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Lecture 19: Life is a Circle, Spiral, Stairstep, Exponential Growth Curve... It's Chemistry!

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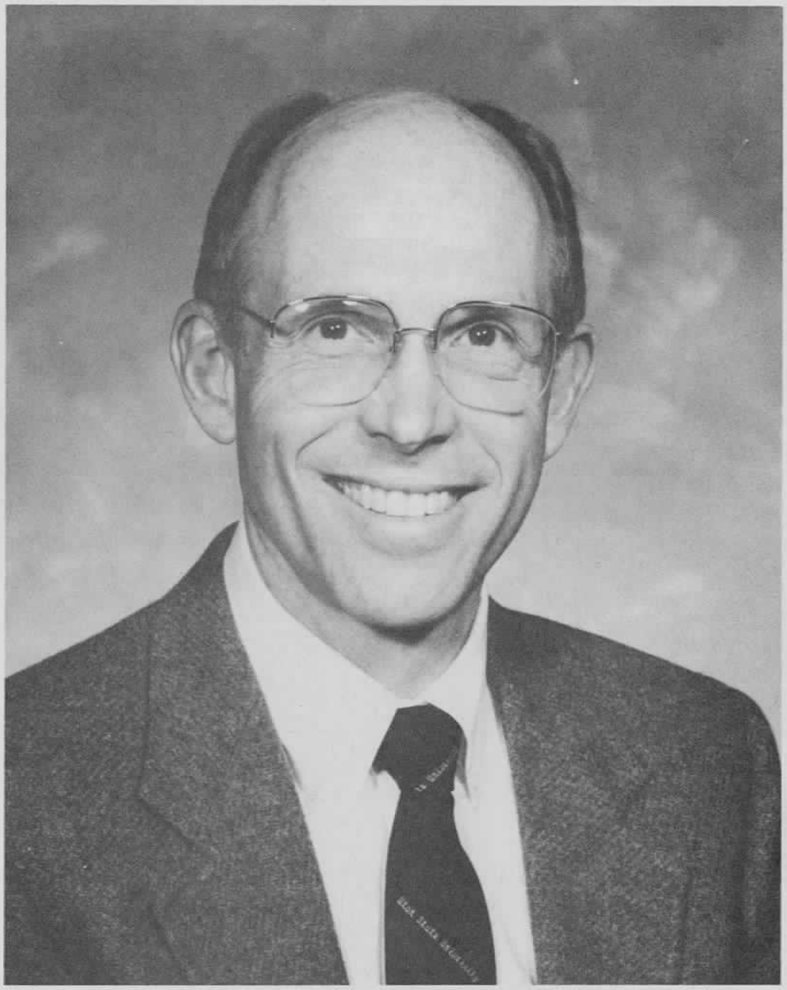
The Honors Program and ASUSU present
the
nineteenth annual

LAST LECTURE



Life is a ~~circle~~ ~~spiral~~ ~~stairstep~~ ~~exponential growth~~ curve ...(?)

!It's Chemistry!

by

Dr. Joseph G. Morse

11.9:60
no. 19

Life is a ~~circle~~ ~~spiral~~ ~~stairstep~~ ~~exponential growth~~ curve ... (?)

!It's Chemistry!

Thank you for the honor and the opportunity presented to me in the invitation to present the 1994 Last Lecture. Having been close to the selection process, I know of the care and thought which the students have put into the selection process and am acutely aware of the magnitude of the honor it thus entails. I was elated and wonderfully surprised by the invitation.

The concept of the Last Lecture award is an interesting one. Who among us faculty, or maybe simply experienced adults (not to say old people), would not relish an invitation to tell a group of students and colleagues what you would like to tell them if it were your last opportunity? Think of it: no student evaluations to worry about in response; a clean get-away! And uniquely in its history, I can give the Last Lecture in just that circumstance.

On the other hand, it is also a daunting prospect. One doesn't want to have the opportunity only to blow it. That concern occupied me for several weeks (some call it writer's block) after the invitation before I could even come up with a title. But as I often told my students in the Honors Writing Seminar, the only way to overcome writer's block is to sit down and start to write.

