tend to turn up their noses at these books, they at least have to admit that the author succeeded in catering to the tastes of the masses, which in itself is a kind of virtue). However, best-seller status is not generally achieved as a result of advertising; a good book generally spreads by word of mouth, as people who enjoy it speak its praises to their friends. Thus, if the first wave of readers numbered a thousand (who might have been hooked by the cover or the name while browsing and purchased it) then, assuming that each person recommends the book to one person **on average** (but sometimes he meets two people and chats with them about the book, and sometimes he reads the book when he's sick and forgets about it by the time he recovers), this is a process which is identical to the one involving surnames. Each reader can be seen as a father and anyone who receives a recommendation as a son. Over the course of many generations of reader-recommender-reader huge differences can develop between books of equal quality, simply because of the nature of multiplicative random processes. This is true not only for books but also for any process that works by word of mouth [think of the huge differences in popularity of various equivalent websites, such as search engines or gaming sites, despite the relatively minimal differences between them]

2. **World Fame**: Who doesn't want to be world famous? Some gain their renown as a result of a single event, such as Neil Armstrong by being the first to land on the moon or Alfred Nobel by establishing a fund to distribute prestigious prizes. But for most, fame results from a string of successes: winning medals or breaking records for athletes, victories in battles for generals, moving up the ranks for politicians and statesmen. In these cases, fame generally increases sharply with the number of accomplishments. Many people remember Mark Spitz, who won seven gold medals in the Munich Olympics of 1972. But nobody remembers Kristin Otto, who won six medals 16 years later, or Kornelia Ender, who won four medals in 1976. Everyone has heard of Julius Caesar, but how many

people know of his great rivals, Pompey and Crassus? Who remembers the name of Abraham Lincoln's Vice President? (Hannibal Hamlin, if you must know)

It seems that fame, like stock market investments, does not increase by a fixed **amount** with every "win" but rather at a fixed **ratio**, so that every win increases fame twofold or tenfold. Again, this is characteristic of multiple processes in which randomness can create huge differences between people of equal skills.

Natural Selection or Just Plain Luck?

Our understanding of the crux of multiplicative random processes has interesting consequences to do regarding Charles Darwin's theory of natural selection.

It's important to distinguish between two different aspects of the theory of evolution. The basic argument, that biological species evolve, appear and sometimes die out, has nothing to do with Darwin. Long before Darwin, geologists had discovered many fossils of ancient life forms were no longer in existence. From these they deduced that biological species develop and become extinct over the course of millions of years. Geology made it possible to date fossils based on the layer of rock they were found in, and this in turn made it possible to determine the order in which different species appeared and that the direction of evolution was from the simple creatures to those more complex. The question was not the very existence of this evolutionary process, but rather the forces driving it. Why do species form and disappear and why do certain species survive? These are the questions which Darwin solved by proposing the theory of natural selection.

Darwin presented a worldview in which the concept of fitness plays a critical role. If there are two lions that are entirely identical in every aspect except for the fact that one of them runs faster, then the odds are higher that the faster lion will catch his prey. Assuming that the amount of prey is limited and sufficient for only one lion, the slower lion will likely die; in any case the faster lion will be healthier, stronger and better nourished and therefore will defeat the slow, hungry lion when competing for a mate. In the end, the faster lion will have more offspring on average, and since traits such as speed are hereditary (say speed is related to leg muscles) then there is a greater chance that the next generation of lions will inherit the trait. Over the course of the generations, claimed Darwin, the slower lions will disappear and only the faster ones will remain. In the meantime a new mutation might appear: a lion could be born with heart problems, with a different color that allows him to camouflage himself more easily on the savanna. Harmful mutations (such as heart problems) disappear while beneficial mutations (such as camouflage) enhance the survivability of the bearer causing them to spread throughout the population. This, according to Darwin, is the mechanism driving evolution: **survival of the fittest**. Offspring are born with a range of characteristics. The fitter ones survive, while the weaker ones disappear, resulting in the range of traits fluctuating over the generations.

This is reminiscent of Marx and Comte's social determinism. It was clear to Darwin that not every beneficial mutation survives and not every detrimental mutation dies out. He understood that the faster running lion might slip on a banana peel and break his neck, allowing the slower lion to survive, but he assumed, in our terms, that the effect of this noise is small, so that the predicted number of offspring for the fit lion is significantly higher than that of the unfit lion. In this sense Darwin was proposing the biological equivalent of social determinism. Marx was also aware of the fact that a general might come down with a stomach ache right before a decisive battle, but he assumed that the effect of these small events would be negligible relative to the great forces driving history.

