

University Lecture  
April 19, 2007

The Excitement of Science: Teamwork, Discoveries, and Communication  
Sandra S. Eaton

## **Introduction**

I am delighted to have the opportunity to present this lecture and to share with you some of the things I have done and learned and why I continue to be excited about what I do.

Some people have the misconception that science is a solitary endeavor – of individuals working by themselves. Actually, the things that I will be telling you about this evening involved the efforts of many people working together. These projects have provided learning opportunities for students at all levels from undergraduate to graduate and post-doctoral. Together we have learned things that we have communicated to the scientific community. Each new piece of information contributes to a broader effort to answer scientific questions.

This work would not have been possible without financial support from multiple sources. The University provides academic year salary and laboratory space. In addition, at several crucial periods in our research the University has provided part of the purchase cost for major instrumentation, supplementing what we received from federal research grants. My undergraduate research was funded by the National Science Foundation (NSF). For 3 of my years in graduate school I was the recipient of a fellowship from NSF that paid my salary. Since becoming faculty members Gareth and I have received research grants from NSF that provided funding for equipment, co-worker salaries, and lab expenses. Over the years the primary source of funding for our work has been the National Institutes of Health (NIH). Their mission includes basic research, such as ours, as well as work that has immediate clinical application. Without federal grant support, our work, and that of the students who work with us, would not be possible.

## **Teamwork**

In high school I was interested in many things including French, math, and sciences. I was not especially interested in chemistry. My high school chemistry teacher was also the coach of the football team and that was a higher priority for him. My excitement about chemistry began when I was an undergraduate at Wellesley College. At that time the chemistry labs were located in Pendleton Hall (Figure 1). The labs have since moved to more modern facilities, but I have fond memories of that old building. I was fortunate that I could spend the summers after my freshman and junior years working fulltime on a research project. That was possible because my mentor, Prof. Emily Dudek, had received a grant from NSF that provided summer stipends for students – 3 of us in her lab and several in other labs. Our projects continued through the school year. It was exciting to make compounds that no one else had ever made and to characterize them by a variety of instrumental methods. Although the facilities at Wellesley were fine for making new samples and doing basic characterization, we did not have more sophisticated tools. Fortunately Emily Dudek's husband was the director of the analytical instrumentation laboratory for the Chemistry Department at Harvard. On Saturdays, the Dudeks would take us, and our samples, to Harvard to use equipment there. That was my first introduction to Nuclear Magnetic Resonance (NMR), which was the primary tool that I later used in graduate school. I learned many lessons about teamwork from my peers in the lab and

seeing how the Dudeks worked together. That experience convinced me that I wanted to become a faculty member and to strive to provide similar learning experiences for my students.



**Figure 1.** Pendleton Hall, Wellesley College, photo from Wellesley College web site.

In the spring of my senior year I was astonished (and delighted) when Prof. Dudek suggested we should write up my experiments for publication in a peer-reviewed journal. That became my first professional publication (Sandra Y. Shaw and Emily P. Dudek, *Inorg. Chem.* **8**, 1360-1366 (1969).).



**Figure 2.** Recent photos of our research group.

You may recognize the photo in the center of Figure 2 as the one from the announcement for this talk, which was taken by Tim Ryan, DU photographer. Gareth and I met and married during graduate school and have done research together ever since. We were introduced to each other by Emily Dudek, my undergraduate mentor, and her husband. We are looking through a piece of equipment that I will tell you more about later. Instrumentation lets us look at the chemical world in ways that would otherwise be impossible. Working together has permitted us to do a much wider variety of things than either of us would have attempted separately.

Many co-workers have contributed to our projects. A small sampling of recent photos is shown in the pictures in Figure 2. I particularly want to point out Engineers George Rinard and Richard Quine (lower left photo, back row, 2<sup>nd</sup> and 3<sup>rd</sup> people from the left) who have worked with us for over two decades and have designed and built much of the instrumentation that makes our experiments possible. I don't want to give the impression that we spend all of our time eating, but we are more likely to take pictures during festive occasions. Clockwise from upper left the photos are: at a farewell lunch for a colleague returning to Japan, after John Ballard's thesis defense, Thanksgiving dinner at our home, and before leaving for England to receive the Bruker prize.

