Science & Math CESE Education

The BEACON

News from

The Coalition for Excellence in Science and Math Education

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Judgment under Uncertainty

Imagine that a rare disease is infecting one out of every 1000 people. Further imagine that there is a very good, but not perfect, test for this disease. The test is 98% accurate; that is, if the patient has the disease, the test will come back positive 98% of the time (and vice versa).

Now, imagine that you have been tested for this disease, and sadly the test has come back positive. The question: How likely is it that you have this disease? (The answer is at the end of this column.)

We deal with uncertainty all the time. Medical decisions, finances, insurance plans, even deciding which route to take to the store—all require us to make decisions without complete knowledge every day. On a broader level, environmental policy, healthcare reform, military planning, and education reform all demand that we evaluate and manage risk as rationally and rigorously as possible. Yet, how many Americans are prepared to do this?

Several years ago, I had the honor of serving on the state's textbook commission, and had an intensive, first-hand look at the mathematics textbooks used at the high-school level. The good news is that, by and large, the materials were excellent. The bad news is that the good news left some serious gaps. In particular, the books reflected the trend in math education over the last 40 years: the push to get students to calculus as efficiently as possible. I saw wonderful series devoted to advanced algebra, trigonometry, analytic geometry, and calculus. But there were almost no major titles, for example, devoted to probability and statistics, a subject that was often relegated to the dungeon of remedial and consumer math.

I suspect that the source of this trend goes back to the scare over Sputnik in the late 1950s. The panic that America was falling behind the Soviets in science and technology led to a complete shake-up of science and math education (anyone remember the "New Math" of the 1960s?), and a clear drive to generate more physicists and engineers; hence the goal of getting kids to calculus by the end of high school.

Though its goals were admirable, I am not sure this trend in math education has served the nation well. Which is more important for an educated and scientifically-literate citizenry: the ability to deal with statistical uncertainty, or the ability to do integrals? Obviously, both skills are important, but which is a more fundamental part of a public education?

I am beginning to wonder if the Cold War philosophy of math education has contributed to the problem of public 'innumeracy'. A public that does not have an easy, intuitive sense of the difference between a billion and a trillion, or between the risk of dying in a plane crash and of dying in a car crash, or between

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David Johnson, Web Master

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Book Review

At Home in the Universe

By Stuart Kauffman

The impression I got from this book is that Kauffman's ideas are a thinking man's version of intelligent design, minus the designer. The ideas of Self Organization and Complexity obviate the necessity for a designer even if you don't believe that random mutation and natural selection alone could achieve the grand diversity of life apparent at the present time. Kauffman, for one, does not believe that selection is the sole source of order.

Kauffman's thesis is that order is not something that was strived for over the long millennia since the Earth formed, but fell out of nature's tendency to self organize. "Order for free" he calls it. This was also the title of his talk at New Mexicans for Science and Reason (NMSR) on February 13, 2002. I must admit that part of my reason to review this book was to better understand his ideas. In his hypothesis, man was not a wildly improbable result, but was more or less expected. Kauffman feels that if selection alone is responsible for order then we truly are very rare and precious, but if self-organization rules the day, then we are "the expected."

The heart of the hypothesis is the idea of an autocatalyzing set. In Kauffman's words, "...when the number of different kinds of molecules in a chemical soup passes a certain threshold, a self sustaining network of reactions, an autocatalytic metabolism, will suddenly appear." According to Kauffman life did not start simple and become complex, but was complex from the beginning. This appearance of an autocatalytic metabolism he likens to a phase transition, as in going from a solid to liquid in water. Research on this idea will be to try to produce an autocatalytic set in the laboratory.

Kauffman believes that evolution takes place on the boundaries between chaos and homeostasis. If a living system is in a chaotic environment, it is changing all the time and never stabilizes. If an organism is in a static environment it never has to change. Within the homeostatic state, but at the edge of chaos, is where there is incentive to change, but where a change can survive long enough to leave descendants.

This is a very dense and complex book, and I can't say that my quest to better understand Kauffman's ideas has been fully realized. It really requires more than one reading to get to the bottom of what he is talking about.

Bill MacPherson
CESE Vice President

Is Intelligent Design Really Intelligent?

