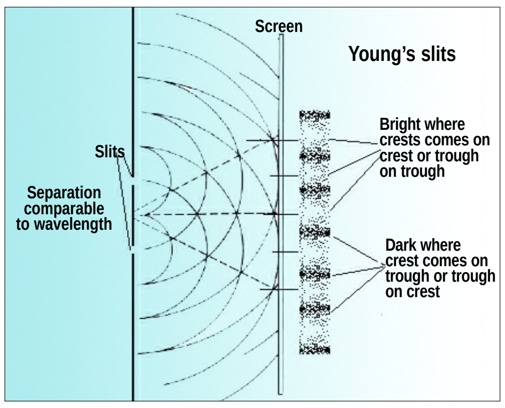
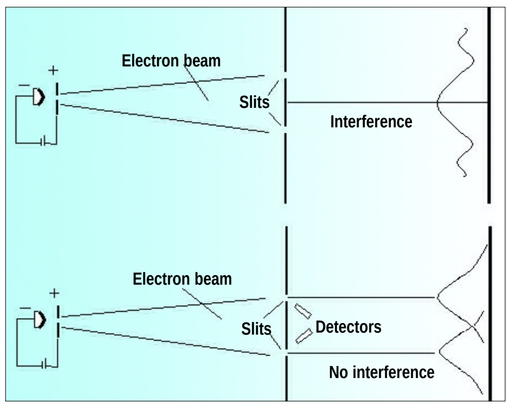
Looking behind the curtain

A glimpse of what should stay 'hidden' may refine the understanding of 'inherent uncertainty' in physics, says
s ananthanarayanan





THE usual rules of physics, which exactly predict the trajectory of moving objects, do not apply in the world of tiny things like atoms. In this world, no object is *exactly* at a place, but its position is *hazy*, and how it will behave or move is a matter of *probability*. In everyday life, where we have large objects like tennis balls and planets, the probability of finding these at one particular place is so predominantly high it is a *certainty*. But at the atom-scale, a particle can be in many *states* at once, to flip into any one, when its properties are measured! An international group led by Aephraim Steinberg of the Centre for Quantum Information and Quantum Control at the University of Toronto, Canada, has questioned this limitation by making a measurement on photons without committing them to one of their two states.


Aephraim Steinberg

Newton's idea of light was that it consisted of tiny, massless particles, like projectiles, which moved in straight lines. This explained the gross effects of reflection, refraction and why a light beam did not bend with gravity. But it could not explain finer things like diffraction or the appearance of fringes at the edges of images or even the dappled look of light that comes down through tree cover. These effects needed the wave theory, which treats light like ripples on a pond. Waves on a pond show reflection or refraction and can also demonstrate the formation of patterns when disturbed by a small object, like a twig, or interference, when trains of waves meet, like we have at the seashore.

The wave theory of light thus exactly explained all features of light beams, and when light was shown to consist of electromagnetic waves, like radio waves, the matter was beyond any doubt.

A classic experiment to demonstrate light waves was Thomas Young's double slit experiment (see picture). Light coming though the two slits becomes two separate sources of light waves that are "in step" with each other at the slits. But when the two waves reach the screen they can be "out of step" at some places, which would show as dark fringes. The light on the screen is thus in dark and bright bands, an effect that can arise only with waves.

But the wave theory was found wanting in explaining other phenomena, particularly the way radiation, as waves, from a warm object was distributed over different frequencies. This and other discoveries, like X-rays and the structure of the atom, soon showed that electromagnetic radiation, which includes light, consists of "packets" of waves called photons, which are like particles, with momentum and energy related to their frequency. The momentum was exceedingly small, no doubt, but it was there – waves, although without mass, did have particle nature. And in turn it was soon discovered that particles also had wave nature, the frequency depending on the momentum. As ordinary objects have sizeable mass, the frequency of the corresponding wave is too high to be of importance. But in the case of truly minute objects, like electrons, the wave nature is both measurable and an inherent and significant part of the particle's interactions.

In fact, an experiment just like Young's slits with electrons shows this graphically. If a beam of electrons is shone on a pair of slits, each electron must pass through one or the other slit and we expect the distribution on the other side to be like two single slit distributions. But the surprising thing is that the electrons also collect in dense and rare bands, just like the light beam, as if the electrons were waves that could pass through both the slits at once and show an interference pattern!

Quantum mechanics

This is the core reality in the physics of small things — that waves have momentum and behave like particles and particles have no defined position, but are hazy, with uncertainty of just where they are. Interactions, like scattering of particles, thus cannot be geometric, like with billiard balls, but leave room for a brace of outcomes with different probabilities. A consequence of this view of the world is that we can never definitely say both where a particle is as well as where it is going. We can know a range, but if we measure either property more exactly, the other gets more uncertain. This inherent uncertainty has been exactly worked and is expressed as a fundamental *principle*, the Heisenberg principle, that the uncertainty in either position or momentum must rise or fall as the uncertainty falls or rises in the other.