So I did.

During my years at USU I developed two passions (in addition to bicycling and running)-- education in chemistry and in liberal arts. The two are <u>not</u> antithetical, as I hope to persuade you this evening. I am convinced more and more that a strong, broad liberal education is essential to "success," according to many definitions of the word, in our changing world. I am not convinced that <u>everyone</u> must have a detailed understanding of chemistry (though I wonder why not everyone wants it), but I think the study of chemistry can serve to illustrate the combination of breadth and depth that I believe is the requisite combination.

So I opted to combine the two.

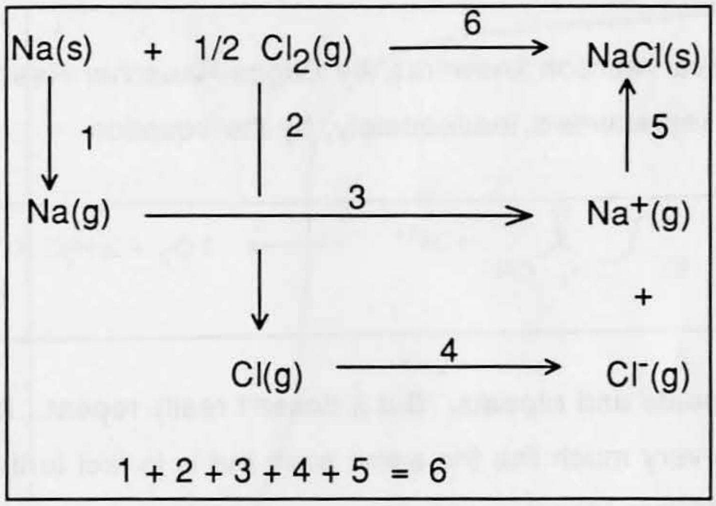
A work very influential on my thinking about this lecture is *The Work of Nations* by Robert Reich, and I must acknowledge my debt to that work up front. Another experience that colored my topic was my taking part in a course called "History of the Future" offered in Fairhaven College of Western Washington University during Winter Quarter. The nine-credit course was intended to give students an opportunity to think very seriously, with some guidance, about what kind of future we may face. As a part of it some professional "futurists" presented their approaches to that enterprise.

Not too surprisingly, they emphasized extrapolation from past experience. Ah, but with what kind of function does one extrapolate? There is the challenge. The title of my lecture this evening represents the kind of frustration that can easily arise in pondering the choices available.

Chemistry is in part the study of change in matter. Life is participation in change. There are aspects of both that share common dynamic features.

Life or chemistry may be a cycle, if not precisely circular. A very useful devise in thinking about the energetics of chemical processes is a thermodynamic cycle. There are several in common use including the Carnot cycle to analyze a heat machine or the Born-Haber-Fajans cycle to determine the strength of an ionic bond. The latter case applies Hess' law to an analysis of the energetics of formation of a chemical compound, for example sodium chloride, NaCl (see Figure 1).

As in chemistry we are accustomed to thinking of some aspects of our lives in cycles. Each year is a kind of cycle. We speak of the cycle of the seasons. Often we perceive our days at school or at work as cyclical. "What did you do today?" "Ah, the same old thing. I got up, went to work or school, did my thing, had lunch, came home, had supper, studied, slept, and started all



(Figure1)

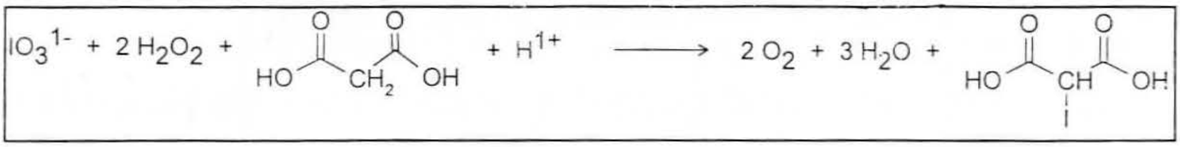
over again."

