Snow

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I was in the office late one evening when the telephone rang.

"Hello"

"Is this the University of Cincinnati?"

"Yes."

"Can you give me the number of a Richard Newrock?"

"You're talking to him."

"Hello! I'm a manic-depressive who hasn't worked for 30 years but I've been working on a solar device for melting bee's honey - you know about bee's honey - well I read about your new Culinary Program at UC and you know manic depressives are associated with creativity and I was wondering about something I read in a physics textbook about solar collectors and if you could put a Fresnel lens - you know Fresnel lenses - they're sort of like Venetian blinds - hey - wait a minute - your telephone number has three sixes - that's the 'Number of the Beast!' - I can't talk to you." (click)

Usually I don't let them run on like that - but then I don't get many calls that start with "I am a manic depressive" and end by calling me the "Antichrist." It was interesting in a way that unsolicited telephone calls and manuscripts never are.

As a physicist I am used to this. In the past it came in the form of self-published books. At one time I kept them - for no good reason - and I had three long shelves full. They were from folks who "found" errors in Relativity or with the Heisenberg Uncertainty Principle or some such. Nowadays unsolicited works come over the Internet. Last week I received one that began

> "I recommend to your attention my study which I publicated on the Internet. Title of my study is "Particle and atomphysics - instead of theories - according to facts and laws of the classic physics."

It continued:

> This e-mail [...] I shall to send to [...] physicists, researchers, [and...] students of the whole world's laboratories, universities, physical institutes and [...] journals. I please you visit to my web page and read my theory!"

These people put their work on Websites because it doesn't get past the referees of reputable journals. I get three to four e-mails a week like that. But at least these people are thinking - well, except for my manic-depressive numerologist friend. Wrong-headed and muddle-headed thinking, perhaps. But they try to understand scientific ideas. That's more than I am able to say

about many of my colleagues and most of the citizenry.

In looking for a topic for this paper, I turned to my usual source of inspiration, the Cincinnati Enquirer. It can always be relied on to publish something inane about science, technology or religion. I even tried to read Peter Bronson's columns - he also can be relied upon to write something utterly absurd. But - perhaps I have become jaded after 32 years of living in Cincinnati - even a lengthy article on the Creation Science Museum in Kentucky, and several letters and editorials about Intelligent Design, failed to arouse sufficient indignation for a Literary Club paper. But looking further afield, I found some stories - each of small interest, but important when taken together.

In the New York Times.[1] Americans are wary of nuclear power because of concerns about radiation releases. However, except for Chernobyl and other accidents, such releases are almost undetectable in comparison with the natural background radiation. Partly because of concerns about radioactivity and the cost of containing it, electric utilities prefer coal-fired plants. 52% of the generating capacity in the United States is coal-fueled; only 15% is nuclear-fueled. Coal combustion produces greenhouse gases that are suspected to cause climatic warming. Burning coal is a source of sulfur and nitrogen oxides, harmful to human health and responsible for acid rain. Not as well known, researchers found that the gases released from coal combustion contain naturally occurring radioactive materials - uranium and thorium.[2] Americans living near coal-fired power plants are exposed to higher radiation doses than those living near nuclear power plants.

The Albuquerque Journal.[3] The Heel company, a homeopathic pharmaceutical company, was planning a new manufacturing plant and was applying for industrial revenue bonds. The owner said his company was hiring more help and expects to create 200 jobs over the next 10 years. The Bernalillo County Commission authorized $8,000,000 in industrial revenue bonds for the company.

The Cincinnati Enquirer.[4] 20 million Americans suffer from depression. 10 million Americans have osteoporosis. 13 million Americans have hyperthyroidism. 8 million Americans are alcoholics. 40 million Americans have digestive diseases. 70 million Americans have arthritis. 30 million Americans are at risk for diabetes. Add it all up and every American over 40 has at least two diseases - or so the foundations, medical school fund raisers and pharmaceutical companies would have you believe.