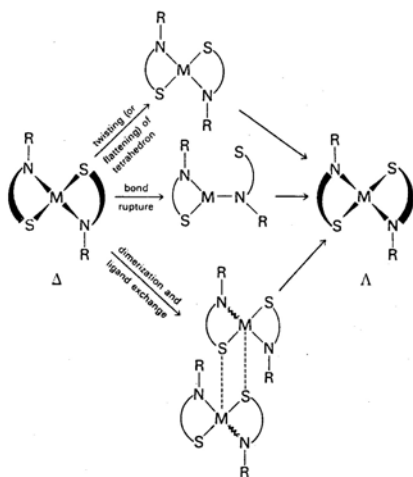
Science is a truly international enterprise. We are fortunate to have had co-workers from 18 countries, in addition to the U.S. Each individual brings their expertise to the project and learns from other people in the group. When we first started as faculty members, most of our colleagues from other countries came with the intent of finding permanent jobs in the U.S. These scientists, and many others like them, have made tremendous contributions to the advancement of research in the U.S. The preference for staying in the U.S. began changing about a decade ago. Scientific career opportunities in many parts of the world are improving to the point that most of our recent colleagues choose to return to their native countries. We are pleased to help with their education and to have their contributions to our projects, but this trend has serious implications for the future of the U.S. As a nation, we shouldn't assume that we will continue to import scientific talent. We need to interest more American young people in careers in science.

## Discoveries

The questions that are interesting and important to work on change with time. The "hot" questions when I was in graduate school have been answered and have become starting points for asking new questions. For tonight's lecture I've picked a few examples of questions we've worked on, selected to highlight how science evolves. Each discovery builds upon prior work, your own and that of many others.

In graduate school at MIT I worked with pairs of molecules called *isomers*. When two molecules are built from the same set of atoms, but the atoms are arranged in different ways, they are called *isomers*. There are many different types of isomers. Two isomers may have very different properties. For example, you have likely heard about *trans* fats, which are isomers of the naturally occurring *cis* fats. Our bodies can digest *cis* fats, but not *trans* fats, which probably is the reason why *trans* fats contribute to health problems. Some pairs of isomers interconvert very quickly whereas others are very stable. If there is interconversion between isomers, what is the process by which that occurs? The answers to these questions will be different for different types of isomers and may determine whether a particular molecule is suited for an intended application. My goal was to study these interconversions for certain types of metal complexes.

Many of my experiments used nuclear magnetic resonance, which I had begun to learn as an undergraduate. I'll say more about the technique in a few minutes.



**Figure 3.** Reproduced from *Inorganic Chemistry* by Kotz and Purcell, 1977. The diagram is based on the paper S. S. Eaton and R. H. Holm, *Inorganic Chemistry* **10**, 1446-1452 (1972), which reported work that I did as a graduate student.

For my first project in graduate school I studied compounds where there are 4 bonds to the metal, and the compounds are therefore designated as 4-coordinate. These molecules are sketched in Figure 3. The metal is designated as M. The 4 bonds to the metal are from 2 sulfurs and 2 nitrogens. To call attention to the key features of the molecules additional atoms are just summarized with heavy lines. At that time computer graphics were not readily available so very simple methods were used to represent 3-dimensional structures. On the left side of the diagram the thin ends of the lines indicate that the N atoms are below the plane of the paper and the heavy end indicates that the S atoms are above the plane of the paper. This molecule is like a right-handed propeller. The isomer on the right side of the diagram is similar but now the S ends are below the plane and the N ends are above the plane of the paper, which makes it a left-handed propeller. We wanted to know how quickly those two isomers interconverted and how that process occurred. We found that these isomers interconverted a few times per second at room temperature and that the rates varied in a predictable way as we changed the metal (M) and the substituent (R). That work was published in 1972 and represented about a year of my effort.

The drawing in the slide is copied from a 1977 edition of an undergraduate text book. When I used that book in class it was fascinating to see the students' reaction when they realized that the footnote at the bottom of the page referred to my graduate work. Undergraduates tend to assume that information in the textbooks has been well known for many years so they were surprised to learn that some information was quite recent and that someone they knew had done the experiments they were reading about.

My next project was to work on molecules in which there are 6 bonds to the central metal ion. I soon learned that some experiments are more difficult than expected. The project was intended to be in cooperation with a group at Dupont Central Research in Delaware. They had several pounds of sap from a rare species of Japanese tree, and planned to separate a compound from the sap that I would then bind to metal ions to prepare the compounds to study. Just as I was about to start the project I got a phone call – the dish washing crew had mistakenly assumed

that the container of tree sap was a dirty dish they were supposed to wash up. They had thrown away all of the precious sap! Imagine my dismay. My thesis advisor was out of town, and the people at Dupont did not want to tell him the bad news, so it was my task to call him. After listening to the bad news, he was quiet for what seemed like a very long time. Finally he responded, “you will have to find a way to synthesize the compound yourself.” I wasn’t enthusiastic about trying to make a natural product, but by then I was determined to find out how the behavior of the 6-coordinate complexes compared with that of the 4-coordinate ones. In those days searching the chemical literature was much more difficult than it is today because information was available only on paper and not electronically. However, I found a synthesis that I was able to perform. In hindsight, making the compound myself was much better because the synthetic approach made it possible to prepare a related compound that was very useful for comparison with the one I had originally hoped to be given.

