UROP Spring Symposium

"The Future Is Not What It Used To Be"

The French poet, Paul Valery, once said, "The trouble with our times is that the future is not what it used to be." If my experience is any guide, your future will be a time of greater change and transformation than any experienced before in our nation's history. You are graduating at a truly extraordinary time. Think about it for a moment. You were born and educated in the 20th century. Indeed, most of you are children of the '60s generation--my generation and that's a frightening thought! Yet, you will be spending the majority of your life in the next century, in the 2lst century.

The Challenge of Change

We are living in the most remarkable of times. Who would have predicted a few years ago:

- the collapse of communism and the end of the Cold War
- the redefinition of the world economic order
- the direct manipulation of the human gene to cure disease
- the Internet phenomena, liking 25 million people worldwide
- digital convergence, in which communications and computer companies merge with the entertainment industry.

Yet all of these events have happened, and the pace of change continues to accelerate.

Indeed, many believe that we are going through a period of change in our civilization just as profound as that which occurred in earlier times such as the Renaissance and the Industrial Revolution--except that while these earlier transformations took centuries to occur, the transformations characterizing our times will occur in a decade or less!

I used to portray the 1990s as the countdown toward a new millennium, as we found ourselves swept toward a new century by these incredible forces of change. But the events of the past several years suggest that the twenty-first century is already upon us, a decade early. We live in a time of breathtaking change, at a pace that continues to accelerate even as I speak.

This last point is very important, for today we are seeing a dramatic shift in the fundamental structure, nature, and perspective of our society. We are evolving rapidly into a society in which the key strategic resource necessary for prosperity and social well-being has become knowledge itself. In this world knowledge will play the same role that in the past was played by natural resources or geographic location or labor pools. Put another way, while forces such as land, guns, and money drove the past, ideas will be the driving force of the twenty-first century.

The "age of knowledge" in which we now find ourselves is accompanied by a fundamental transformation that is reshaping every product, every service, and every job throughout our nation and the world.

Themes of Change

The America of the 20th century that I have known, was a nation characterized by a rather homogeneous, domestic, industrialized society. But that is an America of the past. You will inherit a far different nation, a highly pluralistic, knowledge-intensive, world-nation that will be America of the 2lst century.

These themes of your future--the changing nature of the American population, our increasing interdependence with other nations and other peoples, and the shift to a knowledge-intensive, post-industrial society--are actually not themes of the future, but rather themes of today. In a sense, I have simply been reading the handwriting on the wall.

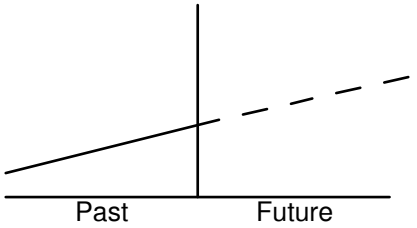
But whether these are themes of the present or the future, it is clear that they are also themes of change, themes that will both reflect and stimulate even more fundamental structural changes in the nature of our society and our civilization.

The Challenge of Change

Indeed, change itself might be regarded as the fourth theme in characterizing your future that I can predict with some certainty. It is clear that the future will never again be what it used to be!

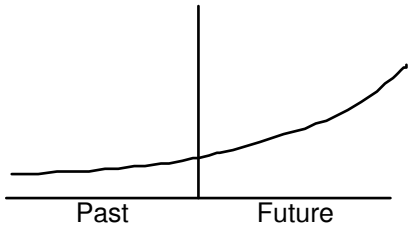
New ideas and concepts are exploding forth at ever-increasing rates. Indeed, in many fields the knowledge base is doubling every few years. The knowledge you have mastered as undergraduates is becoming obsolete even as you are graduating. As the pace of the creation of new knowledge accelerates, it seems clear that we are entering a period in which permanence and stability have become less valued than flexibility and creativity--a period in which the only certainty will be the presence of continual change; and the capacity to relish, stimulate, and manage change will be one of the most critical abilities of all.

Here we face a particular challenge, however, since most of us have been trained from an historical perspective to think in terms of change as a linear, causal, and rational process. We have been taught that by looking to the past, we can simply extrapolate linearly to predict the future.



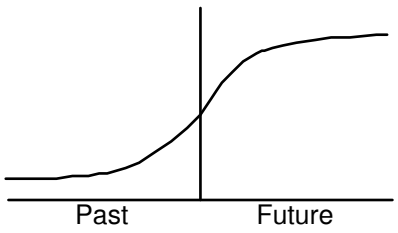
Of course, the scientist has a much different view of change, a view that is somewhat more disturbing. The scientist notes that most change in our natural

world does not occur linearly with time, but rather exponentially, at ever-increasing rates.



