# THE VORTEX

AMERICAN CHEMICAL SOCIETY CALIFORNIA SECTION
VOLUME LXXX NUMBER 10 DECEMBER 2018


Volunteer Amy and Member Alex
A shout out of thanks for Alex
organizing the two great events described on page 2

Photo by Greti Sequin

# *Bay Area Science Festivals (BASF)*

Since 2011, the Bay Area Science Festival has made its mark all around the San Francisco Bay Area, offering exceptional opportunities for public outreach at numerous events spread over the last week of October and the first week of November. This year, CalACS participated in two full-day festival events, North Bay Science Discovery Day in Santa Rosa on October 27th, and Science Discovery Day at AT&T Park in San Francisco on November 3rd. At each event, our volunteers presented the National Chemistry Week theme activities, "Creating Oxygen to Breathe in the Space Station" and "The Sun and Ultraviolet Light: Make Your Own UV Wristband."

Al Verstuyft arrived early at the Sonoma County Fairgrounds in Santa Rosa, where John Branca, Janice Crowley, and Mark Frishberg assisted with setup at a prime location outdoors, literally at the crossroads of the fairgrounds, assuring a steady stream of visitors throughout the day. This festival attracts educators, companies, and civic organizations from across Marin and Sonoma Counties, and the excitement was palpable. The weather was perfect for demonstrating the sensitivity of UV-color-changing beads to solar radiation, and our solar panels put out a steady stream of oxygen (and hydrogen) from the electrolysis of water. Visitors could experiment with electrolysis using 9V batteries and solutions contain in red cabbage indicator, providing colorful evidence for the formation of acid at the anode and base at the cathode. Just about every young visitor wanted to string some beads, and we gave away at least 6000 mixing UV-detecting beads with other colors that don't fade indoors. Most visitors also took copies of Celebrating Chemistry, as well as the latest 118-element version of the Periodic Table in wallet-sized format.

Our team at AT&T Park the next weekend was equally successful, although our location on the Promenade level limited the sunlight reaching our solar panels. With over 200 exhibitors, this event is BASF's grand finale, and the premier STEM education event in the SF Bay Area. Section Chair Greti Séquin, along with Michael Cheng, Trudy Lionel, Elaine Yamaguchi, and Emiko Yoshi, assisted in setting up, and we were soon joined by our neighbors from the Silicon Valley Section. It is hard to say whether our UV-bead bracelets or the Silicon Valley Section's slime was the more popular offering; what's certain is that we were busy with a crowd of visitors from start to finish. We gave away another 6000 beads, and would have run out entirely, but fortunately the Silicon Valley Section had a reserve supply that they generously shared with us. We had some extra fun polling visitors on the question, "What's your favorite planet?"

By the end of the day, Earth and Mars were neck-and-neck with 27% and 28%, respectively. Additional thanks to Marla DeKlotz, who joined us in the afternoon, and to Sheila Kanodia and San Francisco State University student Chimara Stancill, who stayed until the end to help pack up. There's little doubt we inspired some future astronauts, as well as hundreds of young scientists.

Alex Madonik, NCW Coordinator, California Section, ACS


Maria DeKlotz, Volunteer

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## *Chair's Message*

As this year comes to an end let me reflect on the great diversity of programs that our ACS California Section has been able to offer to our section members this year.

The topics of our 2018 section meetings ranged from presentations about microbial volatile organic compounds, to plant-based meat alternatives, to insights into next generation Li-ion batteries, to cryo-electron microscopy to visualize the molecular machinery involved in regulation of gene expression, and concluded with a captivating talk on criminalistics (forensic science) that focused on determining mechanisms of fires and explosions. We are grateful to the USDA Western Research Labs in Albany CA and to Chevron Research, Richmond, who have generously allowed us to use their facilities.

A summer field trip social to the Chico Brewery connected us with our Northern California Section members as well as with the ACS Sacramento chapter. Another field trip, on the chemistry of beer and cheese, took place at UC Davis, at the invitation of our ACS Sacramento Section colleagues.

Our Women Chemists Committee (WCC) has again been most active this year. The highlight was the series of theater performances of the play "No Belles" that our WCC set up to take place at several Bay Area colleges, in a cooperative effort with the ACS Silicon Valley Chapter. In addition, the Women Chemists organized three exciting presentations by women chemists during the year.