When I began to study the metal complexes, the first results were very perplexing. The isomers were interconverting much more rapidly than either my advisor or I expected, which raised many questions. Did I not really have the molecules that I thought I was making? Was there an impurity that was causing the rates to be so fast? Eventually we concluded that our preconceived notions were wrong. The structures of the molecules made the rates faster. Because of the faster rates I had to change my experimental design and use a different method to perform the studies. However, once we understood what was actually going on, it became another “text-book” example.

### **Electrons, Spectrometers, and Spectra**

When Gareth and I began our own projects as faculty members, we decided to pursue questions that were quite different from what either of us had done as graduate students. We wanted to study molecules that contained unpaired electrons – this includes free radicals and some metal ions. The electron is the negatively charged fundamental particle in atoms. It is the “glue” that holds molecules together and in most molecules electrons come in pairs. However, there are special types of molecules where there are unpaired electrons. Unpaired electrons behave like little magnets and their environments can be characterized by placing them in a magnetic field. The technique by which we study them is called electron paramagnetic resonance (EPR). Many of the fundamental principles are similar to NMR, but the instruments required to do the experiments are very different.

Although politicians seem to talk about a billion dollars as if it isn’t much money, a billion **really is** a very large number. A billion is a thousand times bigger than a million. To help you understand how tiny individual molecules are, think about the fact that real individual molecules are about 10 billion times smaller than the sketches of molecules that I have shown you on the screen. We can’t see molecules directly with our eyes. The only way that we can study molecules is by using instruments that are designed to look at particular properties.

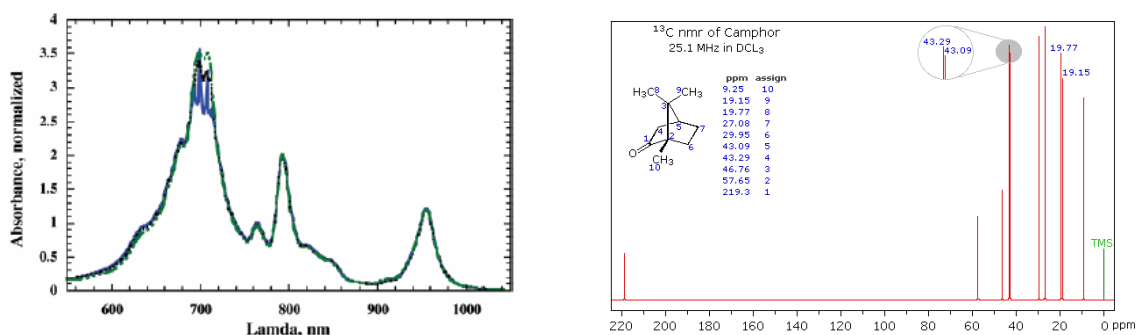
The types of instrument that we use are called spectrometers. There are many different types of spectrometers, depending on what property of a molecule you are trying to study. A picture of one of our spectrometers is shown in Figure 4. The magnetic field is produced by passing electricity through coils of wire in the magnet. The sample is between the poles of the magnet. The white cabinet contains a large amount of electronics that is required to detect the signal. Off to the left edge of the picture is a computer which is a key part of the experiment. Advances in computers have made it possible to analyze data and to do new types of experiments that were unthinkable 15 to 20 years ago. The blue container is a very efficient dewar that holds

liquid nitrogen, obtained by cooling it from the air, which permits us to study samples as a function of temperature.