But just as cycles are in many ways illusory, or imaginary, or in some sense idealized in chemistry, just so are they illusory in life. We can imagine a Carnot cycle or a Born-Haber-Fajans cycle, but we can't realize one. It is an idealized circumstance. Great pains have been taken to account for why that is true and the answer comes: ENTROPY!

I don't know if entropy, in the same sense, applies to human activity, though I know that some economists have incorporated the concept into their thinking. But it is certainly true that no day is exactly like another. We never start tomorrow from precisely the same point as we did today. We would like to think, or to hope, that we will have learned something today which will make tomorrow at least different, if not better.

So I scratched out "circle" and tried something else. If we never start from the same place but in fact from somewhere further on--we have progressed (we hope); so perhaps a spiral is a better metaphor for life.

Here, too, chemistry provides a parallel. I have started what is called an oscillating chemical reaction known as the Briggs-Rauscher Reaction. The reaction can be represented, inadequately, by the equation



Notice how it repeats and repeats. But it doesn't really repeat. It comes back to a point that is very much like the same point but is in fact further on. Ed McCullough or William Moore could show you the detailed mathematics for this, but it has an analogy in the spiral.

Is life a spiral? Sometimes it seems so. We begin an enterprise with enthusiasm; we move to what we believe is a fairly high point only to discover that we haven't really found the solution and we retreat to square 1. But it isn't really square 1, because we know something now that we didn't know before: we know that what we tried didn't work, so we are in position to try again.

So chemistry really can oscillate and life really can "spiral" at least for a time. But just as the reaction ultimately reaches equilibrium and the oscillation ceases, just so our experience as learners and experimenters teaches us that the spiral approach to learning is, at best, an inefficient one which seems to demand that we go through tremendous highs only to arrive at nearly the same point. And like the chemical reaction, the energy to drive us continuously in the direction of the spiral ultimately is exhausted. Though it may sustain us for a time, it is not likely a desirable allegory for life in the long run.

How about an S curve? A titration curve is something like that.

The pH of an acid solution increases as base is added until nearing equivalence, at which point it jumps dramatically, then the increase slows to a crawl again. Are life and learning S curves? In some ways they are, I think.