By Professor Harietta Erectus

(*Edited and reprinted by permission of the author)*

There has been a lot of talk recently by former creationists about something called "Intelligent Design" (ID). This talk seems to have increased significantly since the creationists started losing their battles against evolution, both in the courts and in the political arena.

Evolution is an observed fact. The modern theory of evolution is not in question nor is it a scientists' conspiracy. Those few scientists like Behe who claim that life is too complex to have evolved, have been so thoroughly debunked that no serious scientists takes them seriously anymore. Suffice it to say, Behe should have spent a few hours in the library or asking his former colleagues about the supposedly "non-existent" intermediate evolutionary links for flagella, eyes, human blood clotting, etc. Because he couldn't imagine that such complex biochemical mechanisms could possibly come to be without design, it appears that he never checked for data on the topic, and has thus made a fool of himself. Likewise, Wells is stuck on peppered moths and Haekel's embryo drawings, plus a few other odds and ends. All this to disprove evolution, not to prove creationism (sorry—I meant *ID*). Unfortunately, Wells never bothers to really address the whole peppered moth story, but he does quote liberally out of context. He is right about the embryo drawings – they are grossly oversimplified. But, modern texts have removed them, and instead discuss the observed, real effect that Haekel actually saw. How about Phillip Johnson? Well, he is a lawyer who claims to bring "logic" to the discussion. Yet, any first semester philosophy or law student studying logic can easily take any one page of Johnson's published creationist (sorry, I meant *ID*) defenses and find multiple logic errors.

There are so many examples of evolution as seen from fossil observations, genetic observations, morphological observations, etc., that a person would have to be very foolish, indeed, to say that evolution did not happen. Now, one valid (logical and scientific) question to ask is: "Did evolution occur through a set of interactions caused by natural law (which an intelligent entity or God could have set in motion), or did evolution occur with very specific direction from an Intelligent Designer?"

Well, evolutionary theory covers the observations quite well. It makes valid predictions. It has been tested and passed the test so many times that it is considered to be a valid, scientific theory by mainstream scientists who really get out and study this stuff, despite what that very small minority of nay-sayers would have you believe. In fact, the theory of evolution ties in so well with all the other validated scientific theories that it is hard to see why anyone would throw rocks at it without overwhelming evidence in opposition. Those few that claim such evidence, have been found wanting to the point of absurdity.

However, just because evolution is on sound footing, doesn't mean, per se, that Intelligent Design is wrong. Are you surprised to hear me say that? Well, you shouldn't be. What's sauce for the goose is sauce for the gander! If proponents of ID can make predictions that are observable and that tie into the rest of science, then they may claim a place. However, to date, I have heard not one, single, valid, prediction made by ID proponents. There are, of course, those ID proponents that really mean ID equals God. To them, there is no argument. An omniscient, omnipotent being can do whatever it likes, and no one can say otherwise. But this falls under the definition of religion – not science. Science cannot argue with someone who claims that evolution was miraculously guided. The person who believes that will not listen to other arguments, and is not appropriate to the science classroom, but to the social studies, or history classroom, as I'm sure you will all agree.

Then, to really look at ID, we have to look at the data, or evidence. And when we do this, there comes a great surprise! If ID happened, and the IDer was imperfect, or only semi-intelligent, then

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we can make some predictions. Just like real science!

Let's see how the Semi-Intelligent Designer (SID) model predicts what we observe. First, simply look at all the millions of life forms (species, etc.) that didn't quite work and died off. Look at the problems humans have with their backs. A competent mechanical engineer could have done a better job! Why is it that this designer gave mammals two eyes, ears, lungs, kidneys, etc., but only one heart, liver, brain, etc.? That's just plain dumb. Partial redundancy is not allowed in airplanes for critical functions. Look at the errors we see occurring all the time in every day life: Downs syndrome—which is genetic in nature, sickle cell anemia—again a genetic defect, people born with tails! That merely touches the surface and only looks at homo sapiens. There are thousands of documented design errors. There are undoubtedly millions that we never see.

Errors in design and a changing cast of species are predicted by evolution, too. But, they aren't predicted by ID! If a creationist (I mean *ID person*) tells you that the entity called ID is so smart that it can do anything it wants, including making dead-end lines of living creatures, then that person is, by definition, speaking of a SUPREME BEING—A deity, if you will. Naughty, naughty trying to sneak religion into a science class. Shame! If, however, they accept SID, then we are potentially speaking science.