Translated in terms of the double slit experiment, this means the interference pattern, which locates precisely waves arriving at the place where they strike the screen, is possible because of the uncertainty in the direction of arrival, from one slit or from the other. If that uncertainty is removed, the interference patter would disappear and the arrival of particles from either slit would just be the slight spread in front of the respective slits. This can be demonstrated in the case of the experiment with electrons by making an arrangement to identify the slit through which the electrons pass. Just getting hold of this information destroys the interference pattern!

Weak measurement

Steinberg and colleagues considered that an exact measurement, like detecting an electron as it passes through a slit, would affect the particle's future trajectory, which would be uncertain. But it had been proposed that if the measurement of the particle's position were "weak", so that it did not appreciably affect the particle's momentum, then the interference pattern may remain despite the "weak" measurement. With this concept in mind, Steinberg and team set up the Young's slits experiment with a source of single photons. For detecting the slit of passage, they passed the photons through a quartz crystal, which affects the plane of vibration, called the *polarisation*, of the light wave. Thus, depending on how the polarisation was affected, the slit through which the photon passed could be roughly made out. The distribution of intensity along the screen, as measured by a camera, showed the interference pattern. Thus, over a series of measurements, while the behaviour of light as it traversed the two slits in wave fashion, creating an interference pattern, could be made out, the particle nature showed itself from the inference of the slit through which the photon had come, from the change in polarisation.

But does this mean that the principle of uncertainty and a cornerstone of quantum mechanics have been overturned? Not really, as it is still not a simultaneous measurement of complementary variables. "While the uncertainty principle does indeed forbid one from knowing the position and momentum of a particle exactly at the same time, it turns out that it is possible to ask 'What was the average momentum of the particles which reached this position?' You can't know the exact value for any single particle, but you can talk about the average," says Steinberg. On a more positive note, he adds, "The trouble with quantum mechanics is that while we've learned to calculate the outcomes of all sorts of experiments, we've lost much of our ability to describe what is really happening in any natural language. I think that this has really hampered our ability to make progress, to come up with new ideas and see intuitively how new systems ought to behave."

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The culturomics approach

mishmi takin highlights an original tool in the study of culture and social trends using millions of books

IS it possible to develop a quantitative measure of culture? The idea seems absurd and, intuitively, the value of such an approach seems questionable. This together with the not so original addition of the suffix "omics" to the word "culture" made me glance sceptically at an article, "Quantitative Analysis of Culture Using Millions of Digitised Books", Michel et al, published in *Science* dated 14 January 2011. This paper documents the development of a quantitative tool to study culture. A major limitation for such methods in the past has been the absence of an amenable data-set.

The authors report the creation of a corpus of 5,195,769 digitised books. This represents a staggering four per cent of all books ever published. Google's effort to digitise books has resulted in over 15 million (about 12 per cent of all books ever published) digitised works; the sub-set used in this study was selected on the basis of the quality of digitisation and availability of publication related information (such as date of publication).

It is impossible for a person to read all the books in the corpus, which spans seven languages, with the best representation in English between the years 1800-2000. Given the limitations imposed by copyrights in making the data-set and the results public, the authors chose to study the frequency of occurrence of what they call "ngrams" — where a gram is a string of characters not interrupted by a space such as "indigo" and "mobile phone" is an example of a two-gram and so on.

The usage frequency of an ngram is computed by dividing the number of occurrences of a particular ngram in a given year by the total number of words in the corpus for that year. The intriguing thing is that the frequency of occurrence of a word such as "slavery" follows a known cultural context — peaking near the civil war (early 1860s) and then during the civil rights movement, making this data-set an invaluable tool for social scientists. By careful search and analysis, the authors pick up some extraordinary cultural trends, some of which I will try to highlight here. However a critical discussion of the methods used is beyond my and this article's scope.

The authors find that the English language is growing at a healthy pace with an average increase of about 8,500 words a year, which has resulted in a 70 per cent increase in the size of the language over the last 50 years. Even dramatic incidents fade, both from our minds and from the minds of those around us. This study finds that the precision of collective memory is increasing; however, we, as a society, are also forgetting faster. This trend suggests that people too rise to fame much faster than before but are forgotten sooner.