Pollsters like to visit Ohio, the American Heartland, to find out what the "average American" is thinking. And he has spoken. According to a poll sponsored by the Cleveland Plain Dealer, the vast majority of Ohioans believe that public schools should teach the so-called theory of "Intelligent Design" as science. The Cincinnati Enquirer[5] declared that the Ohio state school board "should pay serious attention to the views of Ohioans revealed in the poll," and noted that

another poll had shown similar results. One question pollsters asked was "Which of the following five statements comes closest to your view about the development of life on Earth?" Here are the statements and percentages of respondents holding each view:[6]

-- "All living things come from a common ancestor [and] evolved over millions of years into different species due to natural processes [...]"... Darwinian evolution (13%)

-- "Living things are too complex to have developed by chance. A purposeful force or being, that may or may not be God, is responsible for designing life. [...] ... Intelligent Design (15%)

-- "God created the universe and all living things as claimed in the Bible. Creation took millions of years and evolution is the method God used to achieve this."... Theistic Evolution (26%)

-- "God created the universe in the manner the Bible describes, but over [...] millions of years [...]. God made all living things, [...], but has allowed some small-scale evolution to take place."... Old-Earth Creationism (13%)

-- "God created the universe exactly as the Bible describes, in a period of six days, and the world is less than 10,000 years old. God made all living things [...], in the form they appear now, and there has been no evolution."... Young-Earth Creationism (29%)

The Jackson Hole Daily.[7] "...Today roughly 75% of U.S. processed foods - boxed cereals, other grain products, frozen dinners, cooking oils and more - contain [...] some genetically modified ingredients. Nearly every product with a corn or soy ingredient, and some containing canola or cottonseed oil, have a genetically modified element. In [a survey] less than half of the people interviewed were aware genetically modified foods are sold in supermarkets. At the same time, more than half wrongly believed that supermarket chicken has been genetically modified."

There are two common themes in these news items. They are issues that are now before the American public, issues that informed - and uninformed - citizens must think about. They reflect a combination of scientific illiteracy and what has been called mathematical innumeracy.[8] It is unfortunate that important decisions about these issues are being made by people who do not have the basic tools to understand them.

Coal-fired power plants are a major source of radioactive materials and other pollutants released to the environment. Coal combustion is far more hazardous to health and the environment than nuclear power, and adds more to the background radiation than nuclear power. It suggests that if radiation from coal plants were regulated, their capital and operating costs would increase, making coal-fired power less competitive. This is an example of where scientific illiteracy is costing us economically, environmentally and medically.

The decision by Bernalillo County is either incredibly stupid or incredibly smart. Homeopathic theories contradict known physical laws. Taxpayer money will be supporting a manufacturer of

worthless "medicine." On the other hand, the company creates jobs - so the community benefits. In a way it echoes the current debate over casino gambling. Anyone who is not innumerate can calculate the poor odds of winning at a casino; but they prosper, we encourage them, and then we tax them. Unfortunately, issuing bonds for homeopathic medicine implies an endorsement of such dubious products by the county.

I won't belabor Creation Science and Intelligent Design - I discussed them in a past paper, they are not scientific theories, and the poll numbers speak for themselves. I will note that the recent editorials in Ohio newspapers indicate that Ohioans are woefully ignorant when it comes to biological science - 42% believe in some form of Biblical creation and 85% do not believe in Darwinian evolution. Also, as the Enquirer appears to suggest, scientific issues are to be settled by opinion polling.

Scientific illiteracy is pervasive in our society- including the academy. When I was younger I did not understand this. In school, my fellow students and I discussed various topics at length - from science to theology to literature to art. When I became a professor, I expected to find a similar community of scholars; instead I found that university people tend to work in intellectual silos - interaction and wide-ranging discussion is rare. A university is really just is a collection of departments with common toilet facilities.[9]

It was the attitude of many of the non-science faculty I found disconcerting. I was told by one Professor of English that a person is uneducated if they haven't read Shakespeare; Hamlet, was his example. That is a position with which I agree - at least for native-born English speakers. On the other hand, he felt that it was perfectly reasonable for him to know nothing about Quantum Theory - indeed he was proud that he had never tried to understand it. This even though it forms the core of modern physics, has deep philosophical implications, and impacts one's existence on a daily basis - through electronics and photonics. It may be difficult to work with, or to gain a deep understanding of Quantum Theory, but it is not difficult to understand the basic ideas and their impact on modern thought. I will return to Hamlet in a different context in a few moments, but I note this Hamlet-Quantum discussion was my first real introduction to scientific illiteracy, which I now know is rampant among non-science faculty at universities and the general public.