Of course, there would be a lot of research and testing to elevate SID to a real, scientific theory, but as a hypothesis, it already predicts more (a requirement for science) than does ID, which predicts nothing!

I propose that all of you open your minds. When you see someone speaking of ID as an alternate scientific theory to Evolution, you are obligated to point out that ID is NOT science. It cannot make predictions. One is only led to ask "Who designed the designer?," ad. infinitum. Instead, talk to them about SID. SID has hope as far as research goes. We can ask verifiable, scientifically oriented questions. We can search for the origin of SID. We can approach SID from a scientific basis.

I am off, now, to express to the Ohio School Board how well SID fits into the definition of science. And, if they insist on including creationism (I mean *ID*), then they must also include *SID*. I hope you all do the same!

Harietta

UNDERSTANDING REGRESSION

You have probably heard about regression, but perhaps have never had it clearly explained. Maybe the following will help, although I cannot claim to be the world's best explicator. It simply means that there seems to be a relationship between an outcome measure and one or more input variables. It does ***not*** imply that there is a causal connection between the inputs and the outcome. For any value of X (the input), the "expected value" of the outcome Y (assuming the relation is linear) is:

$$E(Y) = AX + B$$

If we have many pairs of X and Y, and look at those pairs for which X has some specific value XJ, the first few values of Y might not be close to E[Y]. However, if we look at many XJ, YJ pairs, the average of the YJ's will tend toward ("regress to") the expected value E[Y]. What we need now are the constants A and B. They should be chosen for the "best" fit of Y as a linear function of X. We look at all the actual pairs of X and Y, and choose the constants A and B to minimize the mean squared error between the actual and predicted values of Y. The details of actually finding the values of A and B are not important. If X does a good job of predicting Y, and if we have lots of X, Y pairs, then we might find that the relation between X and Y is significant. By nearly universal convention, we say that the relation is significant if there is no more than one chance in 20 that the apparent relation is due to random chance alone, subject to a number of conditions. Significant relations are not always important and are not necessarily real. If we have many

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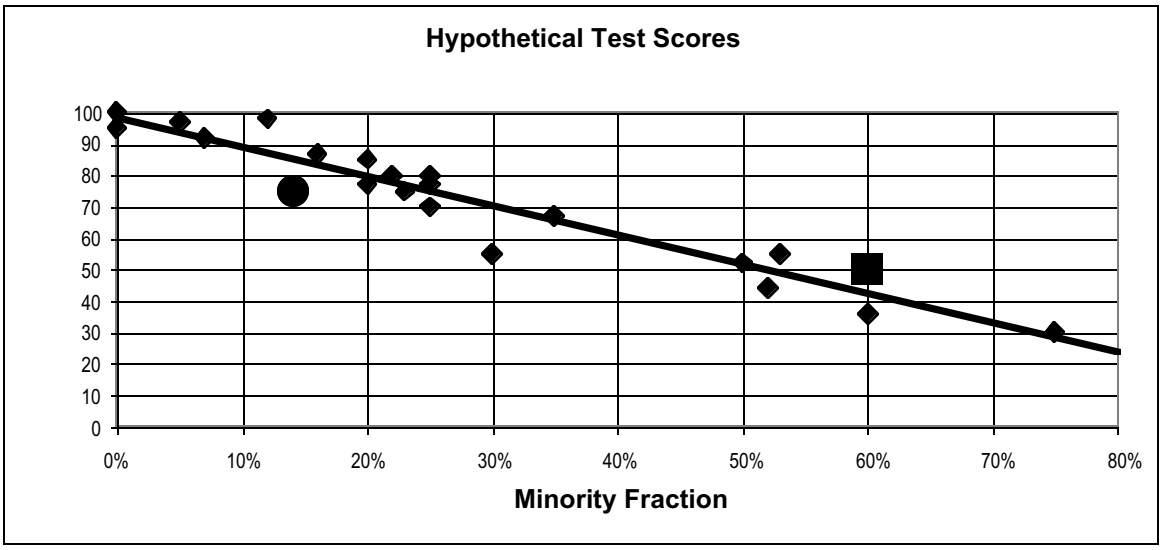

Figure 1. A hypothetical regression plot.