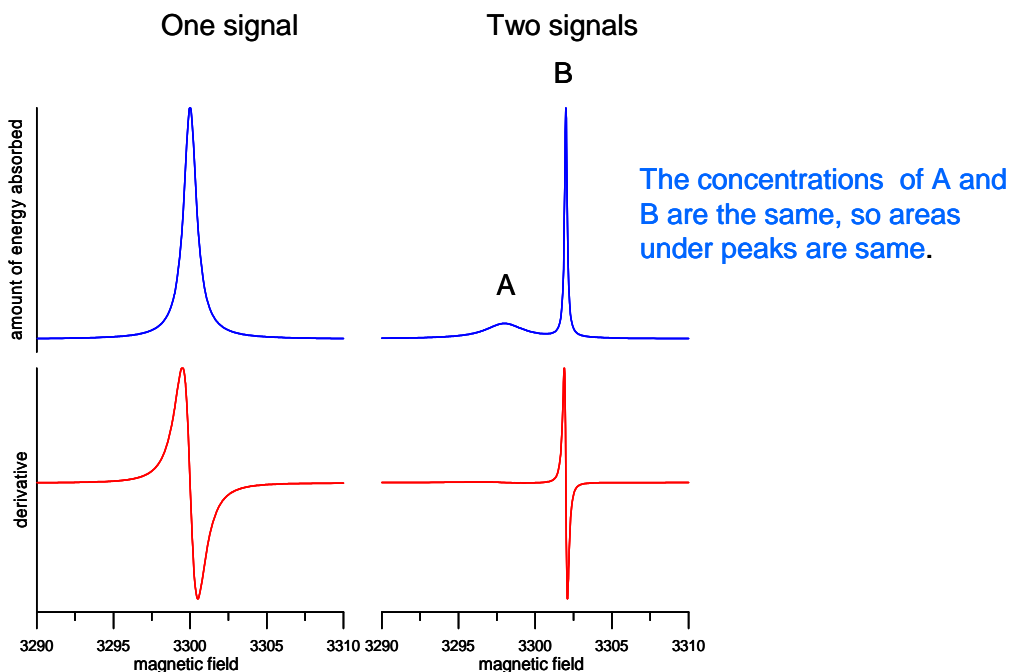


**Figure 4.** An electron paramagnetic resonance (EPR) spectrometer in our lab.

The information that is output from a spectrometer is a spectrum. A spectrum is a plot of the amount of energy absorbed as a function of a parameter that is varied. There are many different types of spectra – two are shown here as examples (Figure 5). The one on the left is a plot of the amount of energy absorbed for different energies of light near the range where are eyes are sensitive. The one on the right is an NMR spectrum, which plots the energy absorbed by protons in the molecule as a function of magnetic field, in relative units.



**Figure 5.** Left: electronic spectrum taken from S.-G. Chen, H. M. Branz, S. S. Eaton, P. C. Taylor, R. A. Cormier, and B. A. Gregg, *Journal of Physical Chemistry B* 108, 17329 (2004). This spectrum was part of a project that was joint with the National Renewable Energy Laboratory. Right: an example of an NMR spectrum. The figure was copied from the web site for an organic chemistry class at Michigan State University.

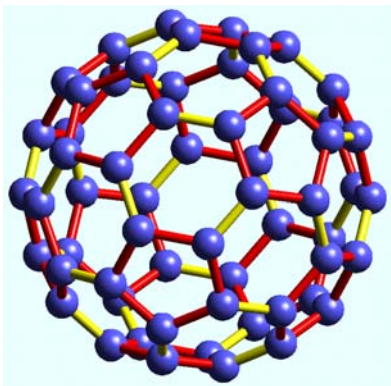


**Figure 6.** Spectra of molecules with unpaired electrons.

We want to focus on spectra of molecules with unpaired electrons (Figure 6). The upper left blue curve is a spectrum for a sample with just one signal. In our experiments the parameter that is varied is the magnetic field. The position of the signal along the axis, the number of peaks, the width of the peaks, and the areas under the peaks all provide information about the sample. EPR spectra usually are displayed as the derivative of the signal, as shown in the red curve on the lower left. On the right side of the figure is an example of a spectrum for a sample with two different signals, **A** and **B**. The areas under the curves for the two signals are the same, which means that the concentrations of the molecules that give the two signals are the same. However, the amplitudes of the two peaks are quite different. Your eye tends to focus first on the tall sharp signal from **B**. In the derivative display you can hardly see the signal from **A**. You can imagine that if the positions of the two signals were closer together it might be easy to miss the signal from **A**, especially in the derivative display. Our projects required careful measurements of how much of various species were present in the samples we were studying, so we learned to be very careful not to overlook signals.

### **C<sub>60</sub> – a new form of carbon.**

For many years students had learned that there are three forms of the element carbon – diamond, graphite (which is black and used as a lubricant), and amorphous carbon as in the soot from a flame. However, in 1985 groups of researchers in Sussex, England and at Rice University in Texas reported evidence for C<sub>60</sub> molecules, which became known as buckyballs (Figure 7). We read with interest the emerging literature but had no intention of working on this ‘hot’ fad. Comparison of the sketch of C<sub>60</sub> that is shown in the figure, with the earlier molecular sketches is a reminder of how improvements in computer graphics were changing the way chemists displayed information.