A critical link in this argument is that there is a relationship between the prevalence of a biological species and its fitness. For example, the abundance of alley cats in Israel as opposed to the prevalence of squirrels in the United Sates would be assumed to stem from the cats lack of suitability to the conditions in the US (e.g. the winters are too cold) and unfitness of squirrels for Israeli conditions. Similarly, if in a tropical forest one species of trees is very widespread while there are many other species with a small distribution, this is assumed to be due to the greater degree of fitness of the prevalent species. This is more or less the thinking underlying the niche theory of ecology.

Over the last few decades the theory of natural selection has been exposed to criticism from a number of directions. It was suggested, for instance, that the extinction of the dinosaurs 60 million years ago was caused by a giant meteor hitting the planet, causing enormous ecological upheaval and lasting climate change, to the extent that the dinosaurs could not adapt to the new conditions and went extinct. If this is true, then analyzing fitness based on data from the past is worthless. A visitor arriving on Earth 65 million years ago would have seen a world full of huge dinosaurs alongside tiny mammals the size of rabbits running around between the dinosaurs' legs and serving as snacks. He would deduce that the dinosaurs are unequivocally the fittest species. Thus it turns out that species go extinct not because of unfitness but because of they are unlucky. David Raup[9] argues that mass extinctions are not a result of bad genes but simply of bad luck. It was impossible to predict the extinction of dinosaurs from their history, just as it is impossible to use financial history to predict the collapse of a large bank due to a single clerk embezzling a massive amount of money.

Similarly, over the past few years long-term surveys have been conducted of the population of trees in a tropical forest, covering hundreds of thousands of trees in a large area of the jungle. Every tree was examined, catalogued, and mapped. These discovered that there are a small number of species, each of which makes up approximately 1-5% of the trees in the forest, and a large number of small species, each with a few individual trees. This is exactly the same phenomenon exhibited by the distribution of surnames. About a decade ago, Professor Steve Hubbell from the Smithsonian Tropical Research Institute have suggested a mathematical expression describing the prevalence of tree species, based on the same random process that determines the distribution of surnames, and found it was a perfect fit.

Hubbell argues that this means that there is no need to use Darwinian fitness to explain why some tree species are prevalent while others are extremely rare. As far as he is concerned one can and should assume that all of the species in the forest have the same fitness; each species reproduces over the generations in a multiplicative random process, just like surnames, causing the similar statistical distribution. This provocative claim caused profound shock among ecologists, and the raging debate on the subject fills the pages of the most prestigious scientific publications up to this very day.

Returning again to the basic problem, Darwin assumed that there is a direct relationship between fitness and prevalence. He even states this explicitly in his book: "When we look at the plants and bushes clothing an entangled bank, we are tempted to attribute their proportional numbers and kinds to what we call chance. But how false a view is this!"[10] I assume that Darwin intuitively relied on the argument that Pareto would later formulate, namely that large differences in prevalence indicate a deterministic mechanism and differences in quality, as opposed to luck and randomness. This, as we saw in the example of surnames, is a mistake, if luck is affected by multiplicative processes.

---

9 Raup. D.M. (1991) Extinctions: bad genes or bad luck? W.W. Norton, NY.

10 Charles Darwin, The Origin of Species, ch. 3.

The Rational Political Discourse and its Enemies:

Modern democracy is based on the principle proposed by Pericles that "although only a few may originate a policy, we are all able to judge it." This mote is presented by Karl Popper in his book *The Open Society and Its Enemies*, where he contrasts it to the Platonic vision of a sophocracy. However, to the best of my knowledge, Popper does not present Pericles' words as an argument that needs justifying, but as a condition for the existence of social institutions which prevent tyranny (what we called the corrupt ruler argument above) or at least as a moral demand, which is some form of a variant on the principle of the spirit of freedom.

However, the veracity of Pericles' statement should be examined. It is not clear that foolish, ignorant and self-centered people should be allowed to judge policy. Why shouldn't the privilege of running society be given to experts or to those in the know? Ariel Sharon explained the shift in his politics that occurred when he took office as the Israeli prime minister by quoting the words of a Hebrew song "Things seen from here can't be seen from there". This was an admission of his disagreement with Pericles' claim, a statement that the simple folk aren't capable of judging his policy. What principled argument can be made against this position?