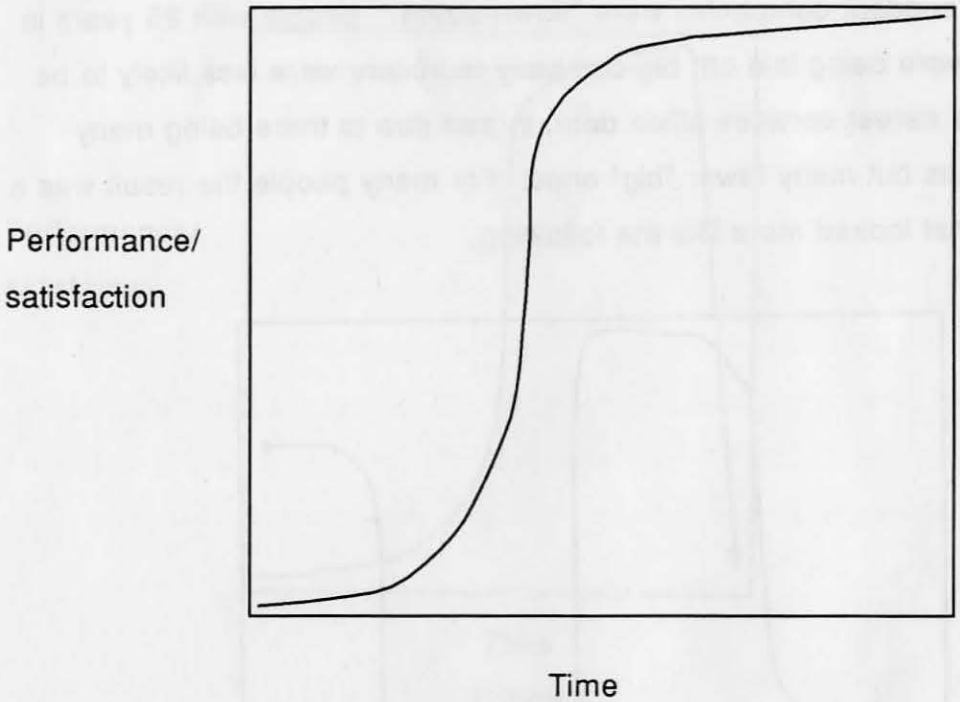


Figure 2

How often we begin a brand new task somewhat tentatively, gradually improving and learning until we gain sufficient confidence that we really know how to do the job. For a time our performance and productivity improve dramatically until we reach a point where we are doing the job with high proficiency. After that things are not so exciting. While we continue to perform the same general task at a high level of proficiency, the excitement of rapid improvement is gone and we settle into a period of high level, but slowly improving proficiency. I think that describes the work life of a great many people during the first two-thirds of the twentieth century.

During that period the model for an employee in industry was to complete some kind of preliminary training (often high school, perhaps college) enter the work force with a company, large or small, learn to perform a task very well, then settle in until retirement. The beginning of the end of the S-curve model came with the beginning of "the information age."

All of a sudden, companies were "down-sizing;" people with 25 years in the company were being laid off; big-company recruiters were less likely to be banging on the career services office door, in part due to there being many more enterprises but many fewer "big" ones. For many people the result was a career curve that looked more like the following.

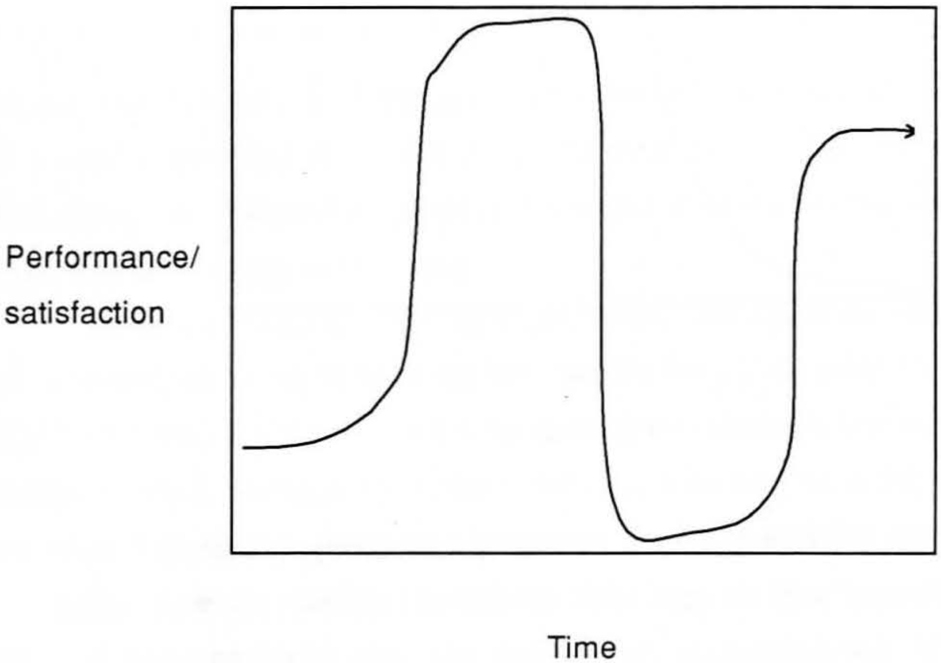


Figure 3

The big question now was what would happen in the next cycle. Unfortunately for many it has looked like Figure 4.

By then some of these people were in middle management; others were relatively senior (read expensive) employees in other venues, too often research and development, whose elimination, the company perceived, would help the bottom line. Where did they go? Rarely to a position with the earning power of the former job; too often to greatly reduced income levels and commensurate job satisfaction.