Our ACS California Section has continued its dedicated involvement with public outreach and has actively participated at more than a dozen different events during 2018. Our volunteers have been engaging audiences of all ages and backgrounds with hands-on activities at Math and Science events for Girls, at Science Fairs, Mini Maker Fairs, Family Science Nights, and Earth Day events, and organized and staffed again booths at the Bay Area Discovery Day events this November.

Note that the year of 2019 will be the International Year of the Periodic Table, as it will be the 150th anniversary of the table's creation by Dmitry Mendeleev. Our ACS California Section has already begun with planning for this year-long event. I hope you will be able to join us at some of these events! We are looking forward to another productive year.

Wishing you the best for the holiday season,

Margareta Sequin

*Volunteers and Members at two CalACS outreach events as described on page 2*



Photo by Greti Sequin

# *PFAS: PFOA, and PFOS (Part 1)*

Bill Motzer

**Introduction**

Recently, on a recycled water chemistry project that I'm working on, I became aware that polyfluoroalkyl substances (PFAS) were being considered for inclusion in California Code of Regulations (CCR) Title 22 analytical requirements. In previous Vortex articles I had discussed increased recycled water usage in California (see *Recycling Water* – December 2011 and January-February 2012 issues). I was also aware that these chemicals were considered as an emerging chemical class (see *A Chemist's Conundrum*, June and September-October 2010 Vortex). However, I did not identify or discuss them in that series. Finally, for many years I've been aware of ACS California Section member Dr. Arlene Blum's web site. Arlene has been a successful advocate for removing these fluorinated chemicals from flame retardants commonly used in baby clothes, furniture, carpets, and plastics (see: arlene@greensciencepolicy.org). PFAS are a "family" of manufactured (anthropogenic) chemicals used in products from the 1940s to the early 2000s that resist heat, oils, greases, stains, and water. Such surface-active agents were used in firefighting foams, stain-resistant products, coating additives (i.e., polytetrafluoroethylene or PTFE also known as *Teflon*), and cleaning products. Industrial uses were widespread spanning the aerospace, automotive, chemical, construction, semiconductor, and textile companies. Under typical environmental conditions PFAS do not hydrolyze, photolyze, or biodegrade. Therefore, they are extremely environmentally persistent with potential to bioaccumulate and biomagnify in wildlife because they are readily absorbed upon ingestion, primarily accumulating in blood serum, kidneys, and liver. Animal toxicological studies have indicated potential developmental, reproductive, and systemic effects.

The most well-known and researched PFAS compounds are PFOA (perfluorooctanoic acid – $C8HF_{15}O_2$; CA$_S$ No.: 335-67-1) and PFOS (perfluorooctane sulfonic acid – $C_8HF_{17}O_3S$; CAS No.: 1763-23-1). Within the United States, PFOS and PFOA are the two PFAS compounds produced in the largest amounts. PFOA is a perfluoralkyl carboxylate synthetically produced as its ammonium salt as the most widely produced form. PFOS is commonly used as a simple salt (such as potassium, sodium, or ammonium) or is incorporated into larger polymers.

PFAS are now found in almost all global environments including remote places. However, there are major environmental concerns for groundwater contamination in urban industrial areas. In cases of groundwater PFAS plume investigations, forensic geochemical techniques are being developed to determine sources. Health-based advisories or screening levels for PFOA and PFOS in drinking water have been developed by the U.S. Environmental Protection Agency and state agencies, including California. Surface and groundwater (well) sampling protocols have also been developed; analytical detection methods include high-performance liquid chromatography (HPLC) and tandem mass spectrometry. Common water treatment technologies include activated carbon filtering and reverse osmosis. Future articles in this series will expand and elaborate these topics.

2018 election Results for 2019.

Chair Elect - Jim Postma
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Director At Large - Wally Yokoyama
Member At Large - Linda Wraxall, Lee Latimer, Peter Olds
Councilor - Eileen Nottoli, Jim Postma

## *Bound to fail: The flawed scientific foundations of agricultural genetic engineering (part 1*)

GMWatch, 13 November 2018

Half a century on from the first promises of wondercrops, GM has delivered little of value... and the same will be true of the new gene-edited GMOs, says researcher Dr Angelika Hilbeck

The GMO food venture is bound to fail because it is based on flawed scientific foundations. This was the message of a public talk given by Dr Angelika Hilbeck, researcher at ETH Zurich, Switzerland, and a board member and co-founder of the European Network of Scientists for Social and Environmental Responsibility (ENSSER), on the evening before the 9th GMO Free Europe conference in Berlin this September.