Charles Percy Snow was a scientist and a novelist. His essay, "The Two Cultures," has entered the popular lexicon of western thought. Snow's basic theme was that there is a breakdown in communication between people in the sciences and the humanities - the two cultures. The essay made an impact when it was published in the nineteen thirties, although today it is hard to see why. As he himself admitted, what he said was neither original nor profound. Snow believed the divide between scientists and "intellectuals" (his word) exists because scientists disregard traditional culture and "intellectuals" refuse to learn from the natural world. His ideas are dated and simplistic: he believed in the ability of science to solve the world's problems. That won't

happen - our problems are social and cultural, not scientific, and are more likely to be solved by sociologists and anthropologists, than by engineers and physical scientists.

Nowadays, communication between the sciences and the humanities is harder because of the difficulties created by the fragmentation of human learning. As late as the middle part of the 19th century it was possible for a well-educated man or woman to be knowledgeable in the sciences and the arts. In fact, he or she could be knowledgeable in nearly everything that was known. But then an explosion in science occurred -especially in physics - and suddenly a great deal of specialized knowledge was needed before one could be knowledgeable in science. As one author has phrased it - rather petulantly, I think:

> "Like priests of some ancient cult, scientists were separated out from the mass of men, elevated above them by their access to secret knowledge. Even more annoying was the fact that even though they had moved beyond what the rest of us could readily understand, they could still listen to Bach or read Shakespeare and discuss it intelligently. The reaction of their peers in the arts, or those who had been their peers, was to make their own fields of expertise as obscure as possible. If Picasso couldn't understand particle physics, he sure as hell wasn't going to paint anything comprehensible. If Joyce couldn't pick up a scientific paper and read it, then no one was going to be able to read his books either. And so grew the two cultures - both with elaborate and counter-intuitive theories requiring years of study."[10]

Well... I suspect there is more then a little hyperbole in those remarks. I cannot see Picasso or Joyce - or anyone - deliberately setting out to create obscure masterpieces to avenge themselves on physicists. But there is an underlying truth - over the years the sciences and the humanities have grown progressively more complex, and humanists and scientists can no longer communicate easily. Unfortunately they don't communicate well with the rest of the world either. As an interesting example of the problems between the two cultures, consider the recent work of the physicist Charles Falco and the artist David Hockney. Hockney[11] observed qualities in the portraits of Jean-Auguste-Dominique Ingres that led him to believe that some sort of optical instrument was used to make the paintings. He felt that the portraits were "too good, too photographic." He embarked on an investigation of a large number of European paintings to determine where and when this started. He noted the sudden and mysterious outbreak of "near photographic reality" in the early Renaissance. He theorized that lenses must have been used by the artists.

Charlie Falco is a physicist with a specialty in optics. He began to examine some of the paintings, looking for "smoking guns" - the presence of optical artifacts which might serve as supporting scientific evidence for Hockney's conjectures. He discovered, he believes, a wealth of such

evidence in a wide variety of paintings, evidence that he feels demonstrates that lenses were used by certain artists to project images as early as 1425.[12]

After finding the optical artifacts, Charlie was able to reproduce them to an accuracy of better than 2%. He used medieval methods to make spherical concave mirrors - which are just a different type of lens and were in common use in the early Renaissance. He found the measured resolution of the images he projected to be as good as the finest detail in the paintings. He looked for optical anomalies in the paintings, found them, and found that they were consistent with the use of lenses. Most importantly they were very difficult to explain in any other way. The acid test of the "lens" hypothesis is in it's ability to precisely predict these non-random errors.

Hockney and Falco claim that the evidence they found shows that some features of some paintings were produced with the aid of lenses. They do not claim that the artist's sense of composition and aesthetic judgment are not intimately involved in the process. They do not imply that the paintings are essentially photographs with images fixed by paint. The lens is simply an artist's tool, like a brush.

I am not interested here in discussing whether or not they are correct - I am interested in the reaction of the art history community to their proposals. It is, in a way, similar to the early reaction against Darwinism. There is no reason for art history to be the sole province of humanists. In recent years economists, historians and anthropologists have used their particular methodologies to study how market, social and cultural forces affected artists' products and productivity. Physical scientists can offer much in the way of explanation of how paintings were made. Apparently this does not sit well with art historians. Indeed they greeted Falco and Hockney's ideas with what can only be described as fury and indignation. Nowadays, if you ask an art historian (present company's spouses excepted) about Falco's work, you are greeted with surprise -surprise that you take his ideas seriously. The underlying assumption of art historians appears to be that Falco and Hockney's claims have been shown to be wrong and should be dismissed.[13] However, as Charlie found, if you press them hard enough, the art historians admit that they do not know the details of his argument - and it is all in the details. An understanding of the exact science is important.