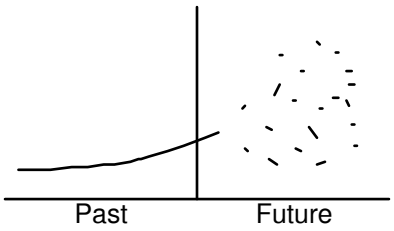
From this view the challenges that face us, challenges such as the growth of the world's population, or the consumption of our natural resources, or the pollution of our planet, are growing ever more serious at exponential rates.

Enter the economist who says, "Not to worry." Sooner or later every exponential phenomenon eventually reaches a limit, a saturation, as a law of diminishing returns sets in.



Sooner or later we run out of the necessary resources to sustain exponential growth, and the process of change slows to a halt. The bacterial colony on the petri dish runs out of nutrient. World population will run out of land surface--perhaps when, in the year 2500, there are forty trillion people on earth with only one square yard per person!

Ah, but we have learned in recent years that the world really doesn't work like this either! Indeed, we have learned that even the simplest systems in nature tend to behave in a far more complex and unpredictable fashion. They follow a change process known in today's popular lexicon as "chaos." While the early stages of change may be linear, exponential, or perhaps even saturating, at later stages change frequently occurs in a far more dramatic and unpredictable way.



In this view of the world, systems become unstable and undergo dramatic and often chaotic change to create new levels of order and complexity. For example, witness the complex evolution of the clouds in the sky, or the complexity of flowing water, or the extraordinary complexity and diversity of living creatures.

There are several particular features of this modern view of change that have major implications for the world in which we live:

l. First, from this modern view, change is not simple and gradual and linear. Rather, it is characterized by non-linearities that lead to complex behavior-- frequently to dramatic rather than gradual change--to revolution rather than evolution.

2. But that's not all. Change is also not predictable and deterministic but rather random and stochastic in nature. The real world works in sharp contrast to the deterministic views of classical science, or Newton or such modern determinists as Freud or Marx or Skinner. That's the bad news. Now for the good news!

3. Chaotic change depends far more sensitively on small disturbances than we had ever thought possible. To mathematicians, chaotic systems are termed "ill-posed." But the popular press has a more picturesque term known as the "butterfly effect." This term arises from the suggestion that even the disturbance in the air caused by a butterfly's wings could cause major changes in the weather half-way around the globe because of the chaotic nature of weather patterns. Translated into more human terms, dramatic change is frequently triggered by a few extraordinary people with extraordinary ideas, or by the young or newly initiated, people who haven't had the time yet to become trapped in the same ruts as the more experienced of us. More specifically, change is frequently triggered by people exactly like you here before me today!

To put it more bluntly, if this modern view of change is right, each of you will have a truly remarkable chance to change the world! But you will also be faced with some unusual challenges.

Implications for you as Graduates

If indeed your future will be one characterized by rapid, unpredictable, and dramatic change, then it becomes apparent that your capacity for continual renewal and personal development will become increasingly important. Has your education here at Caltech helped you to value, welcome, and control change?

I hope so. While most of you have probably looked at your college education as a preparation for a career--as scientists or engineers, as doctors, lawyers, or teachers, or even investment bankers, I suspect that was not the real purpose of your education at Caltech. The eminent philsopher Alfred North Whitehead, once stated that the purpose of a college education was "to learn the art of life." Well, in a very real sense, that is what you should have been learning at Caltech. You should have sought--and must continue to seek--a spirit of liberal learning, a spirit that will enrich your lives and through you, the lives of your families, friends, and colleagues.

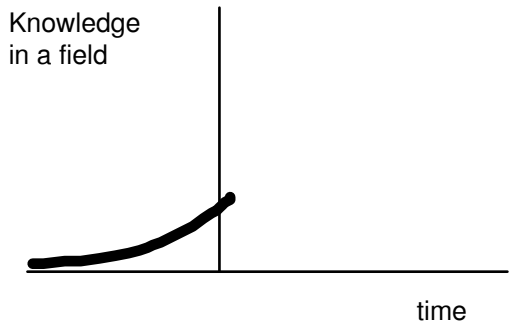
But I suspect that it may be dawning on many of you this afternoon that perhaps you are not learning as much about the "art of life" at Michigan as you might have wished. (I certainly didn't when I was an undergraduate.) But not to worry. Your college education was intended only as a stepping stone to a process of lifelong education. Indeed, most college graduates of your generation will find themselves changing careers several times during their lives. Hence, you will find yourselves continuing to learn--and re-learn--and re-learn yet again through self-study and a return to school on occasion as you adapt to a world of change.

Daring and Venturesomeness

There is yet one other theme that I want to suggest to you as Caltech graduates.