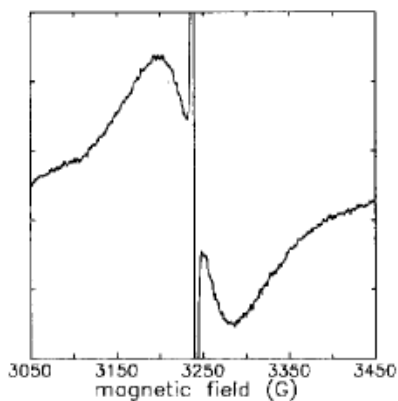


**Figure 7.**  $C_{60}$ , also known as buckyballs.  
Structure copied from  
<http://www.godunov.com/bucky/fullerene.html>

For some molecules it is possible to add an electron and create a new molecule with one more electron, which becomes negatively charged and is called an anion. The study of the anion can reveal fundamental properties of the original molecule. Theory predicted that it should be possible to make  $C_{60}^-$  and experimentalists immediately tried to do so. We were perplexed by some of the spectra reported in the literature for  $C_{60}^-$  and of conflicting reports concerning the spectra, but we had no source of  $C_{60}$  and no experience handling it. Our contribution started with a phone call from a woman at IBM in Yorktown Heights, NY, whom we had not met then, and still have not met. She was working on  $C_{60}^-$ , she knew of our reputation in spectroscopy, and asked if we could use our expertise in studying molecules with unpaired electrons to understand  $C_{60}^-$ . IBM was interested in  $C_{60}$  because of its potential materials properties. Gareth and I discussed the request and decided it would be an interesting problem to work on. Dr. Schell-Sorokin and her group prepared the samples and shipped them to us overnight on dry ice. We ran the spectra. We soon realized why the reports in the literature were confusing. There was a sharp signal that several research groups had seen, but we found that the area under that signal accounted for only a tiny fraction of the total amount of  $C_{60}^-$  that was supposed to be in the sample. When we looked carefully we found that under the sharp signal, and at almost the same position in the spectrum, there was a very broad signal that was being overlooked (Figure 8). Once we realized that the broad signal was the “real” signal, we knew what we should characterize. Subsequent studies also involved Dr. Trulove’s group at the Air Force Academy who had excellent facilities to prepare the anions. Studies of the signal as a function of temperature were very informative. The signals at lower temperature were much more complicated but revealed fascinating features of the molecule. Our contribution was primarily in answering this one part of the puzzle, but it emphasizes the team-work aspect of science.

There’s another interesting general aspect of the studies on  $C_{60}$ . The characterization of  $C_{60}$  changed peoples’ assumption about possible forms of carbon. The search widened to look for related molecules. People soon found other related molecules and eventually a whole new class of molecules with intriguing applications was born. We now know about  $C_{70}$  and  $C_{80}$ , about balls with metal ions inside them, about nanotubes, and many others.



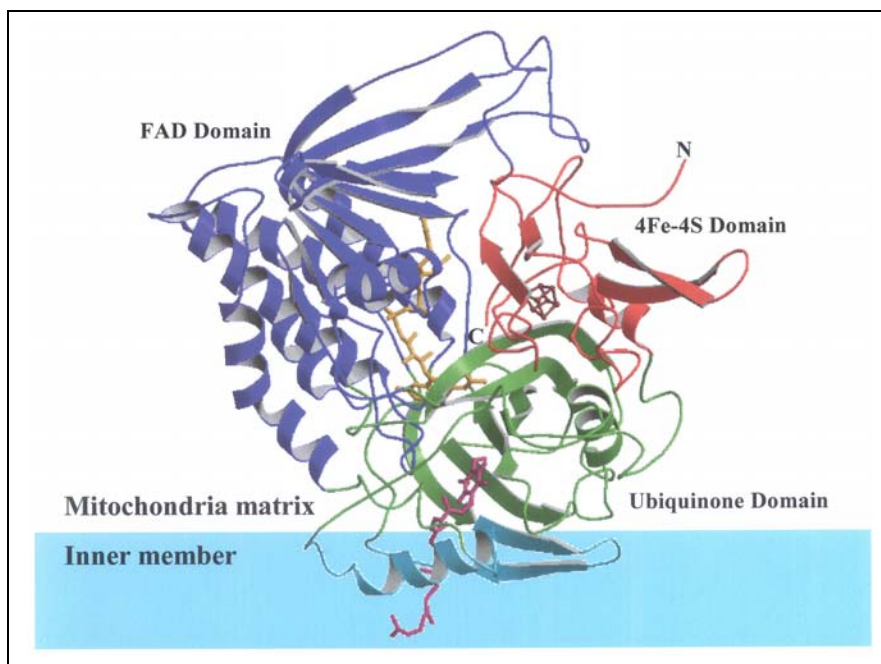


**Figure 8.** EPR spectrum of  $C_{60}^-$  reproduced from A. J. Schell-Sorokin, F. Mehran, G. R. Eaton, S. S. Eaton, A. Viehbeck, T. R. O'Toole, and C. A. Brown, *Chem. Phys. Lett.* **195**, 225-232 (1992).