X, Y pairs, even a feeble relationship can look significant. It is also possible that both X and Y are really caused by some unknown variable Z. It can then falsely appear that X is "causing" Y.

We can show this relationship graphically. Suppose that the input variable is the fraction of minority students in a school, and the outcome is the score on a test. Perhaps the data look like this: (*See Figure 1.*)

One school (the large square) scored better than we would have predicted from its high minority fraction. Another school (the large circle) did less well than predicted from its low minority fraction. Remember that we cannot say that the minority fraction "causes" scores to be high or low. Maybe it is true, but it can't be accepted with certainty from this limited data.

How far does the actual score for each school exceed or fall short of the prediction? We calculate the actual score minus the predicted score for each school (the difference is called the "residual"), and calculate the standard deviation of the differences. We can then determine whether the score for any school is significantly higher or lower than would be predicted from its minority fraction. If a school's score is significantly better than the predicted score, we can reasonably suspect that the school is doing quite well. On the other hand, if the score falls significantly below the predicted score, we might suspect that it is not doing as well as it should.

The method is not limited to a single input variable or to linear relationships. When we have many input variables the mechanics of finding the constants can get a little more complicated but the principle is the same. We try to find constants in an equation such that for all values of the input variables, the mean square error will be smaller than for any other values of the constants. We test significance for each of the variables. If any input variable turns out not to be a significant predictor, we drop that variable and determine new values for the constants with the reduced set of input variables.

It often turns out that several input variables taken together will predict the outcome better than any one variable. The superior prediction comes at the expense of complication in displaying the results. It is hard to show several input variables graphically. If there are only two input variables, we can display a "response surface", a three-dimensional plot of outcome against two input variables. The response surface does show the effect of both variables acting together. However, the concept is not easy to understand, is limited to two input variables, and it is nearly impossible to show all the individual points.

My preference is to define a linear combination of all the input variables. The derived variable is the linear function

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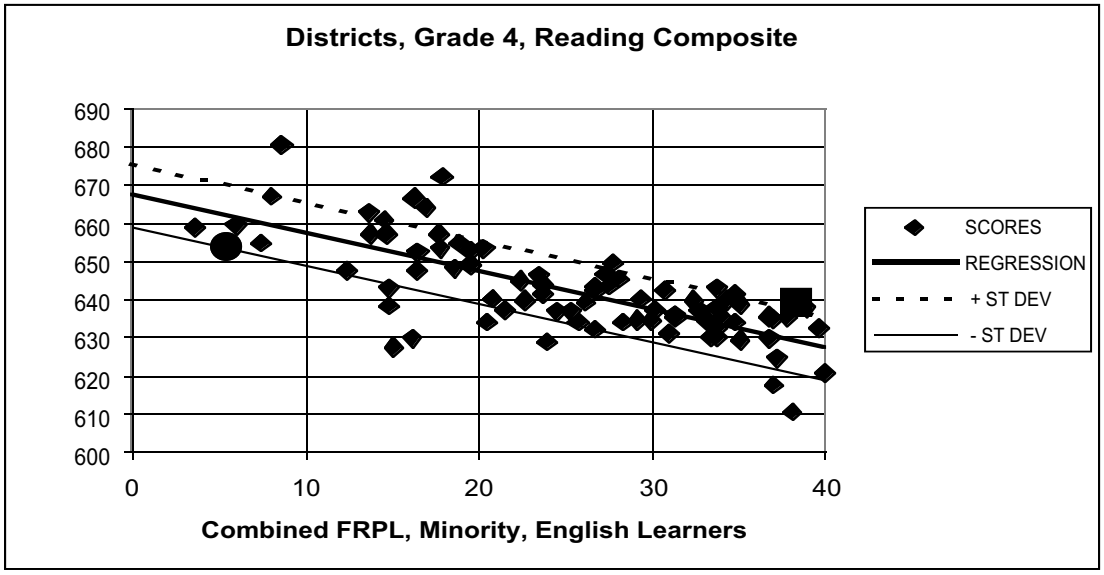

Figure 2. An actual regression plot.

of the actual input variables that gives minimum squared error. It is simple to compute; we just take the regression coefficients with the sign reversed. The defined variable "V" at point "J" is:

VJ = - A1X1J – A2X2J – A3X3J - ….