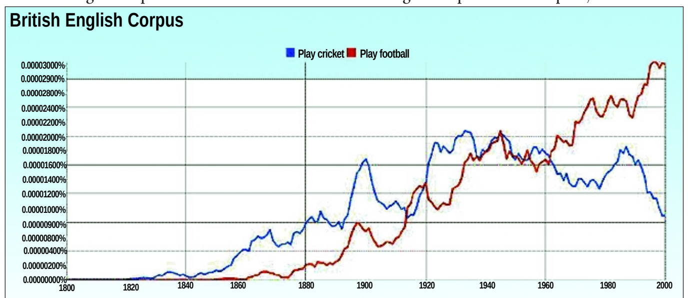
Events leave imprints; sometimes careful analysis can detect even a shallow footprint on the sands of time. In a world of military regimes and suppression of free speech, it is common knowledge that people and ideas are forcefully buried. One of the most impressive features of the culturomics approach is its ability to uncover such undeserving graves. In this study, the authors tried to identify victims of Nazi suppression *de novo*.

Given the volume of historical research that has been conducted on this subject, it was possible to verify the results thrown up by this study. They looked for marks of suppression of names of individuals in the English and the German corpus. They found very few hints of suppression in English, whereas in the German corpus about 10 per cent of the individuals show marks of suppression (including Pablo Picasso, Walter Gropius and Hermann Maas). Also, they found an enrichment for a group of individuals (Nazi and Nazi supporters) who presumably benefited from propaganda.

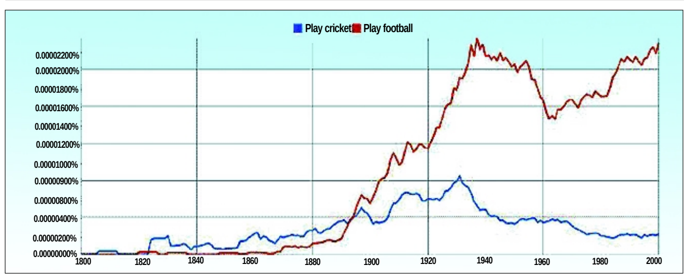
It is fascinating that just looking at books can reveal cultural trends and suggest trends that have gone unnoticed so far. All of the data-set used in this study has been made available at *www.culturomics.org* and *ngrams.googlelabs.com.* It is possible to use this data-set for doing your own experiments — but I warn you (as do the authors) that this is addictive. Here I cite some of my own explorations in the hope that it will reveal some of the scope and limitations of this nascent methodology.

I queried the two grams — *play football* (in red), *play cricket* (in blue) in the British English corpus and American English corpus…

British English Corpus

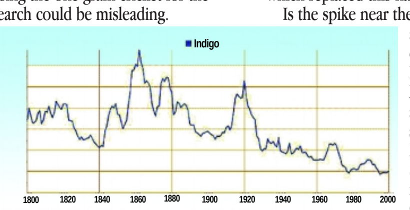


American English Corpus



… One possible interpretation of the above "culturomic trajectories" is that cricket was more popular in the British English world than football, which has now moved ahead of cricket, and that in America cricket was never as popular as football.

Of course, given that we are simply looking at frequency of the ngram, there are multiple confounding factors. Prime among these is the absence of context; although we look for a word, we don't know why it was being used and if it has consistently had the same meaning over time. For example, cricket is the *game* and an *insect*, so using the one gram cricket for the search could be misleading.



The trace for the one gram "indigo" has two well separated peaks in the British English corpus which are absent in the American English corpus. The corpus is case sensitive, so "Indigo" and "indigo" would not have the same traces. However, since the traces are linked to the books in which the ngram appears, it is possible to do a manual check on the ngram and verify its usage.

The first peak in the trace for "indigo" is around the 1860s. Could the possible explanations be the Indigo revolution in Bihar/Bengal in 1857, the publication of *Nil Darpan*? A discovery, perhaps, of a new chemical method for processing or making this dye? Is the subsequent decline a consequence of the introduction of the artificial dye which replaced this natural colourant?

Is the spike near the war because of a renewed demand for Indigo as war had made the artificial dye scarce? Or the launch of the Satyagraha movement in Champaran, Bihar, against the forced cultivation of cash crops like indigo in lieu of food crops?

The usage frequency, during the first peak, increased from about 0.00025 per cent to about 0.00065 per cent. Is this a significant change which even deserves an analysis of context?

In other words, is it real? These questions lie within the realm of statistics and will require careful analyses and cautious interpretation. *A priori*, it would have been hard to believe that such clean trends can emerge from a data-set such as this — which does not for now include newspapers, periodicals, magazines, art, music and other material. It is hard for us as complete outsiders to look at the world of "culturomics" now and accustom ourselves to "all the wonder that will be". However, thanks to this effort, we now have Ngram — a peep hole into this unexplored way of thinking about the evolution of culture, through words and the various factors such as political climate and social ideas that influence it. In some ways it is a subtle unveiling of the power of the written word — a new way of wielding the pen in the age old battle with the sword.