### What are we working on now?

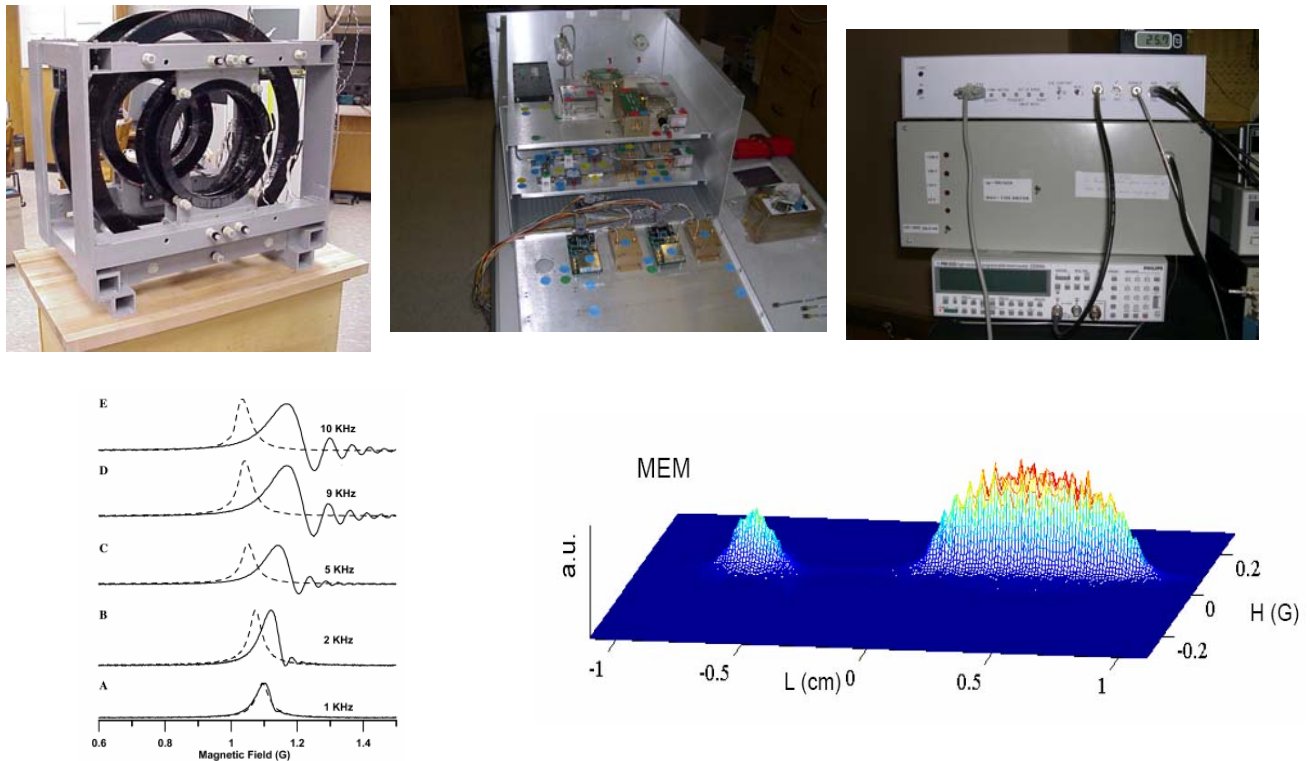
Our interests have evolved into larger more complicated biological molecules and systems. I'll briefly outline three projects we are currently working on. These are not finished stories.

A challenge that we have been interested in for many years is how to measure distances between unpaired electrons in biological molecules. Different approaches are needed for different types of molecules and different environments for unpaired electrons. An example of why we are interested in these measurements is the protein shown in Figure 9. This is a sketch of a protein that is crucial for life of all mammals, including people. This project is joint with Prof. Frank Frerman, University of Colorado Health Sciences Center. Naturally occurring changes in this protein, called mutations, have very serious consequences – the most serious defects result in death of the infant within a few days of birth. If we could understand the structural consequence of the defects in the proteins, perhaps a treatment could be designed.



**Figure 9.** Diagram of a protein that is required for fatty acid metabolism. The diagram was provided by Frank Frerman. Note the improvements in computer graphics.