There is not a simple question. It is possible to imagine a public with such degraded morals or intelligence as to rule out democracy (this type of government may only be possible in societies with a sufficiently large percentage of literate people as to enable a reasonable level of public discussion).[11] The foundation of modern government is the realization that everyone is (to some extent) rational, and therefore rational discussion and argumentation are common currency. But it seems that this very same rationality advises putting experts in charge, as is done in medicine or construction.

As shown throughout this essay, one of the fundamental insights is that, so far social engineers' expertise has not produced particularly impressive results. Randomness plays such a large role in human social, economic (and perhaps even biological) interactions that even the best policy architect's forecasts won't be given more than a 50-60% chance of coming true. Anyone claiming to perfectly predict long-term social and political trends is most likely a charlatan. As people living in an open and democratic society, we must be more aware of the weight randomness plays in our lives. This can be seen in a number of areas:

1. **Strategic Planning**: There's much talk among pundits on the lack of a "leader with vision", someone who can see a few steps ahead in the international or political or social game, like a brilliant chess player who is always five moves ahead of his opponent/enemy culminating in a fantastic blow to end the match.

---

[11] Even the great advocate of freedom, John Stuart Mill, admitted that the demand for liberty has its limits, both in terms of the level of the public and in terms of the state of the country. On the former he writes: "Liberty, as a principle, has no application to any state of things anterior to the time when mankind have become capable of being improved by free and equal discussion. Until then, there is nothing for them but implicit obedience to an Akbar or a Charlemagne, if they are so fortunate as to find one." (On Liberty, 23) On the latter subject he argues that: "the regulation of every part of private conduct by public authority, on the ground that the State had a deep interest in the whole bodily and mental discipline of every one of its citizens … may have been admissible in small republics surrounded by powerful enemies, in constant peril of being subverted by foreign attack or internal commotion, and to which even a short interval of relaxed energy and self-command might so easily be fatal, that they could not afford to wait for the salutary permanent effects of freedom."
Unfortunately, there will always be politicians who claim that we are now in an emergency situation and hence civil liberties must be suspended, and there will always be academics to explain why the public is stupid enough to place their freedom in their hands (some of the exaggerations of the global warming camp, or the propaganda of behavioral economists such as Dan Ariely are good examples of these phenomena, respectively). In the end there is no choice but to exercise the common sense.

We need to understand that there is no such thing. Reality is so complex and unpredictable that any attempt to completely foresee its course is dangerous. Our belief in the existence of such social prophets is built on judgment borne of hindsight.

2. **Ex Post Facto Judgment**: We tend to attribute supernatural capabilities (such as foresight in strategic planning) to the great gamblers of history, politics and economics, while gamblers who were no less reckless but happened to lose (and these are the overwhelming majority) are simply forgotten. History books are filled with such failures: The wise King X who invested in his army and won, the foolish King Y who built a large army and thus lay down the foundations for the rebellion that destroyed him. On one page we read of the ruler who expelled the minorities from his country creating religious uniformity which strengthened the nation, while two pages later we find of a second ruler who expelled the minorities from his country and thus lost artisans and merchants, causing his country sink into decline. The truth is that given the conditions of uncertainty only a very long string of successes (even if accompanied by a few failures) can testify to true quality. It's reasonable to assume that Napoleon was indeed a gifted military strategist, who understood better than his opponents the new battlefield which developed after the introduction of the *levee en masse.* But there is no justification in thinking that Julius Caesar, Genghis Khan and their ilk were anything other than extreme risk takers who just happened to win a long series of gambles.

3. **What Ifs**: Often time the argument is made that "If authority figure X had only taken/not taken step Y, everything would be dandy." This statement compares our concrete reality to a reality which we think would have been "if only". People tend to compare history, which actually happened, with **their** assumptions of what would have happened in an alternate reality that didn't take place. In doing so, they implicitly assume their ability to foresee the course of history from a given hypothetical point in the past onward. To the best of my understanding, it is impossible to make such predictions, certainly not retroactively.