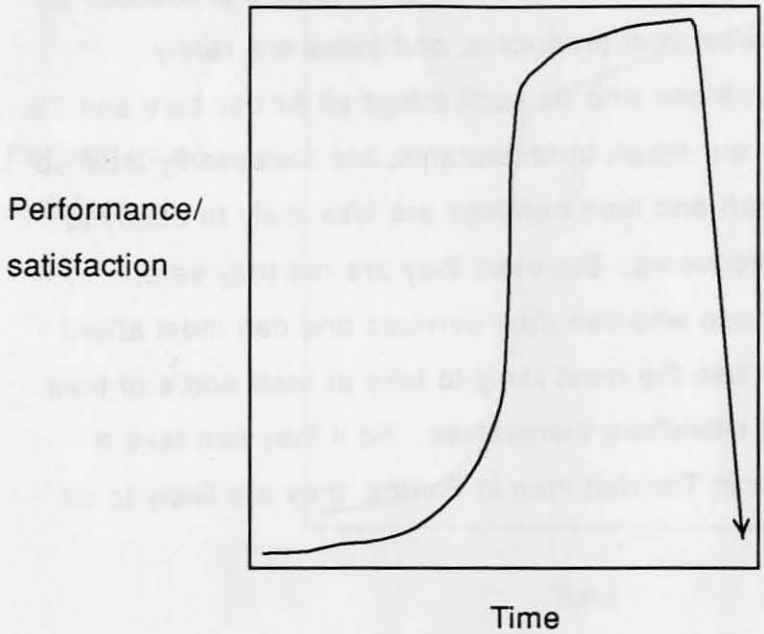


Figure 4

So now is the time for the students among you to prepare yourselves to avoid the sinking S curve. For those who believe it is too late to prepare anew, I wish you well.

How to prepare? That is the real challenge. Here is where Reich's book is suggestive, if not instructive. As some of you no doubt know, Reich views the economy of the future as one of increasingly web-like relationships among contributors from any number of nations. The strands of the web are readily interchangeable as different skills and knowledge and costs are required or available to the "strategic brokers" who put enterprises together. That picture is certainly one which is consistent with experience of the recent past. It becomes more and more difficult to purchase any manufactured item that is U.S. conceived, developed, produced, and marketed. The same is true of any of the other developed nations, and surely of the rest of the world.

Reich divides the present and future work force among "symbolic analysts," "in-person servers," and "routine producers." Routine production is increasingly moving to the lowest cost producers, and those are rarely American. In-person servers, those who do such things as fix our cars and TV sets, who prepare and serve our meals in restaurants, are necessarily local so those jobs are difficult to export and their earnings are less likely to decay to the same extent as routine producers. But even they are not truly safe, because, as Reich argues, those who use their services and can most afford the higher priced service are also the most likely to take at least some of their business elsewhere by going elsewhere themselves. So if they can take a high-service vacation cheaper in Trinidad than in Florida, they are likely to do so.

Symbolic analysts inherit the future. These are the idea people, the problem solvers, and the brokers who put the idea people and the problem solvers into productive contact with one another. What are the characteristics of a symbolic analyst and how can you prepare to be one? Perhaps more important, how can you prepare yourself to continue to add value and, therefore, follow a career curve that looks more like this (Figure 5)?

Reich makes some interesting arguments and takes some positions which are consistent with my own thinking and biases, so I like them. One assertion is that no nation educates its future symbolic analysts as well as does America. That is an interesting assertion because it flies in the face of much of public rhetoric and hand-wringing about the condition of American education. But, it is perhaps important to give the whole quote: "No nation educates its most fortunate and talented children [emphasis added]--its future symbolic analysts--as well as does America." (p 225) In fact, Reich goes on to argue that no more than 15-20 percent are being "perfectly prepared for a lifetime of symbolic analytic work." (p 227)