Dr Hilbeck's talk introduced a panel discussion with four other scientists: Prof Jack Heinemann of the University of Canterbury, New Zealand; Dr Ricarda Steinbrecher of Econexus; Dr Sarah Agapito-Tenfen of Genok Centre for Biosafety, Norway; and Prof Ignacio Chapela of the University of California Berkeley.

Below is our summary of Dr Hilbeck's talk, given from her perspective as an ecologist. This article will be followed by a second commentary on the same theme by the London-based molecular geneticist Dr Michael Antoniou, this time from the standpoint of molecular biology.

Agricultural genetic engineering is a promissory science that set itself up to fail from the get-go. In this talk I'm going to put forward the possible reasons for this. In doing so, I shall examine the scientific foundations of genetic engineering...something that scientists should have done when they started on the GMO venture 30-40 years ago when the tools were invented and we started engineering organisms... and put them forward for debate by known experts in this field.

The sky was supposedly the limit when it came to what you could do with these tools. But now, 20 years after the first commercial GMOs were introduced into agricultural and food system, GM has not delivered on its promises.

Now there is a new round of the same promises, this time based on the new "genome editing" scissors available. Will the new GM technology ever deliver on its promises?

The answer hinges on why it has not delivered with the old---but still widely used-- techniques.

The first round of promises from genetic engineering advocates are now half a century old. They include:

Abolition of hunger and malnutrition

Higher yields

Adaptations to changing climate

Tolerance to diseases, pests, drought, salinity, aluminium toxicity, heat&cold

Better nutritional value-vitamin A, iron fortification.

This is the same vision that underpins the making of any GMO. It was a four-step process not only to feed the poor but to feed anybody and most of it would take place in a petri dish in the laboratory.

The process would start by identifying a donor organism that you want to take the trait from and put it in another organism that is unrelated to the donor organism, which you wish to equip with this trait. So you have to identify the DNA sequence where you think this trait is coded, cut it out with the molecular scissors, put it on a shuttle (biolistic or Agrobacterium), and engineer it into the recipient plant.

Three of these four steps happen in the petri dish. Then there would be one further simple step-- the fourth-- of putting it into the chosen plant variety and growing it in the field. And then you would feed the poor, according to them.

### The promises

These conceptual ideas had already gained currency in the early 1990s. These were the kinds of presentations that I saw at the university in the US where I did my PhD. The predictions were that we would be out of agronomic traits by the year 2000, and then in five-year leaps we would go into products for food processing, pharmaceuticals, and speciality chemicals by 2010. I heard many presentations in the US in which this

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was not even questioned. It was presented as “This is how it will be.”

The agronomic traits would be herbicide resistance and insect resistance. We would then be leaping-- why we would be leaping, I don’t know, the scientific foundations of these five-year leaps have never been explained---into food processing traits, output traits, and consumer traits to give better foods, better oil composition, and starch composition. Then we would be going into pharmaceuticals or other kinds of industrial products, such as speciality chemicals.

These were promises to deliver. It was not “Maybe we try, perhaps it works.” It was, “This is what we will be doing.”

The reality

Now we are in 2018, way down the road from these promises. And the reality is that 99% of all GM crops grown in the field have only two traits: herbicide resistance (the majority to glyphosate-based herbicides) and insect resistance, with all of the latter based on traits taken from the bacterium Bacillus thuringiensis (Bt). What we see in terms of further innovation is that these two traits are simply being combined with one another, notably through conventional breeding, and less so through molecular stacking.

Golden rice still doesn’t exist to this day, because that small step that was envisioned to introduce the “golden” trait into a variety popular with farmers has not worked. All attempts to put that golden trait into a rice variety that would be grown by farmers have so far failed. Golden rice proponents have not delivered plants that would be acceptable to farmers and would function in the market and production environment.

