Address by Harry McLaughlin, Professor of Mathematical Sciences
2005 David M. Darrin '40 Counseling Award Winner
Delivered at the Spring 2006 Phalanx Honor Society Tapping Ceremony
March 5, 2006

As a boy growing up I was encouraged repeatedly to "ask why".

Why are there rainbows?

Why is there gravity?

Why do some people act in altruistic ways?

As the years went by I became increasingly uncomfortable with this advice, but remained unable to crystallize the concern.

Now, quite a few years later, I suspect that "asking why" may not be such a good idea.

More appropriate may be the questions:

Is there an atmospheric model within which rainbows are consistent?

Is there a physics model within which the notion of gravity is consistent?

Is there a sociological model within which altruism is consistent?

Perhaps this sounds like an academic restating simple questions so that they become unintelligible. Well maybe---but we can observe that a focus on models skirts the usually impossible issues of cause and effect.

In these remarks the notion of a model plays a central role.

This afternoon I am lucky to sit in the presence of talented scholars who will emerge as leaders of world societies and organizations.

What role can a mathematician play in a celebration of their leadership accomplishments and their already-anticipated societal leadership roles?

Maybe ask a relevant question? Ok, what about?

What is the role of complex systems models in decision making? And I italicize the word complex, for were there no complex systems, we would need no leaders, only managers and the police.

Believing that a leader's most far-reaching actions are, in the end, based on gut judgments, one has to believe that a model-based gut judgment (even if the model is flawed) is more appropriate than a whimsical judgment. Frequently, a leader has to listen to a cacophony of views, then retreat to a quiet place where an appropriate mental model emerges. From that derives action. In such instances it is easy to get "sucked into" the immediacy of the moment and miss the "big picture".

Here I am reminded of the two race horses, Sam and Joe, who, after some years, had been put to pasture. While grazing in the field one sunny morning Sam said: Joe we had a good life racing.

You're right, said Joe, but you know, every time we raced together, you won. Sam replied: Joe I don't think that's the case; you won some of the races in which I finished second or third.

Just then a dog walked up and overhearing part of the conversation said "Sam, Joe's right; every time the two of you raced together, you won." Sam hesitated a moment, looked at the dog, then at Joe, and said "Look Joe, a talking dog."

Back to models. Most of us have been brought up on predictive models, e.g.: the Leontieff input-output model, in economics; F=ma, in physics; statistical models, in queuing theory, etc. But one can imagine other models: complex systems models--models that are not predictive, but instead reveal a whole palate of possible phenomena (outcomes).

It strikes me that these are exactly the models (most) appropriate for leaders. So, more about them shortly.

As an instructor in mathematics I listen carefully to student reflections on course learning environments. Rensselaer students can be brutally honest; I guess their honesty keeps one humble. However, two years ago, I received a positive comment (a compliment I think). While leaving the classroom one of the participants commented, in passing, "This course makes my head hurt."

Complex systems are laden with "head hurts". Below we encounter a few in exposing the thesis that complex systems models are those most appropriate for leaders. (After this you can return to your roommates/apartment-mates and describe your afternoon experience, in part, as being a real headache.)

Here are some getting started "head hurts". (They use "why" and "how" in a colloquial sense. Think model.)

- Why do we as humans have two arms, two legs, two eyes, two ears, etc. and not three or one or five? What is the role of two?
- Given that all keys on a computer keyboard have finite string representations in terms of the two symbols, 0 and 1, one can conclude that all documents, ever written, and all computer programs, ever written, can be expressed in terms of one long finite string of the two symbols, 0 and 1. What is the role of two? The history of all of human thought can be recorded by the action of two agents: 0 and 1! That all communications can be encoded with two symbols, is a mind bending thought! Even more mind bending: since a finite string of 0's and 1's represents an integer in our number system, all documents and

computer programs, ever written, can be encoded as a single number! (Think of the assertion "I've got your number.) This a bit of a digression.