4. **Lack of Goals**: What are we supposed to demand, or expect, from our political leadership? The answer has two parts. The first is some sort of vision, not in the sense of a long term strategic plan but in the sense of setting ultimate objectives. Leaders are supposed to approach their position with a list of goals – peace, equality, welfare, education or any combination of these and other elements. This enables them to respond to situations with an aim in mind. Without this outlook no progress is possible. Coming up with these fundamental goals and their relative priorities should be the focal point of political public debate.

The important thing is progressing by small steps while reducing speculation about the future as much possible. As we exemplified by the rocket discussed at the beginning of this article, random effects accumulate over time. A short term forecast is immeasurably more accurate than a long term one: this is the reason why meteorologists happily provide forecasts of the weather four days from now, or at most a week, but will never agree to predict the odds of a strong wind blowing in a month's time. Walter Bagehot described the British Prime Minister of his day, Lord Palmerston, as "a statesman for the moment. Whatever was not wanted now, whatever was not practicable now… he drove quite out of his mind ". In my mind this is a fine compliment for a politician. It is no wonder that Karl Marx, the greatest believer in planning history, hated Palmerston, and this of course is a compliment that is hard to beat.

5. **Rational Risk Assessment:** Insurance companies insure our homes, cars, and even our lives. For a specified sum, the company promises to give us compensation equivalent to the value of our car if it is stolen. How does the company know how to price this commitment? It assesses the risk based on previous data. The insurer has statistics which say that one of every hundred Subarus is stolen annually. Assuming that this will continue to be true in the future, the company offers to insure a Subaru at a certain premium, say 2% of the car's value. If one out of a hundred insured cars is stolen, the company will still have the price of an entire car after compensating the victim of the car theft.

Note the critical sentence: the company makes an assessment based on previous data. It has no real possibility of foreseeing a financial crisis causing thousands of desperate poor people to specialize in car theft, a category 5 hurricane hitting an east coast metropolis causing its complete destruction, or an earthquake launching Los Angeles into the Pacific. All of these are things which can happen but it not humanly possible to evaluate their likelihood, making the pricing of such events as an insurance policy is, frankly, baseless. A clerk sits in some office and throws out a number. If some extreme case does come to pass, the insurer will simply go bankrupt.

A similar risk model lies at the foundation of many established and respected financial institutions. The seventh president of the United States, Andrew Jackson, summed it up very well. When he closed the Second Bank of the United States after a long struggle, he wrote to its president, Nicholas Biddle, that "I do not dislike your Bank any more than all banks. But ever since I read the history of the South Sea Bubble [a wave of bankruptcies that swept England at the beginning of the 18^{th} century, after a speculative bubble burst] I have been afraid of banks"

A similar principal should inform our attitude on the way to the polls. The odds that whatever leader is elected will correctly foresee political events which are the equivalent of a category 5 Hurricane are nil. The person we want in control is not a prophet but rather someone who won't lose his cool when the unexpected happens, when a crisis emerges that cannot be solved using general principles.

Simply Complex: From the Atomic Nucleus to the Animal Kingdom

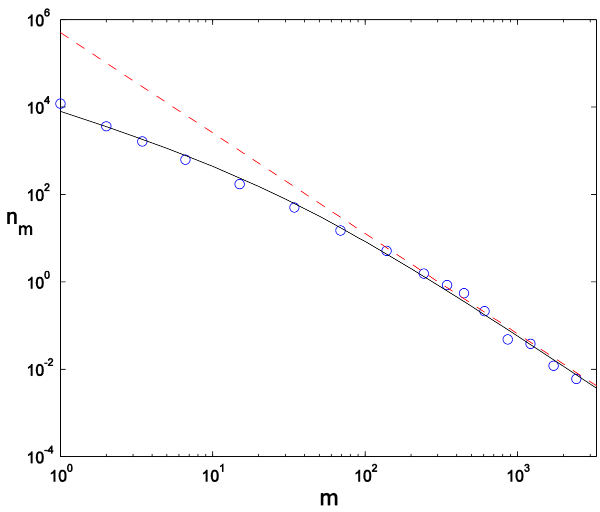
The physics of complex systems has gained a lot of momentum in recent years. Physicists have found themselves involved in analyzing the spread of contagious diseases, the dynamics of the internet, the formation of human and animal social systems, vegetation models, organization and self-organization in ecological and evolutionary processes, analysis and forecasting of the stock exchange and more. What physicists bring to the table in these fields comes from two directions. The first is the analysis of non-linear systems which have a large degree of randomness, in which physicists at the junction between statistical mechanics and non-linear dynamics specialize. The second and perhaps more profound is experience in attempting to quantify systems based on a limited number of simple presuppositions.