Higher yields were also promised. By 2009 we heard from the US, one of the heartlands of GM crops, that contrary to the myths about the superiority of GM crops, the yield gains that were observable were not due to the GMOs but to traditional breeding and improvements in the cultivation of these crops.[1]

In 2013 Prof Jack Heinemann and colleagues published a comparison of yield data submitted by governments annually to the FAO (Food and Agriculture Organisation), which showed how yields have fared in two comparable regions in terms of production, and access to the means of production, and where the only difference was that one region (North America) had adopted GMOs and the other region (Western Europe) had not. Yields continued to increase in both regions, but regions growing GM crops did not have a steeper increase. They didn’t find much difference in yield for the crops that both regions were growing In fact, there was an increasing trend since the introduction of GM crops for yields in non-GM-growing Europe to outstrip yields in North America, and to do so with lower pesticide use.[2]

From Heinemann JA et al (2013). Sustainability and innovation in staple crop production in the US Midwest. International Journal of Agricultural Sustainability. 14 June. 71-88.

In 2016 the New York Times checked the data and found that nothing had changed since 2013 when Heinemann and colleagues published their paper. Yields continued to increase, but regions growing GM crops did not have a steeper increase in yields. Yield gains from GM were not delivered. So the NYT spoke of broken promises.[3]

It was the same with drought tolerant plants or plants adapted to other difficult environments. There is one GM crop out there today that Monsanto claims has a trait that improves yield protection under moderately water-limited conditions. They use very complicated phrasing, but if you look at the Web of Science you don’t find independent peer-reviewed literature that has actually looked at whether or not that is true. So it is still unconfirmed. Interestingly, we hardly hear anything about this so-called drought-tolerant maize, even during these years of severe drought.

The same point was also made by the author of an article in Nature in 2014, who said that cross-breeding crops is actually delivering where GM is not.[4]

We do have drought-tolerant maize varieties-- very good ones actually, I have worked with them -- but they have been produced through conventional breeding, sometimes

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with the use of molecular breeding [the application of molecular biology tools such as gene mapping] or marker assisted breeding --not with GM.

So these promises, made two decades ago, have not materialized. For over 20 years we have been stuck in the agronomic trait phase. We must ask ourselves why.

### Gene editing

Now there's a new kid on the block: so-called gene editing, which includes the CRISPR-Cas method. Instead of trying to work out why the first generation of genetic engineering tools hasn't delivered or worked, so that maybe there could be lessons to be learned for the next generation, they are now coming up with the same promises---but even bigger, if that is possible.

There is no critical debate or analysis--least of all of the scientific reasons why GM didn't deliver the first time.

In 2014, on the topic of CRISPR-Cas, a Newsweek article stated, "GMO scientists could save the world from hunger, if we let them". Really? Saving the world with point mutations? Again? Have we not learned from the last 20 years, when we tried that and it didn't work?

### Regulations blamed

It hasn't escaped the agbiotech lobby that they haven't delivered. But their analysis of why that might be is somewhat different from mine. They put the blame squarely on regulations. Regulations are the obstacle and are blocking progress, they say. But in North and South America there is no regulation that would stop anything or anybody. North America boasts that they are "deregulating" GM plants without lengthy approval processes. So why haven't they delivered there?

A colleague from my university, Ingo Potrykus, also puts the blame squarely on the regulations, which, in his view, must be revolutionized.[5] He implies that unjustified and impractical legal requirements are stopping GM crops from saving millions from starvation and malnutrition.

Really? Or is it maybe because GM is based on outdated science? Maybe they haven't done the right analysis and haven't learned what other fields in genetics have been finding over the years. When they discovered DNA as a material structure that carried the genetic information, they also promoted a dogma regarding its function and form. That dogma---genes make RNA molecules, which in turn make proteins---was not to be questioned. It was even called the "Central Dogma." It also held the idea that information will only be passed on to the next generation if it is coded in DNA, in nucleotide sequences: nothing else will be passed on and the information will only go in one direction.

### Digital biology

Others likened nucleotides to a digital code, so that you could use those four nucleotides to replace the binary code of the IT field. That was the hope. If that worked, it would be a quantum leap indeed. A paper from Nature in 2003 said that a remarkable feature of the structure of DNA is that it can accommodate almost any sequence of base pairs and hence convey any digital message or information. It said DNA has two types of digital information that you can manipulate, and then you can construct genes that encode proteins and genes that encode regulatory networks that determine the function of the genes. They claimed that the discovery of DNA was the start of a journey that would end in the grand unification of the biological sciences with the emerging information-based view of biology.