The reason for reversing the sign is that most of the variables we work with—fractions of minority, poverty, special education, and English deficit—have negative regression coefficients. Reversing the sign makes the defined variable come out positive. The plot is tidy, but it is not easy to explain. An explanation that uses the phrases "minimum mean square error," or "regression coefficients with reversed sign," or "linear combination of input variables" will go over most people's heads. Simply saying that it is the "best" combination of the variables will probably make some observers suspicious.

Figure 2 is an example of real data: district average scores in 4th grade reading on the 2001 TerraNova test. The fraction of students eligible for free or reduced-price lunches (FRPL), the fraction of minority students, and the fraction of English learners were significant. The variable on the horizontal axis is a linear combination of FRPL, minority and English learner fractions. These variables together account for 59% of the variance in scores. That means that 41% of the variance in scores is attributable to factors other than demographics.

The solid line is the expected score for any value of the demographics. The short dashed line is one standard deviation above the expected score, and the long dashed line is one standard deviation below the expected score. Unfavorable demographics—high fractions of poverty, minorities, and English learners—are to the right. One district (large square) scored more than one standard deviation above the regression line, in spite of disadvantageous demographics. This district had 78% eligible for FRPL, 98% minority students and 9% English language learners in 4th grade, and scored higher than many districts with more favorable demographics. On the other hand, one district (large circle) scored about one standard deviation below the regression line. This district reported only 48% FRPL, no minorities, and no English learners in 4th grade, but scored lower than some districts with less favorable demographics. Unfavorable demographics do not always doom a district or school to low performance. Favorable demographics do not guarantee high performance. Good performance comes from competent teachers, motivated students, and a good learning environment.

The greatest power of a regression analysis is that it can focus attention on areas where on-the-spot investigation would be fruitful. It is not enough merely to point out that some district or school does not do as well as expected; we ought to try to find out why.

Walt Murfin
CESE Statistitian

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the risk of being a victim of violent crime and of being a victim of a handgun accident, is simply not well-equipped to make good decisions about life in the modern world.

And while I cannot imagine a less-inspiring education reform agenda than to try to beef up the teaching of probability and statistics, I think that this is precisely what we need if we really hope to improve students' skills in critical thinking and scientific literacy.

Answer to the puzzler: Believe it or not, the 2% false positive rate and the prior probability of 1:1000 for getting the disease combine to mean that you actually have less than a 5% probability of having the disease, even though you tested positive. In short, out of 1000 people, 20 will test positive but not have the disease, while only 1 will test positive who actually has the disease, so your chances of having it are only 1:21; you can also use something called Bayes' Theorem to work this out precisely. Psychologists and mathematicians who study intuitive attempts to reason about uncertainties have found that people not trained in probability almost never consider prior probabilities when making judgments like this.

Timothy Moy
CESE President

Junk Email and Filtering

With the growing volume of unwanted email messages appearing in our inboxes, many of us are now 'filtering' —using various means to eliminate unsolicited and objectionable messages. With this, CESE is seeing increasing numbers of updates (from ceseducks@lyris.nmt.edu) rejected by CESE members' email servers. In several instances we know that members did not intend for these messages to be bounced. If you believe that you might have been dropped from the CESE Ducks list serve and would like to have your subscription renewed (or if you are a CESE member who would like to have your name added to the list) contact CESE Secretary Marilyn Savitt-Kring at—

mmkring@juno.com,

providing her with your email address. You might like to review your filters if you were dropped from the list.

Filtering email may be accomplished at various places before it arrives in your inbox. Many service providers (AOL, Earthlink, etc.) provide options that screen incoming email at the server. Most popular email packages come with filters that can be configured by the user to manage (including automatic deletion) email as it is received by your computer. Third party software is available, but it duplicates features provided with most mail