- Why does it take two humans, and not three, to produce an offspring? (Don't think about that too long, lest you get distracted and miss the rest of all of this.) What is the role of the number two?
- How can a food distribution system, with no central control, make it possible for us to routinely go to the grocery store without thinking about what foods may or may not be available?
- How does a seed know to grow into a flowering plant? Into a thinking individual? (All cells contain the same DNA structure. Evidently, gene expression depends upon the local environment and upon what the neighbor is doing.)
- Why do ant colonies comprised of ants whose lives are short relative to the age of the colony, develop such a refined organizational structure? (A male ant lives one day!)

What are complex systems, exactly?
No one knows for sure, but quite a few people write and speak about them. They have some characteristics that, most people would agree, are common.

- The number of component parts and their interactions transcend the processing capability of the human brain and current computers. Prediction of outcomes is not possible. (Think: the spread of disease; neuronal wiring in the human brain; the formation of the internet; etc.)
- They are multi-agent systems in which the actions of each agent are determined by the local environment--not a central control. From the agents acting autonomously there emerges an organized and sometimes elegantly constructed whole. (Think: ant colonies; neighborhoods in a big city; students in the university; formation of vendor stands on the bridge across the Charles River in Prague, etc.)
- They show a propensity to self–organize, usually to a critical state. (Think: the earth's plates and the occasion of earthquakes; prices in a stock market and the occasion of crashes; budgeting in a large organization and the borrowing necessitated by unexpected disruptions; prototypically, the sand pile.)
- Usually (unanticipated) behavior and design emerges over time. (Think: bee hives; traffic patterns on the autobahn; flocking of birds; human fads; etc)
- The notion of a steady state is not applicable. Evolution dominates. (Think: market preferences; organizational cultures; wars; etc.)

What is a model of a complex system?
This is a tough one. The jury is still out. The study of complex systems is in its infancy; most models are yet to be discovered and those that exist may later be viewed as primitive. However, there is enough known for the identification of a leadership paradigm.

What can we now take away from the state of the art?

- The core take-away is a mind-set. Some systems cannot be controlled. Sit back and

marvel at what emerges.
- However, it is sometimes possible to provide an environment for desirable, but unspecified, emergent phenomena. (It is nature's way!)
- There exists an array of cellular automata models for phenomena such as forest fires, spread of information and disease, evolution of ideas, traffic on the highway, the egress of people from a burning building, etc. These can be used for getting-started development of a complex systems mind-set.

Maybe you will permit a personal reflection here?
As I look back I can see that acquiring a complex systems mind-set has dramatically affected the way I design mathematics learning environments.

- It is not possible for me to control learning—I can provide an environment in which learning emerges.
- Students in a learning environment constitute a multi-agent system. Their approaches to learning are determined more by their "neighbor's" actions than by my well intentioned advice. (Parenthetically, this observation and realization supports the thesis that learning is, indeed, a social phenomenon.)
- I am able to marvel at what emerges!
- I don't yet have a complex systems model for engineering learning environments, but I am working on it. Until recently I believed that such was impossible, (an oxymoron) but now I think not.

At this point we are close to the end of these remarks. Some of my more closely held ideas about the challenges facing future leaders transcend what has been exposed here. They are colossal "head hurters" and await another Sunday afternoon.

Maybe this is an appropriate place to finish. I'm sure that you are aware of the danger in listening too carefully to a mathematician, that proper perspective can only be gained by listening to other view points and then developing your own model for the ideas at hand. To emphasize this advice I leave you with the following story.

Sitting at an outside table, at the coffee shop, sipping coffee, were a physicist, a biologist and a mathematician. They watched two people go into the house across the street. A bit later three people walked out.

"An error in measurement." said the physicist.

"They multiplied." countered the biologist.

The mathematician thought for a moment and then said "We need to wait until one more person goes in: then the house will be empty again."