Well, 15 years have passed since these bold predictions were made, with nothing close to them materializing.

### Life as construction kit

The vision is of life as a construction kit where you just replace binary code with the four digits of the DNA, and then these kinds of imaginaries will come true. You could build your own molecular computer, for example. Terminology like intentional biology [in which nature is seen as a source and code] and digital biology has emerged. These are fantasy fields resembling science fiction more than science--but they have been attracting huge amounts of money in the form of venture capital.

But there was one problem that they al-

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ways ran up against. And those old papers make good reading to understand how they see the world. It's when they take these organisms--or the biochemical pathways that they generate in the lab--from the highly controlled, stable, and steady conditions of the lab out into the real world, where you have fluctuating conditions. Then the environment comes into play. They find this stochastic (random) information or events, unpredictable depending on the environmental conditions. These events generate "noise" that ruins their signals and their idea--so they need to be attenuated. Hence, most of their energy goes into addressing how they can control this "noise" and these organisms and get the organisms to function like computers.

Epigenetics virtually ignored

What they are missing is knowledge from other fields in science, for example, epigenetics. It means information passed on to the next generation that is not coded in the DNA. So that good old Central Dogma has been falsified, right there. Epigenetics shows that you can convey information to the next generation based on what you experience in your life. That is pretty revolutionary and fundamental. But astoundingly, it has not made much of an impression in the field of biotechnology. Why? A look at the history of these sciences gives a clue. There's a timeline in which DNA was discovered, the Central Dogma created, and a narrative woven around it. Then scissors were discovered that enabled us to manipulate DNA and see what happens with the resulting organisms. And then came the big surprise in 2001 when it was discovered after sequencing the human genome that humans have fewer genes than most plants and we don't have more protein-coding genes than a tiny little nematode, for example. And nobody would claim that a tiny little nematode is as complex as a human or a human as simple as a nematode. So something wasn't quite working out; it didn't line up with how we had thought it should work until then.

Split in science

But instead of then going and inquiring further, the field split into two sectors. In the first were those who pushed for more and more genetic engineering--that's when all the above ideas came up in the early 2000s, right after the discovery of the human genome and the revelation that genetics did not work as we had thought; we saw the push for genetic engineering and an even more extreme arm of genetic engineering called synthetic biology, where it got more and more narrow. The second sector was the epigenetics field, which finally got the recognition it deserved.

Epigenetics is not a young science. Researchers had known for decades that the idea of the linear functioning of DNA didn't quite line up with other observations. But they were in a minority, they were marginalized and they weren't listened to. In the early 2000s their findings started to gain acceptance. And the field of genetics and evolution is getting broader and broader, to the point where today, even the concept of a gene is becoming blurred. Does the gene, as a discreet entity coded only in DNA, even exist?

The RNA world was discovered, the epigenetics world was discovered, and yet they didn't permeate through to the other applied technical sector of the science. There is a wall through which hardly anything passes. It became clearer and clearer in ecological genetics, for example, that traits like variability, plasticity, and adaptability of organisms are the key to survival and evolution. But on the other side of the wall, these survival traits became noise that had to be quenched and attenuated.

So I see a real schism in biology, with one sector indulging their fantasies of making life into machines---intentional digital biology-- and the other saying--I'm not even sure genes exist. "I'm not even sure about a lot of things anymore that we thought we had figured out twenty years ago."

Discussion needed

We need to open a discussion on the scientific limits to gene technology. As I see it, the questions that must be addressed are:

How can we separate the science from the science fiction--which predictions can we solidly make---what does the science support? And at what point does it become

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more fiction than science?

Has this whole endeavour of biotechnology become--with all the enormous funding that went into it--too big to fail? Perhaps we can no longer take that step back and critically reflect because the consequences of having to admit that we put our money into a bound-to-fail exercise are just too big to swallow?

Should civil society build in these understandings of the scientific limits of gene technology before we start doing science fiction risk assessment of science fiction organisms--- and if so, how?