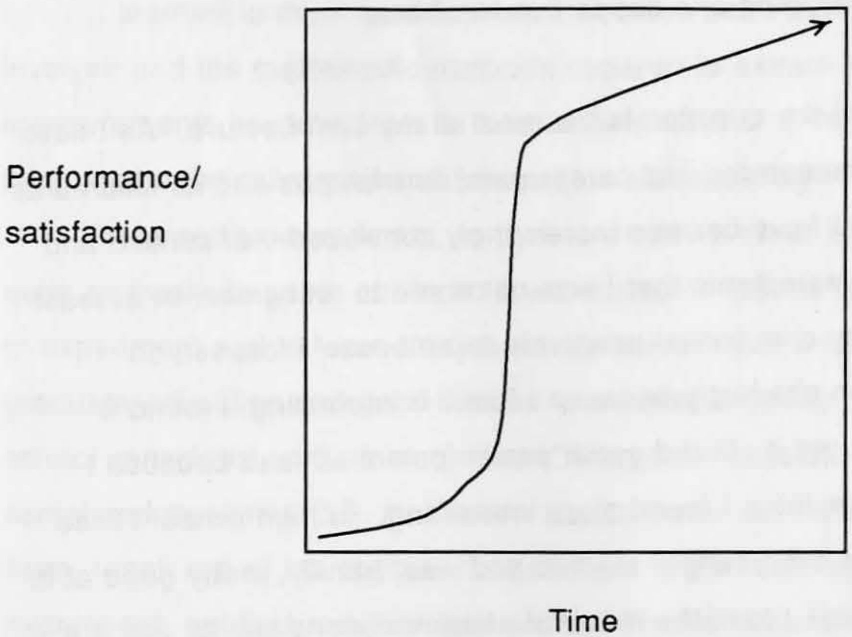


Figure 5

What constitutes that perfect preparation--and why do only 15-20% receive it? The latter is the easier to answer in brief, so I'll do that first: because only a small fraction have access to the private schools and/or the good public schools where they are tracked through advanced courses in the company of similarly fortunate peers. One can argue that virtually everyone in Utah has such access. And that is more likely here than in many places, but even in Utah only a small fraction takes full advantage of that access and follows it up by taking full advantage of the best college education available. Why not? I believe that it is very heavily a function of parental involvement and support, probably beginning at birth. These parents take their children to museums, concerts, plays, historic sites, and they talk about things of moment at the dinner table. The children who share in that kind of upbringing and the stimulation of intellectually active peers in school have a great leg up in the process. But I think most will agree that sometimes students gain this kind of preparation in spite of everything, often because of an inspiring and supportive teacher somewhere along the way. And I suspect others are sidetracked because of less than inspiring and supportive teachers.

The other part of the question is the meat of my Last Lecture. As I have ruminated over my own learning and career path, its triumphs and its failures as well as its frustrations, I have become increasingly convinced that context and connection are critical ingredients that I was not made to recognize--or at least did not recognize--in my own formal academic experience. I focused on chemistry. I focused on chemistry because I found it interesting, I found it challenging, I was assured it offered good "career potential," and because I didn't stumble across anything I found more interesting. In high school I liked everything--well, almost everything--I studied and was, frankly, pretty good at it. When I went off to college I took the required elective options just as you are required to do, and usually found them interesting, but I was a "chemistry major" so none of it but math and physics was seen to be very important to my goals.

Now, lest I give the wrong impression, there was a great deal of value in my chemistry major, especially because I did find it interesting. I learned things of broader value than I realized in the process. I learned to think abstractly. It is very difficult to really think about chemistry otherwise because it has only been in the past few years that anyone has been able to "take a picture" of an atom or a molecule in anything like the sense that we can take a picture of even a cell. Certainly not in the sense that we can see a hamburger patty (the preparation of which is a common alternative to symbolic analysis). Surely one can work at chemistry without abstraction in depth. We can learn to mix this with that, to extract something from the *misch*, to read the dials and indicators on a spectrometer, and to report what we find. But one can't really think about what is happening without getting into the abstract world of atoms and molecules and photons and energy.

I learned to think quantitatively. At some point the orders of magnitude involved and the mathematic methods required to extract meaning from measurements became more or less second nature. (I never really learned to think mathematically, mathematicians, just quantitatively.)