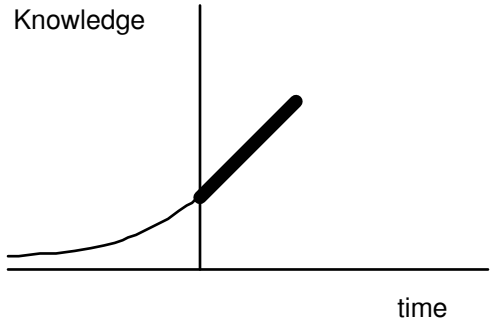
Michigan has achieved distinction because of its ability to attract a very special type of person to its faculty and to its student body, the type of person who prefers to operate on "the exponential part of the knowledge curve." Let me explain.

This term comes from a discussion I had a number of years ago with a scientific colleague at Caltech, Carver Mead, in which he characterized the growth of knowledge in a field over time as a familiar S-shaped curve. In the early stages the growth of knowledge is exponential with time, since the more your learn, the more rapidly the rate of knowledge increases.



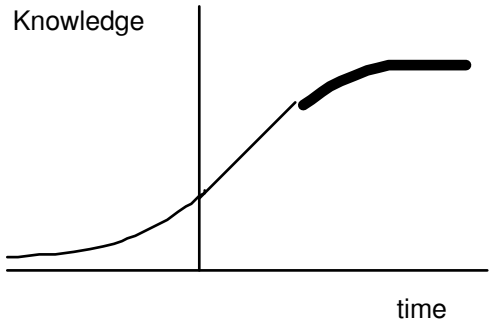
At this early stage, a few individuals of exceptional ability and great intellectual span can have truly extraordinary impact, essentially stimulating and defining entirely new fields of knowledge. This is the high-risk area, since it can frequently take years (in addition to great talent) to achieve something.

As the field matures, the growth in knowledge becomes linear with time. In this stage, the more resources you throw at an area, the more people or dollars, the more you learn.



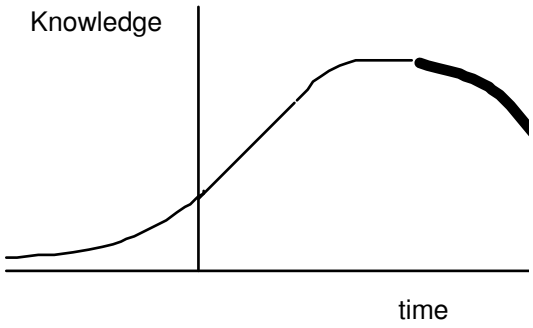
I usually refer to this as the Michigan region of the knowledge curve. You might prefer to call it the MIT region instead. This is where it is "safest" to work, easiest to get grants and to achieve tenure.

As the field matures still further, the growth in knowledge trails off--it saturates--a law of diminishing returns sets in as one mines most the new knowledge out of a field.



All too often, many of us get trapped in this regime, essentially trapped in a rut.

Some of my colleagues suggest there may be a fourth phase--they refer to it as senility--where continuing to work in a field actually is counterproductive and reduces its knowledge content.



(Actually, there have been times recently when I have begun to wonder if my old field, nuclear fusion, has entered this final phase of intellectual evolution as of late.)

All too often people--and institutions--tend to regard their roles more as keepers and transmitters of existing knowledge than as creators of new knowledge. They choose to work only on the safe problems. But you, as a Caltech graduate, have not only the talent, but also the education to work down in the high risk, exponential part of the knowledge curve.

A Future of Hope

The modern view of change suggests that the future is indeed not what it used to be--or at least as it has been traditionally portrayed, as a time of gradual, predictable change, rigidly moored to the past. Rather, my crystal ball suggests a future characterized by rapid, unpredictable, and frequently dramatic change in the nature of our people--in our bonds to other socieities--in what we do. It will be a future of great challenge and responsibility.

Indeed, as you stand today on the threshold of a new century, it seems clear that your generation will face problems and challenges of a magnitude that would have been incomprehensible in earlier times. Further, your years following graduation will be a time of less security, less stability, and more unpredictability than mine. But you will also face a future of extraordinary opportunity and excitement. For, as the philosopher Whitehead has noted, "The great ages have been unstable ages!"

Emerson once noted that the wisest counsel of all to the young was to "always do what you are afraid to do." The truth is that adapting to change and challenge is what keeps our species evolving. We should relish change, welcome it, seek it out--not for its own sake, but for the challenge it brings and the possibility for progress. We should approach life as a true adventure of opportunity and risk. We are made for risk. We thrive on it.

I guess I tend to be an incurable optimist. I believe that we can be masters of our fate, that we can seize control of the forces around us--most of all ourselves--and bring progress to the world. In fact, I even think that each individual has the possibility to change the world. Just remember the "butterfly effect." You can

change the world with the beat of your own wings. As Caltech graduates, you are uniquely qualified to work in the exponential region of the knowledge curve!

There is an old saying that "the best way to predict the future is to invent it!" That is the real challenge before you: to go out into that exciting world full of challenge and opportunity and to invent the future! Indeed, it is your challenge to make certain that the future will not be what it used to be!