Notes

1. Union of Concerned Scientists (2009). Failure to Yield. https://www.ucsusa.org/food_and_agriculture/our-failing-food-system/genetic-engineering/failure-to-yield.html#.W96xr6ecZ2Y

2. Heinemann JA et al (2013). Sustainability and innovation in staple crop production in the US Midwest. International Journal of Agricultural Sustainability. 14 June. 71-88

3. Russell K and Hakim D (2016). Broken promises of genetically modified crops. New York Times. 29 Oct. https://www.nytimes.com/interactive/2016/10/30/business/gmo-crops-pesticides.html

4. Gilbert N (2014). Cross-bred crops get fit faster. Nature 513(7518). 16 Sept. https://www.nature.com/news/cross-bred-crops-get-fit-faster-1.15940

5. Potrykus I (2010). Regulation must be revolutionized. Nature 29;466(7306):561. doi: 10.1038/466561a

Dr Hilbeck's talk and the subsequent panel discussion were organized by the European Network of Scientists for Social and Environmental Responsibility (ENSSER) in collaboration with GLS Bank, Zukunftsstiftung Landwirtschaft (Foundation for Future Agriculture) and Vereinigung Deutscher Wissenschaftler (Association of German Scientists).

The California Section,
the Executive Committee,
the Board of Trustees and the
staff of *The Vortex* wish all a
peaceful Holiday Season and a
Happy New Year

## *November Meeting Report*

Linda Wraxall

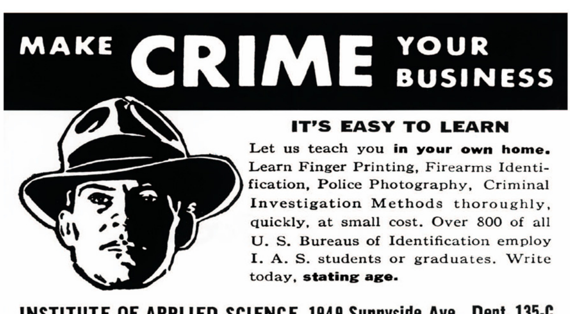
On Wednesday November 14, 2018, about 25-30 ACS members gathered at the USDA in Albany to hear a talk given by John De Haan, a trace evidence chemist, on "Criminalistics – A Look Back and a Look Ahead." The content was well constructed to help the audience understand the basic principles of forensic lab work and illustrated by personal anecdotes, ranging from the recreation of the Great Chicago Fire of 1871 to his seminal research work on human deaths by fire.

The trace evidence chemist applies knowledge and skills to the analysis and interpretation of physical evidence in the investigation of a crime. The work is usually done in a public sector lab (law enforcement) or a private lab (often working for the defence). It can be criminal or civil in origin and can involve the identification of a wide variety of physical pieces of evidence taken from the scene, the victim, or the suspect. Evidence that could be glass, paint, soil, fibers, hair, metals, handwriting, and accelerant and explosive residues. DNA analysis, which is currently enjoying the forefront of many investigations, is limited to being able to tell who did it and not how the crime was committed, which can be more important.

Dr. De Haan also gave insights into giving testimony in court and the need to be sure of your science, be prepared, and keep your cool. The Frye and Daubert Rules have been a big challenge to the expert forensic witness. The Frye Test or Standard is applied by the court to determine the admissibility of forensic evidence when the scientific technique is generally accepted as reliable in the relevant scientific community. The Daubert Standard in US Federal law is also a rule of evidence regarding the admissibility of the expert witness's testimony.

Today's criminalists stand on the shoulders of forensic giants like Max Frei-Sulzer (tape lifts), George Popp (serology), Edmund Locard (the exchange of materials), R.A.Reiss (photography), John Glaister (hair id), James Osterburg (police instrument chemist), E.O.Heinrich (handwriting analysis), Paul Kirk (microscopist) to name but a few, and not least, Sherlock Holmes.

Finally, he gave specific advice for those considering a career in criminalistics. This requires a good scientific approach and hypothesis testing so that the right answers are obtained for the right reasons. First impression bias and outright blunders (most prevalent in the insurance industry) can then be avoided, especially by applying abductive reasoning i.e. the creation and testing of alternatives through "what if" scenarios. Forensic science offers a lot of variety – few cases are the same - but also many challenges. It is meaningful work, sometimes grim where death is a factor, but the necessity to work "outside the box" and "follow the science" is paramount.



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- http://www.calacs.org/page.asp?id=22


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