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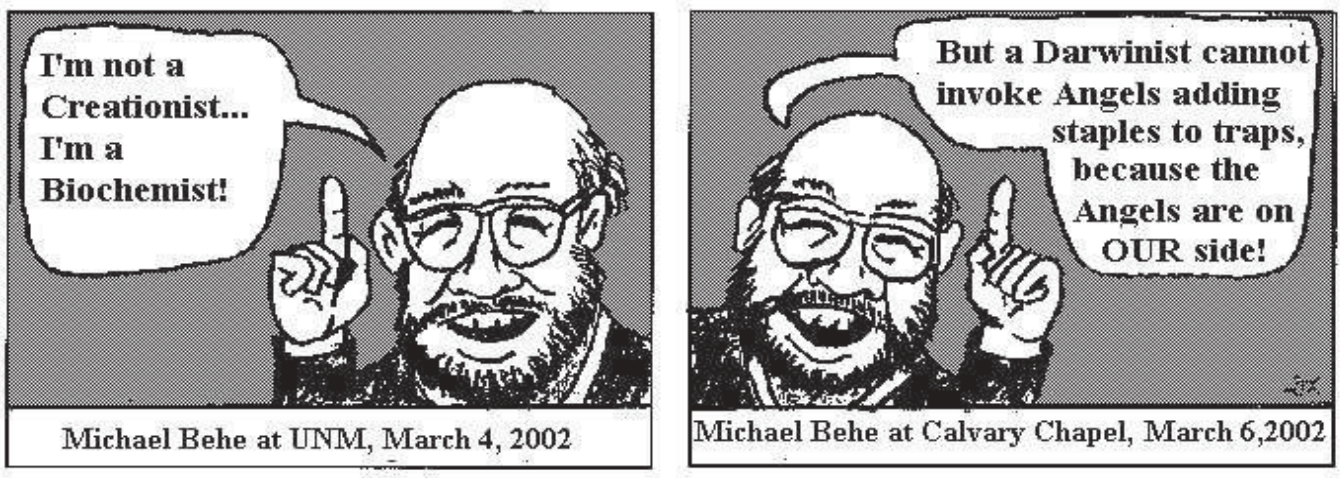
'Toon' by Thomas



"Irreducible Complexity" proponent Michael Behe proves that he's a better Tailor than Scientist!

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readers. Many who begin filtering learn that there are some unintended consequences.

Don't let this dissuade you - just use caution until you develop confidence in how your filters work.

I recommend that you use the options that come with your email software. If you want to make changes, these are often more discriminating and easier to reconfigure than those available from your email provider. Although details differ between products, most permit you to send specified kinds of messages to separate folders. I have the filter look for "lyris" in the "Sender address." If "lyris" is present, that message is automatically stored to an email Folder called "Lyris."

I searched Google using "email filtering" and came up with several useful sites. Good starting points for those using MS Outlook or Netscape Messenger include http://www.earthlink.net/internet/email/filtering/ and http://www.newbie.org/reference/email04g.html. Each provides a step-by-step approach to setting up filtering that is customized to your needs.

David B.Johnson
CESE Webmaster

Kansas Physicist/Activist to Speak at UNM

Adrian Melott, Kansas physicist, will speak in Albuquerque, Monday, April 22, 2002, at the UNM Law building, Room 2402 at 7:30 P.M. His topic will be "Intelligent Design is Creationism in a Cheap Tuxedo." The lecture will be sponsored by CESE, NMSR (New Mexicans for Science and Reason) and NMAS (New Mexico Academy of Science). The public is invited, and there is no charge.

Dr. Melott is in town for a meeting of the American Physical Society (APS), which will be presenting him an award for his role in reinstating quality science standards in the Kansas state K-12 curriculum.

The citation for the Joseph A. Burton Forum Award reads:

"For his outstanding efforts in helping to restore evolution and cosmology to their proper place in the K-12 scientific curriculum. As both a distinguished cosmologist and respected member of the clergy, he played a key role in helping the people of Kansas reverse their State Board of Education's anti-science action."