I learned to experiment, to try it and see. I never have learned to do that quite as freely as some nor to do it without some fear of failure, but I did learn to experiment and to learn from the experiments I perform. In this case I credit graduate education and good fortune more than anything my undergraduate school consciously did. It would have been quite possible for me to have completed my entire B.S. curriculum having never performed a real experiment. Sure, I took lots of lab courses, but all were of the "canned" variety. Do this experiment, get that result or lose points. That is necessary but not sufficient, I think. You have to learn to step off the edge into the unknown, but thoughtfully. I did get involved in some undergraduate research through which I began to understand that, but it was my graduate mentor, Bob Parry, who helped me to understand what a real experiment entailed and how to brainstorm my way along. In addition to the pragmatic, career-enhancing merit of learning to experiment and how to do so, I am convinced that regardless of the area of endeavor, if you never take a leap based on your best informed judgment you can never achieve real success in that endeavor. If you inherit Mom's company and if she and Dad set it up well, you may be able to run it a long time and may even make a lot of money doing so; but unless you have tried to make it better, it is still Mom's creation, not yours.

Somewhere along the line I learned to communicate reasonably effectively. This lecture demonstrates a lack of elegance in that communication, but I trust you will at least leave here knowing whether I had anything to say, not wondering what I said. I will gladly credit my writing and speech professors at South Dakota State with some of that. And I will credit the institution that demanded that I do it.

So an old-time chemistry major did help me to become a competent "symbolic analyst." But it also had some deficiencies. How much of that failing was mine alone and how much institutional can be argued, but deficiencies there were. And some of those deficiencies can be addressed by institutional initiative.

Robert Reich has summarized what those deficiencies might be in terms more elegant than mine. He says that the education of a symbolic analyst entails "refining four basic skills: abstraction, system thinking, experimentation, and collaboration." (p 229) I have asserted that I believe my basic college education was very helpful in developing my ability to think abstractly--the defining skill of the symbolic analyst, the mental manipulation of symbols. Ultimately my graduate education helped me to develop experimentation. And I distinctly remember my first conscious recognition of something approximating system thinking.

Prof. Parry had a rather sizable research group when I was a graduate student. Each of us had a project that we pursued enthusiastically. We had semi-regular group meetings during which our progress or lack thereof was discussed and suggestions were made by Prof. Parry and by each other. So I had a pretty good idea of what each of us was doing. But it wasn't until Bob gave a departmental colloquium about his research that I realized that all of us were addressing different parts of a chemical system. I recall turning to a neighbor in the seminar room, perhaps it was my wife, and saying "So that's what we're doing!" It was a pretty tightly constricted system, but a system, and I recognized the importance of seeing my own work in context.

You may also see the germ of collaboration born in the meetings of the research group. Years of working as a faculty member in a research university nearly drummed that habit out of me. Collaboration is the norm in some disciplines--biochemistry and high-energy physics are cases in point--with large groups of scientists working together on various aspects of a problem. But in others it can be positively deadly: How does one decide whether a person's work deserves tenure when all publications are co-authored with scientific peers? What is one person's contribution? The system often encourages the lone wolf.

Why weren't system thinking and collaboration explicitly incorporated into my undergraduate experience? As I have pondered this I have been forced to admit that they were incorporated in one aspect of my formal education--in ROTC of all places! Fortunately or not, ROTC is no longer a required course at most land-grant universities. Still, I will argue that there was virtually no reinforcement of those modes of thinking elsewhere in the curriculum. And I think the omission resulted from a systemic failing in much of American higher education, then and now, to think "systemically and collaboratively" itself. In part that reflects the economy of an earlier time when the rewards were great for the well prepared symbolic analyst, but the penalty for being less well prepared was not so great as we see it now. One could enter the big firm, grow and move within the firm. Now tenure in any given firm is much less likely to be long enough to allow the luxury of seeking and finding a niche and hanging in there, as was often the case in the past.

As I noted earlier, Reich asserts that the fortunate American students, that 15-20%, do get an education appropriate to the preparation of symbolic analysts. And now I would like simply to quote him somewhat extensively, because what he describes is, I think, a pretty fair description of the coupled objectives of the Honors and Liberal Arts and Sciences Programs at USU, to both of which I am very proud to have been a contributor.