The critics use many arguments against his hypothesis - but Charlie finds that they all fall into six categories:[14]

Artists did not need to cheat or use lenses - they were that good and talented.

Artists' lenses would have been too cumbersome.

No written proof exists that artists used lenses.

Artists could have used a grid to get the perspective right.

The lens hypothesis is overstated.

Even if the lens hypothesis is true it is not of interest to art historians.

The last two are not worthy of discussion. The problem with the first three is that they do not rule out optical devices. Whether or not they had the skill, whether or not lenses were cumbersome, whether or not someone wrote about them, artists may still have used them. The argument about talent and training is at odds with the arguments about grids and geometry. No one suggests that artists of the Renaissance were so talented they could draw in perfect perspective - and tools such as strings, grids, and glass panes were known to be used. The problem with the grid argument is that the use of a grid explains how the artists got the perspective right - but it does not predict the errors they made.

To be valid a scientific theory has to be able to make predictions. That is, it has to be falsifiable. To decide whether or not to accept a scientific theory about the arts - or about anything - you must evaluate the evidence in detail to see if it supports the claim. Then you must ask how the claim could be subjected to further tests - that is, can it be falsified? In other words, one needs to think scientifically. And there is the crux of the matter - most people are not taught to, and do not try to think scientifically and are, too often, proud of it. They simply do not appreciate the limits of their thinking. When historians argue that the artists did not need lenses because they were so talented, they do not appear to realize that this does not rule out the use of lenses. When they say artists used a grid to generate the correct perspective, they do not realize that a "grid" theory does not predict the perspective errors found.

But scientific literacy alone is not sufficient. In order to make informed decisions on scientific - and other - arguments, and to determine if they are reasonable, one must have some facility with numbers. People's facility with numbers differs, but too many people are downright poor at it. They are innumerate. They cannot do simple calculations, or make rational estimates. Young people today cannot estimate the tip in a restaurant even when tax is printed on the bill. Richard Gass once asked a class to estimate the circumference of the earth. Several students estimated it to be on the order of 10,000 meters, or 10 kilometers - I guess they circumnavigate the earth on their the way to the airport. The inability to make a rational estimate is one of the three numerical areas in which I find people to be especially deficient - the other two are a lack of appreciation for the implications of really large numbers, and a lack of understanding about probability and coincidence.

About 20 Americans are killed by terrorists each year - outside Iraq, that is. How should you react to that? What does a megaton - two billion pounds - of TNT really mean? Does McDonald's really sell 1200 billion hamburgers a year?

One pound of TNT will destroy your car - and everything in it. A nuclear submarine, with many multiple-megaton warheads, contains more explosive power than the sum of the

explosives expended by both sides in World Wars I and II.

About 20 million Americans travel abroad each year. Assuming you don't do something really stupid - such as booking a tour of Baghdad nightclubs - the chances of being killed by a terrorist is one in a million. Statistically, there is one chance in 70,000 of choking to death, one chance in 75,000 of dying in a bicycle crash, and only one chance in 53,000 of dying in an automobile crash. Yet the same people who worry over going abroad do not worry about driving.

The number of hamburgers I quoted for McDonald's yearly sales is from an article in a news magazine. A simple calculation using reasonable estimates about cows and farmland shows that there would need to be several cows per acre of arable land over the entire world to make that many hamburgers each year. Not a likely scenario - the magazine was edited by an "innumerate."

Doctors' - or I should say physicians' - understanding of risks are often off the mark. A decade ago I had a shoulder operation. The surgeon (not a member of this august body) told me that the chances of a problem occurring were minuscule. He said it was less than 1 in 10,000 - and then he added that he was 99% sure of that![15] This doesn't surprise me - physicians also seem to believe that it is possible to fit ten fifteen minute appointments into one hour.

The ability to make reasonable numerical estimates is important. It is surprising how much useful information can be obtained in simple ways from minimal facts - by what physicists call "back-of-the-envelope" calculations and others call "ball-park estimates." When I was regularly sitting on physics graduate student thesis committees and wanted to see how well a student thought, I would ask very simple questions: Estimate how many gas stations there are in Cincinnati? How many piano tuners are there in the metropolitan area? If you are interviewing someone and want to see how they think and handle really large numbers, ask them to estimate how long it would take to haul away Mount Rainier by truck.