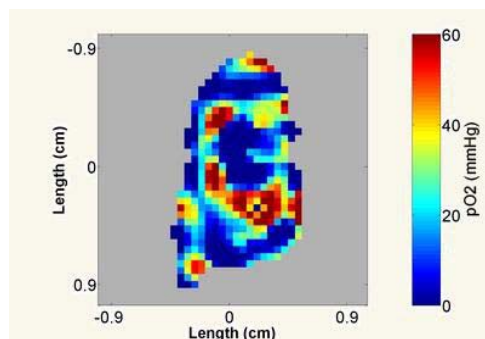
To perform some of the experiments that we want to do, we need to develop new spectrometers. That work has been done jointly with 2 engineers - George Rinard and Richard Quine, and some graduate students from the Department of Engineering. Figure 10 shows some of the modules that were built for a project I will describe shortly. On the left is a magnet that was designed to create weaker magnetic fields than in the spectrometer I showed earlier. You may recognize this magnet as the one in the photo of Gareth and me at the beginning of the talk. The middle panel shows some of the electronics components for the signal detection system. On the right are control modules for scanning the magnetic field. This instrumentation was designed to detect signals in a new way, which is why the spectra in the lower left don't have the same shapes as what I showed you earlier. The oscillations occur because of the way the experiment is done. However, the "normal" signals that are shown as dashed lines can be recovered computationally. So far, we are the only group that can do this experiment, but we are working with a commercial instrument manufacturer to make this capability available for other labs. Usually we work very hard to make the magnetic field uniform over the sample. However by deliberately causing the magnetic field to vary over the sample, we can acquire data that can be combined to form "maps" of the spatial variation of the signal. The picture in the lower right corner of the figure is a display of the spectrum as a function of position in the sample, along a single direction. The concept is similar to MRI, but for unpaired electrons.



**Figure 10.** Instrument development and new detection methods.

The primary goal of the instrument development that I just described is measurement of the local concentration of oxygen in living creatures – initially mice, but eventually humans. On this project we are working with an oncologist, Dr. Howard Halpern at the University of

Chicago. You probably have all seen that when a person is taken to the emergency room, a device is attached to the finger to monitor the oxygen level in the blood, which is an extremely important test of heart and lung function. The assumption is made that what you monitor in the finger is representative of the whole system. We are interested in measurements in areas of the body where a detailed knowledge of local concentration is crucial – during radiation therapy and in treatment of diabetics, for example. When radiation is used to destroy a tumor, the treatment works better if there is a normal concentration of oxygen in the tumor. Very reactive molecules produced by interaction of radiation with oxygen are thought to be part of the tumor damage mechanism. Immediately after a radiation treatment the oxygen level is low. The effectiveness of the next dose of radiation is greater if you wait just long enough for the oxygen level to return to normal, but not too long. Today the treatment protocol is based on assumed typical response times. Each person and each tumor is a bit different so it would be helpful to have a way to monitor local oxygen concentration. Here's a second example of the importance of measuring local oxygen concentration. Poor circulation can cause low oxygen concentration in the feet of diabetics. It would be wonderful to have a way to determine whether medications were actually improving the supply of oxygen to the feet. The large magnet in the upper left corner is under construction at Chicago, based on George Rinard's design. The electronics will use as many components of a commercial system (right side of Figure) to facilitate eventual incorporation into a product that can be made widely available. At the bottom of the slide is a false-color map of an image of local oxygen concentration in a tumor on the leg of a living mouse. The dimensions of the map are 1.0 cm by 1.5 cm. This is a long-term project, but we enjoy the challenge to contribute to it.



**Figure 11.** Measuring local concentrations of oxygen in living creatures.

## Communication

Once we have discovered new information in the laboratory it is important to share that knowledge with other people working in related areas. Scientific conferences play a key role. Results usually are presented at conferences before publication in printed journals. This is the opportunity for colleagues to ask questions that sharpen our perspective. We also learn from what other people are doing. We have made more than 250 presentations at scientific conferences describing the results of projects that we have worked on. That includes invited lectures in 14 other countries (Australia, Belgium, Brazil, China, England, Germany, Hong Kong, Italy, Japan, Poland, Russia, Siberia, Sweden, and Tatarstan). Contacts made at conferences can later be pursued by email or phone.

As part of our broader “teaching” role Gareth and I have helped to organize an annual research conference for colleagues who are studying molecules with unpaired electrons. It is very satisfying to see people who come first as young students and watch them develop into independent researchers and leaders in the field who bring their students to the conference. It is gratifying to hear that our conference has contributed to their professional development through information learned, contacts made and often their first presentation at a conference. It is satisfying to talk with people who are just learning about the field and to hear them comment on what they learned from our published papers.