> In America's best universities, the curriculum is fluid and interactive. Instead of emphasizing the transmission of information, the focus is on judgment and interpretation. The student is taught to get *behind* the data.... The student learns to examine reality from many angles, in different lights, and thus to visualize new possibilities and choices. The symbolic-analytic mind is trained to be skeptical, curious, and creative....

> To discover new opportunities ... one must be capable of seeing the whole, and of understanding the process by which parts of reality are linked together. In the real world, issues rarely emerge predefined and neatly separable. The symbolic analyst must constantly try to discern larger causes, consequences and relationships....By solving the basic problem, the symbolic analyst can add substantial value.
>
> The tour through history or geography or science typically has a fixed route, beginning at the start of the textbook and ending at its conclusion....And yet in the best classes of the nation's...universities, the emphasis is quite different....The focus is on experimental techniques: holding certain parts of reality constant while varying others in order to better understand causes and consequences;...making thoughtful guesses and intuitive leaps and then testing them against previous assumptions. Most important, students are taught to accept responsibility for their own continuing learning.
>
> Symbolic analysts typically work in teams, sharing problems and solutions...[and] spend much of their time communicating [emphases added] concepts--through oral presentations, reports, designs, memoranda, layouts, scripts, and projections--and then seeking a consensus to go forward with the plan.
>
> Learning to collaborate, communicate abstract concepts, and achieve a consensus are not usually emphasized within formal education, however....Yet in America's best classrooms... the emphasis has shifted. Instead of individual achievement and competition, the focus is on group learning....They learn how to seek and accept criticism from peers, solicit help, and give credit to others....This is an ideal preparation for lifetimes of symbolic-analytic teamwork. (p 230-233)

To truly accomplish this kind of learning requires, I think, study in depth and in breadth. You can't take a smattering of this and of that and really "get *behind* the data." That requires that you really dig into something. Chemistry is a great choice but certainly (probably?) not the only one. And you can't really "see the whole or develop an understanding of the process by which parts of reality are linked together" if you focus "like a laser beam" on one narrow discipline.

So you students at USU have the opportunity, at least, to work with a faculty that is wrestling with what its objectives ought to be and is really thinking about how best to accomplish its objectives, to engage in their pedagogical experiments as well as in their disciplinary research programs as real experimenters and to work within a program which is consciously designed to help you to see the big picture and the connections among disciplines and the problems they uniquely address.

Among the truly rewarding aspects of both programs for me was the opportunity to work with faculty who are constantly assessing their own methods and approaches to assisting in student learning, (some call that teaching), who are willing to take chances in the classroom as well as in their research, and who are willing to share what they find to work.

And on the other side are the students who volunteer to jump in with both feet and experiment and learn with us, who are after more than the minimum required to get that certifying diploma. Many came here already part of that 15-20%, Reich's fortunate American students. But some have joined them in spite of prior experience, and sometimes against the advice of those still engaging in what Reich calls "vestigial thinking."

And so I commend those of you who have opted to work within the university for a better university and for a better education. It would be wrong to say that none of these good things happen outside LASP and Honors, because many of you have made them happen in other ways. Many of you here tonight are captive to the Last Lecture because you want to receive just recognition for your creative, scholarly contributions to Scholars Day--your symbolic analyst practicum, and I know you are not all in LASP or in Honors. However it is done, I admonish all of you to try to assure, one way or another, that every graduate of Utah State University has been informed of the options available to them, of the benefits that accrue to them on taking full advantage of them, so that all were given a real shot at a lifetime curve that moves ever upward.

Finally, I want to illustrate one more chemical reaction process. Not because it bears especially on the economic or pragmatic merit of a strong liberal education but because it is fun. Surely there must be room for that in learning, in life, and in chemistry. Maybe, when all is said and done, that is still the best argument for a strong liberal education. The balloon is filled with a mixture of hydrogen and air. (End with a flash and a rain shower.)

Reich, Robert B., *The Work of Nations*, Vintage Books, New York, 1992