The consequences of the public - and politicians - inability to make estimates and generate a proper assessment of risks are serious. Such as the abovementioned risk of traveling abroad. This inability leads to either crippling anxieties or atrocious and impossibly paralyzing policy decisions. I mentioned the chance of dying in an auto accident. One could reduce those deaths to near zero by a strict enforcement of a five miles per hour speed limit. But no one would advocate that - we do the sums, look at the risk-reward ratio, we drive at sixty miles per hour, and accept the risk of the higher chance of dying. But this is because driving painfully slowly has immediate and direct consequences on our lives. When the results are not as direct, we make dumb decisions. We demand the shutdown of nuclear power plants, even though the risks to public

health from coal-fired power plants are far greater.

Before I discuss really, really big numbers, I should take a moment to explain scientific notation to those unaware of it. This notation is preferred for very large or very small numbers. We don't say one billion - we say 10^9. Think of it as a 1 followed by 9 zeros. A million - 1 followed by 6 zeros - is 10^6. Thus if one has a really big number - say 10^{100} - one doesn't have to write - or read - 1 followed by 100 zeroes. Similarly, one-thousandth is $10^{"3}$, a millionth is $10^{"6}$, etc. It is easier to say - or read - 4.35672×10^{25} than it is to say forty three million, five hundred sixty seven thousand, two hundred billion billion.

Let me give you a sense for large numbers: It takes 11 1/2 days for a million seconds to pass. But a billion seconds is 32 years. Modern man is about 10 trillion - 10^{13} -seconds old. The universe is about 10^{17} seconds old. Agriculture has been around about 150 billion seconds, Christianity 62 billion seconds, Henry Winkler nearly 3 billion seconds, rock music for about one and a half billion seconds and rap music for 200 million seconds - although it seems much longer.

Understanding large numbers is extremely important in understanding impossibilities. My favorite example is a problem I used to assign in a statistical physics class - it can be called "the meaning of never."[16] Ironically, given who originally posed the problem, the answer is often used by Creationists to support their ideas. The problem was first published in the 1930's in a book[17] by a physicist, James Jeans, who attributed the following quote to Thomas Huxley, Darwin's champion. As phrased by Huxley - or Jeans - "Six monkeys, set to strum unintelligently on typewriters for millions of years, would be bound in time to write all the books in the British Museum." This oft quoted statement is wrong and gives a very misleading sense of what really large numbers imply.

What's the probability that monkeys could accidently type Hamlet? Assume all the monkeys that ever lived are sitting at computers - 10^{10} monkeys. Assume that each monkey hits 10 keys per second and that he does so for 10^{17} seconds, the age of the universe. Assume a keyboard has 44 keys and ignore upper case characters. Hamlet has about one hundred thousand characters. From this it is easy to show that the chances of producing Hamlet, if all the monkeys that ever existed typed for the age of the universe, is 1 in $io^{164,316}$. That is one chance in 1 followed by 164 thousand, 316 zeroes. In any operational sense of an event occurring, the probability is essentially zero. The original statement by Huxley is nonsense - one play, never mind the entire British Library, would never occur in the entire literary output of all the monkeys who have ever lived. Creationists, and especially Intelligent Designers, have taken this as an argument in favor of their ideas - and that Darwin and Huxley were wrong. They say that life is too complex to have arisen by chance. Peter Bronson's analogy was dumping a truckload of bricks off the Empire State Building and asking of the chances they form a house on impact. But the calculation does not support such things - all it shows is that monkeys don't write great plays. They'd be better off

simply waiting around until they evolve into something a little smarter. Bronson should have asked if one dropped a million loads of bricks what was the chance two bricks would be found touching. As an aside I note that one author[18] has inverted the problem - he asks what is the probability that Shakespeare, via random muscle twitches, might have found himself swinging through the trees like a monkey.

One can also use simple calculations that generate large numbers to understand issues of scale - consider those who wish to interpret the bible literally, the Young-Earth Creationists. In Genesis, in discussing Noah and the flood, it is stated that "all the high hills that were under the whole of heaven were covered ..." Taken literally, 20,000 feet of water covered the earth. Since it rained for 40 days and 40 nights, about 1000 hours, the rainfall rate had to be about 20 feet - 240 inches - per hour. Fast enough to sink a battleship let alone a wooden ark. This is an example of an internal numerical inconsistency - like the numbers in the article on McDonald's sales. Numeracy is useful in discovering internal inconsistencies in literal-minded ideas. The additional point is that interesting information can be gleaned from the barest of "facts" and claims refuted on the basis of raw numbers alone. If people were more numerate, many obvious inferences would be drawn and fewer absurd notions would be entertained -homeopathic medicine comes to mind.