A little more than fifty years ago, the world's greatest physicists were busy trying to solve a difficult puzzle: how can one explain the spectrum of electromagnetic radiation emitted by atomic nuclei. The nucleus of an atom is a very small area in which there are strong interactions between the nucleons (protons and neutrons) which are its basic components (as understood at the time). They wanted to understand these forces well enough to be able to predict the frequency of the light which is emitted. This is a very difficult undertaking which still has not been completed for this very reason: the interactions are both complex and very strong. This means that the general law of attraction/repulsion between two nucleons cannot be formulated as a simple mathematical expression. When the nuclear physicists despaired of solving the necessary equations, Eugene Wigner came up with the brilliant idea of turning the problem upside down and achieving maximum simplicity precisely in the case of maximum complexity.

Wigner's argument went something like this: since the forces governing the interaction of nucleons are both strong and complex, it might be possible to describe the end result as a system in which completely random forces are at work. This is similar to the case of the piece of paper thrown off a roof on a stormy day which was discussed earlier. At any given moment the wind is applying relatively strong forces to it, but because the direction of the gusts of wind changes so fast in both time and space, the end result is movement that is almost totally random. In order to provide a basic analysis of the piece of paper the speed of the wind at point x and at time t are best ignored, and it should be thought of instead as a particle which is constantly jumping right or left, up or down at random. On the basis of this consideration, Wigner developed the **Random Matrix Theory**, and succeeded in showing that the spectrum of atoms produces results which are equivalent, to a fairly high degree, to those seen in a system of particles in which completely random forces are at work.

Physicists dealing with complex systems implement this line of thinking in many different fields. For example, it is clear to everyone that ecological systems have weak interactions. In an ecological system there is obviously a free for all going on, where there every two individuals are in competition over resources and reproductive possibilities. Is it nevertheless possible to characterize the system using only a small number of parameters and simple dynamics? If Wigner's line of thinking is correct here as well, then the answer could well be yes. The simplest example of this would be the same random-neutral dynamic which Stephen Hubbell argued for and which we described above.

One of the tricks physicists use in order to simplify complex phenomena is the power laws discussed earlier. We explained that a multiplicative random process produces a power law, and that many natural systems are characterized by the statistical distribution which is described by the same law. However, there are technical problems in implementing this law. Specifically, in most of the systems which were examined the exponent law was only valid for the tail of the distribution, in other words for the richest part of the population or for the most common biological species. Since the data for this tail come from a limited number of individuals (there are only a few billionaires and only a few names with a distribution similar to that of Smith, Johnson or Chang), it is hard to get reliable statistics for them.



Yossi Maruvka, David Kessler and I recently developed a new mathematical tool to solve the problem,[12] expanding on the previous work by Susanna Manrubia and Damián Zanette.[13] Using the jargon from the study of surnames, we expanded the Galton and Watson' original model: everyone bequeaths his surname to a random number of descendants, but any one of those descendants can become disenchanted with his surname and change it to a new one. Additionally, the size of the population is not constant: the average number of descendants a person has is greater (or smaller) than one, so that the population is either increasing or shrinking (obviously, the case of a constant population is a special case of our theory).

In the end, it turns out that there are two parameters: the population's growth rate and the odds that an individual will change his name. With these two parameters we can get a mathematical expression for *n* number of families of *m* size (if there are a thousand families with a unique family name then n(1)=1000. If there are 20 family names, each of which is common to 50 families, then n(50)=20 and so on).

[12] Maruvka YE, Kessler DA, Shnerb NM. 2011. The Birth-Death-Mutation Process: A New Paradigm for Fat Tailed Distributions. *PLoS ONE* 6(11): e26480. doi:10.1371/journal.pone.0026480

Maruvka YE, Shnerb NM. Kessler DA. 2010. Universal features of surname distribution in a subsample of a growing population. *Journal of Theoretical Biology*, 262: 245-256.