Journal articles are the primary means of communicating new knowledge in our field. An indication of the importance of teamwork is that we have co-authored papers with 26 undergraduates, 25 graduate students, and 30 post-doctoral associates, and with colleagues at 24 other institutions. The science to which we contribute is changing fast enough that edited books are much more common than single-author books. The chapters in edited books and in the few journals devoted to review articles provide opportunities to synthesize and evaluate a body of information.

Our presentations at professional meetings have given us the opportunity to visit interesting places and meet colleagues from all over the world. I’d like to share with you two anecdotes from one of our trips that demonstrate things I’ve found apply to many aspects of life, not just science.



**Figure 12.** Red Square, Moscow, Sept. 1989.

The first answer may not be the full story!

When I was a college student in the '60s, at the height of the cold war, I never imagined that I would one day stand in Red Square (Figure 12). However, Gareth and I were invited to present lectures at a meeting in Novosibirsk, Siberia, in September 1989. We arrived in Moscow on a Saturday evening and learned that our travel plans had been changed and we would not be continuing on to Siberia until the following evening. We were informed that arrangements had been made for us to stay overnight at a hotel that belonged to the Soviet Academy of Sciences and we would have time to go sight-seeing on Sunday. Gareth could read a little Russian, and I had learned enough to say please and thank you, but that was all. We made our way, just the two us, through the color-coded Moscow subway and entered Red Square. Most of the visitors were in line to see the Lenin mausoleum. The guide book that we had brought with us said that the old churches had been converted to museums and that there were wonderful pieces of art inside. We went to the entrance of the first museum and tried unsuccessfully to buy admissions tickets. After trying increasingly loudly to speak to us in the Russian, the elderly woman at the door gave up in disgust and waved us to enter without buying tickets. We were glad to have the opportunity to go in, but did not want to repeat that process. Somehow we needed to get tickets. There were many police on guard in the Kremlin so we decided to ask one for help. We approached cautiously and asked slowly "Do you speak English", to which we quickly received the response "nyet", which we knew meant no. We looked at each other, either he understood the question or he just said no all the time. We then asked, "where do you buy tickets"? He looked over his shoulder as if checking that no one was looking, motioned toward a gate and replied in perfect English "go down to the gate and turn right". He turned away. We followed his instructions, found a kiosk that sold tickets, and managed by pointing and gesturing to buy tickets. I use this story to make that point that in science, as well as in travel, the answer to the first question may not be the full story. We need to keep asking questions.



**Figure 13.** Lake Baikal, Sept. 1989.

What is the REAL issue?

That evening we flew to Siberia for the conference, which was an amazing experience in many ways, but there isn't enough time to tell those stories. Each of the invited speakers from the west had paid their own travel expenses to/from Moscow. Expenses within the country were paid by the Soviet Academy of Sciences. After the conference, as a thank-you, the invited speakers were taken on a trip to Lake Baikal, which is the largest body of fresh water in the

world. Including a few spouses we were a group of about 20 people. We flew to Irkutsk, then were taken by bus to the Lake and given an hour or so to look around. We soon noticed a dock and hydrofoils taking groups out on the Lake (Figure 13). We asked our guides if we could go on a boat ride. We were told ‘no’. Fortunately a member of our group was from East Germany and spoke Russian. With our typically Western perspective most of us initially thought that the cost of the ride would be the issue so we offered to pay. At that time a dollar was worth about 10 rubles at the official exchange rate and about 20 rubles on the very active, but strictly illegal black market, so the cost seemed very nominal to us. We were again told ‘no’ – if we took a ride on the lake we would miss dinner back at the hotel. We did not want to offend our hosts, but although we were being fed very well relative to typical Siberian meals at that time, we would have been glad to miss dinner if that was what was necessary. Gradually we realized that the real issue was control. The guide was supposed to have us back at the hotel for dinner at a designated time so we must not deviate from the original plan. After much negotiation, a couple people agreed to go back on the bus while most of us got on the boat. It turned out that the boat could take us along the end of the lake and then up a river to a dock that was very close to the hotel where we were staying in Irkutsk. It was a lovely autumn afternoon and the deciduous trees on the surrounding hillsides were turning golden, so we had a wonderful ride (Figure 14). The hotel even delayed dinner for us. My moral from this story is that when you find out what the REAL issue is, you are more likely to find a solution.



**Figure 14.** Lake Baikal, looking back toward the dock.

What a great solution!

## Summary

I hope I’ve conveyed to you a bit about what we do in our research group and why I am so enthusiastic about it.

I’ll close by saying that in many endeavors if we persist in asking questions, we can determine the “real” issues. Once we have defined the real issues, we have the possibility to work together to find answers to challenging questions.

Thank you for your attention.