It works the same way with tiny numbers. An interesting idea comes from Archimedes, indeed it is a principle named after him. It says that any number, no matter how large, can be exceeded by adding up sufficiently many smaller numbers, no matter how small. This seems obvious — but the consequences are often ignored. Computers cycle on a nanosecond time scale - but those nanoseconds can add up to huge bottlenecks. A Ph.D. student came to Richard Gass a few weeks ago with a potential thesis problem. He had a model of a physical system that he could represent by 24 equations. He did not want to actually solve the equations, he only wanted to compare them to one another in sets of pairs. He needed to make about 10^{24} comparisons. At one million calculations per second, a reasonable rate, the student would complete his thesis work in about 10^{18} seconds - 30 billion years - or about three times the age of the universe. assume the student chose a different thesis topic - or thesis advisor.

The universe is about 40 billion light years across. A proton is about $10^{'15}$ centimeters in diameter. How many volumes 1/10 the diameter of a proton would fit[19] in the universe? The answer is about 10^{125}. A computer the size of the universe with working parts 1/10 the size of the proton has to contain fewer than 10^{125} parts. This implies that computations on problems requiring more parts are not possible. There are many such problems, and practical ones at that; meteorology and climatology come to mind.

Probability and coincidence is the other area in which innumeracy is rampant. It seems to be an area that many people find difficult to grasp. An apocryphal - I hope - story illustrates the problem. A man worries incessantly about a bomb on his airplane. He calculates the odds and

finds them low - but not low enough. So he packs a bomb in his suitcase, reasoning that the odds of two bombs on one airplane are infinitesimal.[20]

People are amazed by coincidences - they do not realize that they occur more frequently than they might think - indeed, innumerates always severely underestimate the frequency of coincidences. A classic example: what are the odds that two people in a room have the same birthday? To be absolutely certain you need 367 people in the room. But if you would be content with just 50% odds then the answer is only 23 people - not half of 367.

Things happen in threes - yes, if you wait long enough. The fact that Columbus, an Italian, found the New World in 1492 and Enrico Fermi, another Italian, came to the New World in 1942, is ... meaningless. So is the fact that President Lincoln's secretary was named Kennedy and President Kennedy's secretary was named Lincoln. You sit on the airplane and discover that the woman next to you has a husband who took a class taught by your wife's cousin. Such coincidences are surprisingly common and are not evidence of some overall super harmony in the heavens. There are 200 million adults in the United States. If each one is at least remotely acquainted with 1,500 people, then the chance is 1 in a 100 that they will have an acquaintance in common -and 99 in 100 that they will be linked by a chain of two intermediaries.

Innumeracy has a close relationship with pseudoscience - astrology, numerology, copper bracelets, homeopathic medicine, tarot cards, ESP - the list is endless. Consider astrology - people will ask you what your sign is and then proceed to discuss your personality and your future. One mathematician used to answer such questions by saying he was a Gemini - and Gemini's don't believe in Astrology.[21] It is a particularly ripe area for nonsense - believers show both scientific illiteracy and mathematical innumeracy. Astrology maintains that the positions of the planets at the time of your birth determines your personality and your future. If one believes that there must be a measurable effect, then one can only assume that they are referring to the gravitational interaction between you and planets. A fairly simple calculation based on Newton's Law of Gravity shows that at birth the gravitational pull of the obstetrician on the baby is far greater than the pull of all the planets on the child. Perhaps someone could do a Ph.D. thesis on personality differences in babies delivered by fat or thin obstetricians. Astrologer's predictions are generally so vague that something like them is likely to occur - coincidentally. People then recall the correct "predictions," but conveniently forget the incorrect ones. Astrology wouldn't be so worrisome if it weren't that so many people believe it - including some presidents.

Another interesting pseudoscience is numerology - common among ancient and medieval societies. I referred to numerology in my opening paragraph - my caller hung up when he noted the three sixes in my telephone number. Numerology concerns the assignment of numbers to letters - and then looking at the numbers that are generated by words. In our decimal system, A = 1, B = 2, C = 3, T = 20; "cat" equates to 24. Or simply count the letters; "cat" equates to 3. It is all

based on coincidence - often forced coincidences.