The writer would like to thank Jean-Baptiste Michel for critical feedback

Chemicals inside bacteria

tapan kumar maitra focuses on microbial molecular processes that sustain life

THE bacterial cell contains the main chemical elements, organogehes, nitrogen, carbon, oxygen and hydrogen. The percentages (dry matter) of nitrogen and carbon are 8-15 and 45-55 per cent respectively; those of oxygen and hydrogen 30 and six to eight per cent respectively. From the various elements and their compounds, micro-organisms synthesise proteins, nucleoproteins, carbohydrates, lipids, lipoglycosides, lipoglucoprotein complexes, nucleic acids, enzymes, vitamins, etc.

The water content in the cytoplasm of most species of bacteria varies from 75 per cent (colibacilli) to 85 per cent (diphtheria bacilli, tubercle bacilli, cholera vibrio). Water is the main component of the cell, and is found free and bound with other component substances. Bound water is a structural element of the cytoplasm, and cannot be a solvent. Free water serves as a dispersion medium for colloids, and as a solvent for crystalline substances, as a source of hydrogen and hydroxyl ions, and is involved in chemical reactions. For example, the hydrolytic processes of the breakdown of proteins, carbohydrates and lipids take place as a result of the binding of water. Water plays an important part in the processes of respiration.

Inorganic substances (phosphorus, sulphur, sodium, magnesium, potassium, calcium, iron, silicon, chlorine, etc.) and trace elements (molybdenum, cobalt, boron, manganese, zinc, copper, etc.) are also found in the bacterial cell. The total amount of mineral substances in bacteria grown on standard nutrient media varies from 2 to 14 per cent of the dry matter of the microbial mass.

Prokaryotic Cell Structure

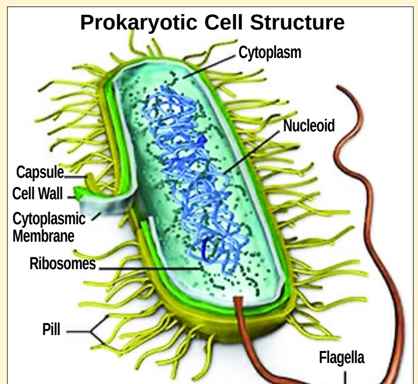


Figure 1

The organic part of the dry matter of bacteria consists of proteins, nucleic acids, carbohydrates, lipids, and other compounds. More than 50-80 per cent of the dry matter of the bacterial cell is made up of proteins found in the cytoplasm, nucleoid, cytoplasmic membrane, and other cell structures.

Proteins are composed of certain nucleoproteins, the prosthetic group of which is made up of nucleic acids. Lipoproteins pertain to the second component part of proteins. Their prosthetic group is made up of fats (lipids) or fat-like substances (lipoids). Lipoproteins are found within the cell as inclusions having a semisolid consistency, including mesosomes. On the surface of the cytoplasm Hpoproteins form a membrane which regulates the substances entering the bacterial cell. Enzymes which play an important part in the life processes of micro-organisms are proteins which have prosthetic groups (active groups). The protein part of the enzyme (apoenzyme) has a specific function, and the prosthetic group carries out a chemical reaction. In some cases the prosthetic groups are not bound firmly to the protein and easily separate from it while others can bind themselves to different proteins. These freely existing non-protein catalysts involved in biochemical transformations are known as coenzymes. Another group of enzymes contains haemin compounds as the active group. Enzymes concerned with oxidation belong to this group.

The amount of nucleic acids in the bacterial cell depends on the bacteria species and the nutrient medium, and varies within 10-30 per cent of the dry matter. Nucleic acids are normally bound to proteins and complex radicals of the cell structures of bacteria. Ribonucleic acid takes part in the synthesis of proteins, and desoxyri-bohucleic acid determines hereditary properties. This qualitative and quantitative variation of proteins and their complexes and amino acids gives the micro-organisms their type specificity.

Carbohydrates and polyatomic alcohols comprise 12-18 per cent of the dry matter in the bacterial cell. These include a) polyatomic alcohols, b) oligosides, c) polyosides, d) neutral oligopo-lyosides containing N-acetylamino groups, e) acid polyosides and f) oligo- and polyosides containing sialic acid. The main part of the carbohydrates is a polysaccharide complex, free from or bound with proteins and lipids, found in the cell wall and slime layer. The cytoplasm of many bacteria has a comparatively large amount of inclusions chemically resembling glycogen or starch.

Some microbes have hexosamines which on hydrolysis break down into monosaccharides, aminosaccharides, and amino acids (type I, IV, XIV S. pnewnoniae, bacilli of diphtheria, tuberculosis, etc.). During acid hydrolysis of polysaccharides, galactose, glucose, levulose and other monosaccharides are released. The type specificity of microbes depends on the polysaccharide fractions. This is of great significance in laboratory diagnosis, in the preparation of vaccines, and medicinal and diagnostic sera.

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