More information on this award can be found at:

http://www.aps.org/praw/02winners.html

Quoting from the APS website,

"Adrian Melott is currently Professor of Physics and Astronomy at the University of Kansas. He received an M.Div. from Starr King School for the Ministry in Berkeley, CA in 1971 and was for seven years minister in a Unitarian Universalist church. He received his Ph.D. in physics at the University of Texas in 1981, and has pursued research in physics at the Universities of Chicago, Oxford, UC Santa Barbara, Moscow, and Cambridge. His research emphasis is the use of supercomputers to do massive simulations of the formation of structure in the Universe. Recently, he has become interested in uncovering correlations between the properties of objects on supercluster scales—separated by up to 100 million light years. In 1996 he was named a Fellow of the American Physical Society 'For groundbreaking studies of the origin and evolution of cosmic structure.' He is a founding Board member of Kansas Citizens for Science, and in 2001 received the Steeples Award from the University of Kansas for his public outreach activities in science. He recently co-authored a Sunday school curriculum 'Celebrating Our Origins in the Universe,' which introduces the ideas of the Big Bang and the evolution of life to elementary school age children."

Marilyn Savitt-Kring
CESE Secretary

From Scientific American on line

GEOLOGY

Study Supports Impact Explanation for Permian Mass Extinction

Around 250 million years ago, at the end of the Permian period, life on the earth almost disappeared completely in the most devastating mass extinction of all time. Yet despite the magnitude of the event (nearly 70 percent of terrestrial species and 95 percent of marine species vanished), its cause has proved difficult to identify. Unlike the extinction that claimed the dinosaurs some 65 million years ago, the biological and environmental changes that characterize the Permian crisis seem to have unfolded gradually. Most earth scientists thus favored scenarios involving climate and sea-level fluctuations, a dwindling supply of oxygen in the oceans and severe volcanism.

More recently, however, indications that the Permian extinction proceeded far more swiftly than previously thought have surfaced. And earlier this year, researchers reported detecting in Permian rocks signatures of extraterrestrial molecules that most likely arrived on an asteroid or comet. Now findings reported in the September issue of the journal Geology are lending additional weight to the argument that, like the dinosaur-squelching extinction after it, the Permian catastrophe resulted from an extraterrestrial impact.

Geochemical and paleontological analyses of late Permian sediments from southern China, Kunio Kaiho of Tohoku University and his colleagues report, suggest that an asteroid or comet hit the ocean at the end of the Permian. This collision, they argue, prompted a massive release of sulfur from the earth's mantle to the ocean-atmosphere system, which in turn led to oxygen consumption and strong acid rain.

"Understanding the cause of this event is important because it represents the largest mass extinction and it led to the subsequent origination of recent [life] on Earth," Kaiho remarks. "We would like to clarify the paleoenvironmental changes and causes of the end Permian mass extinction in different places and of the other mass extinctions that occurred during the past 500 million years." —**Kate Wong**

A Final Note

As most of you know, we have seen a significant push over the last few years from the creationists. They are now calling creationism "Intelligent Design." Granted, there may be a few who think of the word "alien" as the intelligent designer, but most are the same old crowd –Behe, Johnson, Wells, etc. In fact, this has been a stratagem that has been publicized (the Wedge). First, get your foot in the door with something that will pass as nonreligious, then gradually change the whole system so that religion is the tent pole that holds up education in the United States.

Creationists see this as a God given duty. Almost all creationists see anyone who does not believe in the literal translation of the Biblical creation stories (and contradicting ones, at that!) as atheists. In fact, many people in America are deeply religious and accept evolution as God's way of creation. Granted, there are atheists who believe in evolution, too. But, to the same old crowd (as mentioned above), evolution equates with atheism.

We, in New Mexico, were the first who really organized to fight the creationists in 1996 when the creationists changed the State Board of Education Science standards to promote evidence against evolution. Fortunately, we know that evolution is an observed phenomenon, as is gravity. The modern theory of evolution is real science in action, and is accepted as a real scientific theory. It makes predictions. Creationism and Intelligent Design do not.

We were the first modern group to fight the creationists in an organized manner. We won the battle, but still have the war to fight. Kansas won a battle. Other states are fighting as this is going to print – Ohio, Alabama, Idaho, etc.

Next year, the State Board of Education is scheduled to review the state science standards. We have already seen evidence that the creationists are girding for a fight—Behe and Dembski's tour. Next year, expect Intelligent Design to be pushed. We may have won a battle six years ago, but we are still fighting a war. Next year, we will all need to prepare for another battle! **—Kim Johnson**

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WHAT'S HAPPENING

PUBLIC INVITED
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Intelligent Design is Creationism in a Cheap Tuxedo
UNM Law Library Building, Rm. 2402
Monday, April 22, 2002, 7:30 PM

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