The number 26 was deemed especially important by the ancient Hebrews - in the Hebrew system 26 is the numerical equivalent of Yahweh, the divine Hebrew name for God.[22] In Verse 26 of Genesis, God says, "Let us make man in our image." Adam and Moses were separated by 26 generations. In the Hebrew system, if we subtract the numerical equivalent of Adam (45) from Eve (19) we get 26. Rabbis did a lot of this -often deliberately ignoring powers of 10 - that is, making 10 into 1 and 20 into 2 and forcing more coincidences. Thus Yahweh could be made to equal 17 and not 26. The Hebrew word for love is "tov;" it has a numerical equivalent 17, thereby making God equivalent to love.

Christian mystics tried to understand 666, said by John the Apostle to be the "Number of the Beast of the Apocalypse," the Antichrist, the entity my caller assumed me to be. Caesar Nero, the first Roman emperor to persecute Christians has a value of 666 in the Hebrew system. A catholic writer noted that in the Latin system Martin Luther had a value of 666 and so he must be the Antichrist. Luther's followers soon noted that the words in the papal crown, "Vicar of the Son of God" add up to 666 - if one used the Roman numerals corresponding to the letters of the phrase. One finds similar nonsense among Moslems and among ancient Greeks and Romans. When one can choose number systems at will, one can find all sorts of coincidental matches.

Let us return to probability. We've heard sports announcers speak of the "hot" hand -the batter who gets four straight base hits or the basketball player who shoots four straight baskets. Is it meaningful? Is there really such a thing as a "hot" hand?" If you were flipping coins and had a run of four straight heads would you say you had a "hot" hand? The answer is probably no. Consider a basketball player with a 50% shooting average. If he takes 20 or more shots a game, one can calculate that the probability is nearly 50% that he or she will sink four baskets in a row at some point in the game and a 20% chance of five in a row. He or she does not have a "hot" hand.

Consider Pete Rose's 44 game hitting streak - or Joe DiMaggio's for that matter. Is it really remarkable? Is its occurrence by chance so improbable that it is a major feat? Assume that Rose averaged .300 for a season (he fails to hit 70% of the time) and that he bats four times a game. The odds of his NOT getting a hit in any one game are about 25%. So the probability of at least one hit per game is about 75%. This means the chances of 44 consecutive games with at least one hit is about $(.75)^{44}$ or about 6×10^{-6} - very small indeed. If we allow the string to occur anytime during the 162 game season it rises slightly, to about 4×10^{-5}. So it might seem that hitting in 44 straight games is a real feat. However, if we instead use the average batting average of all major leaguers in history, multiply by the total number of players in the majors over that period, and

multiply by the number of years baseball has been played, then the probability of a 44 game hitting streak is not at all unlikely - indeed it is almost probable that one will occur.

At this point it would be desirable to examine the problem a bit closer, and take a look at the American educational system to determine exactly why so many of us are scientifically and numerically challenged. But that is a large order, perhaps a subject for someone in a future Literary Club paper.

But it is an important issue. We are all aware of the globalization of the economy - and of jobs moving overseas. At first it was manufacturing jobs - now it is engineering, computing and research jobs. Thomas Friedman has written an interesting book on the topic, called "The World is Flat." His thesis is that globalization and technology have flattened the world and large countries like India and China, long on the margins of the world's economy, are now able to effectively compete. This represents a huge challenge for the US - our dominance in science and technology is coming to a close. Friedman observes that Asian countries now produce eight times as many bachelor's degrees in engineering than we do. The percentage of foreign-born PhDs in the US labor force has risen to 38%. Federal funding for research in science, mathematics and engineering is dropping rapidly - it has declined 37% as a share of the GNP from 1970 to 2004. I would add to Friedman's observations. Recent immigration issues have decimated the foreign student population in US graduate schools - there won't be replacements for all those foreign PhDs in our industries. We won't do it with Americans as our K-12 education system is not producing Americans with the requisite skills. The so-called "creative-class" in the US - workers involved in activities that can be deemed creative - is shrinking in comparison to other western countries. The great industrial basic research laboratories are gone - at IBM, RCA, Xerox, GE, and the best of them all, Bell Laboratories. These labs, and others, developed the scientific base for the technological infrastructure we have today. The leaders of these companies have decided that they do not need to do research - its cost detracts from the bottom line. They assume that they will simply buy what they need. But who will be doing it? Who will they buy it from? Not from other US companies and their labs - they don't exist anymore. Not from Universities - they no longer have the funds to do the job properly. Can we rebuild? Not in the near future - there are not enough scientifically and mathematically-minded students - our K-12 educational system is a complete failure where math and science are concerned. Where will we buy the research results needed to support the next generation of technology? From Japan? China? India? Probably, and it will be costly in dollars and in technological leadership.