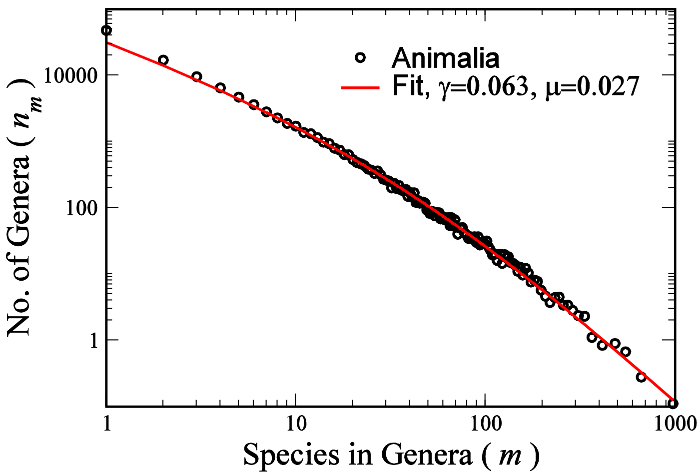
[13] Manrubia SC, Zanette DH. 2002. At the boundary between biological and cultural evolution: The origin of surname distributions. *Journal of Theoretical Biology* 216: 461–477.

How does this work? The figure on the right shows the distribution of surnames as documented in the US Census of 1790. The results used were from such an old census for two reasons: first, at the time the US population was largely English in origin so that the great waves of immigration had not yet introduced a large number of foreign surnames. Secondly, the rate of population growth increased sharply (almost sevenfold!) around the year 1800. The 1790 data therefore represent a relatively homogenous population with a constant rate of growth. One can see the nice fit of the model (the straight black line) with the empirical results (blue circles). This match is much better than a simple power law (the broken red line) which only succeeds in describing the tail on the right. Additionally, from this match the rate of the population growth can be deduced, and since this is a population which emigrated from England, which has had censuses ever since the days of William the Conqueror at the end of the 11th century, we can compare and see that the method indeed identifies the correct rate of growth.

This is all well and good, but it remains to be shown how surname statistics relate to the question at hand. This brings us back to the point which we emphasized earlier. Surnames have neutral dynamics: the odds of having any given number of descendants, as well as the odds that of descendant changing his name, have almost nothing to do with the surname itself. Is it possible to apply these simplifying assumptions to other cases as well?

Here is an example of this. It is well known that every biological species has a "first name" and a "surname" which are derived from the Linnaean taxonomy. Modern man, according to this taxonomy, is *Homo Sapiens*: *Sapiens* is the name of the species (unique to modern man) while *Homo* is the name of the genus to which other species such as *Homo Habilis* belong as well. Well, there are genera which contain many species (the Smiths and Johnsons of the animal kingdom) and many more genera containing a small number of species each, with some having as few as one. What would a graph look like that describes *n* number of genera which contain *m* species?

Pay attention to the figure on the right. Here the points again represent the empirical data for the entire animal kingdom, and the red line is our surname theory. The parameter γ is the population growth rate, that is the rate at which new species are formed minus the rate at which others become extinct, while μ is the odds of a change in surname, here representing the odds that a new species will be so different from the species from which it evolved that it can be classified independently.



It turns out that the same theory that was developed for surnames also describes the distribution of species within genera very well. Not only that, but it allows us to retrieve the basic parameters of macroevolution: the rate of formation and extinction of species and the rate of creation of new genera. In a new article we show an excellent match of the same simplistic theory to the statistics of genetic groups, internet interconnectivity, families of proteins, the word frequency in a text, the number of employees at a company and more.

Is it all vanity?

The results presented here can have a somewhat despairing effect. Everything is neutral, everything is dependent on luck, there is no advantage to the wise or talented man relative to the boor good-for-nothing - it is all vanity. Is this so?

The direction of research we are trying to develop today leads, perhaps, to a slightly more complex answer to this question. Let us return for a moment to that piece of paper thrown off a roof into a storm. Although its movements seem entirely random on small time scales, we can say with some certainty that after long enough we will find that it has hit the ground. It might take hours, days or weeks, but eventually gravity has its say. A similar concept appeared in the field of genetics a few years ago called weak selection. Therefore, although there are qualitative differences between biological species, social systems or political leaders, it is not simply the case that the strong decisively beat out the weak but rather there is a slow drift in a certain direction, with course corrections and whirlwinds along the way. This slow drift is very difficult to identify on the basis of statistical data, since it drowns in the noise created by random events. The development of methods which allow one to find the deterministic needle in the stochastic haystack is one of the projects we are working on, and the initial results look promising.