The Cincinnati Enquirer, April 25, 2005. A student at Mason High School wrote an opinion piece that contains all the elements of the problem. He was writing to refute Richard Cohen's column "Odd, sad fight over evolution continues." The student writes:

"Evolution within a species [...] is supported by science and fits well into Creationism.

However, species to species evolution [...] finds little to no grounding in science. The genetic complexity and blind chance required for species to species evolution to occur on even the smallest scale makes it highly improbable, if not impossible. This is the form of evolution that Creationism justifiably refutes."

He continues:

"The second area in which Creationism and evolution contradict is the origin of the universe. Mr. Cohen suggests several times in his article that the respective theories are compatible or even 'all the same' and wonders 'that many Americans do not accept evolution at all.' This again is a baseless simplification of the truth. Science does nothing to disprove a created universe; in fact it sometimes suggests a divine presence. On the other hand, many evolutionary theories on the origin of the universe are shaky at best under scrutiny. (I challenge readers to type in 'disproving the Big Bang' on Google. You may be surprised.)"

I am *not* surprised. There we have it - scientific illiteracy and mathematical innumeracy highlighted on the editorial page of the Enquirer - a prime example of why the fight over the teaching of theories alternate to evolution is important. What exactly is Mason High School teaching its students? Apparently it is not scientific or mathematical thinking -and it certainly is not critical thinking. The author does not understand the science or the mathematics behind evolution. He does not understand what a falsifiable theory is. He invokes Intelligent Design and Old-Earth Creationism as if they are falsifiable scientific theories. Worrisome - to me at least - is that the discussion is moving towards another fundamental area - cosmology. Perhaps we will shortly be questioning electrodynamics and quantum mechanics. Even more worrisome is his thinking that the Internet and a Google search is the appropriate way to learn about science. The net is hardly the place to do such research - information on it is completely unrefereed. Anyone can write on any topic and post it on the Internet - and Google will pick it up and deliver it to you - as I noted in the beginning of this paper.

Global warming. Energy. Stem cells. Evolution. Cosmology. Our evolving theocracy. Scientific illiteracy and its co-conspirator, mathematical innumeracy, make me fear for the future. Or as, our late colleague, Tom Gebhardt, used to phrase it, in a different context in his Mr. Whig columns, "Gentlemen, I fear for the republic."

Notes

1. Unfortunately, I have lost the reference to the article that contained these ideas.

2. P. McBride, R. E. Moore, J. P. Witherspoon, and R. E. Blanco, "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants" Science, 12/8/78.

3. The Albuquerque Journal, August 18, 2003.

4. The Cincinnati Enquirer, April 17, 2005.

5. June 14, 2004,

6. I've edited the statements a bit

7. The Jackson Hole Daily, March 24, 2005.

8. A term coined by the mathematician John Alien Paulos.

9. This "quip" is not original, but I do not recall where or from whom I heard it.

10. Brothersjudd.com.

11. Much of the following is from a paper by David Hockney and Charles Faico,

   presented at a symposium on Renaissance Art and Optics at the Annual Meeting of the Optical Society of America, October 11-14, 2004. The paper is called "Optics and the Old Masters."

12. David Hockney and Charles M. Faico, Optics and Photonics News 11, 52, July 2000. David Hockney and Charles M. Faico, Technical Digest of the 87th Annual Meeting of the Optical Society of America, OSA, 2003.

13. This is from conversations with Faico - a similar view was presented by Ellen Winner in an opinion piece in the Chronicle of Higher Education, http://chronicle.com/weekly/v50/i43b01001.htm.

14. From Ellen Winner, http://chronicle.com/weekly/v50/i43b01001 .htm.

15. John Paulos tells a similar story in "Innumeracy."

16. C. Kittel and H. Kroemer, "Statistical Physics," Freeman, Second edition, 1980.

17. James Jeans, "Mysterious Universe," Cambridge University Press, 1930

18. John Alien Paulos in "Innumeracy"

19. This was first posed by the computer scientist Donald Kneuth

20. From "Innumeracy."

21. From "Innumeracy."

22. George Ifrah wrote on this in "From One to Zero;" these examples are his.