

Caltech Commencement -- Spring, 1989

Opening Remarks

It's great to be back at Caltech!!!

It really feels like old times...

...the warm sunshine...

...the quivering of the earth...

Two decades ago when I sat where you are today,

I always suspected that I would return frequently
to Pasadena.

But I never would have dreamed that my trips west would not be
to visit the Caltech campus...

but rather to lead troops into battle over in
the Arroyo Seco on New Year's Day.

In fact, in all my years as a student at Caltech, the closest

I ever got to the Rose Bowl was peering over the crowd
along Colorado Boulevard at the Rose Parade.

You know, the Rose Bowl has a great many traditions, but of course
the most famous is the annual Caltech prank!!!

Each year, you Caltech students try to outdo yourselves...

...Rearranging the UCLA card section so that
it flashes a giant Beaver

...Or taking over control of the scoreboard with a
microprocessor and remote transmitter...

designed to give the score of the MIT-Caltech game!

...When we were out two years ago, your prank was
prematurely foiled when a maintenance worker's
walkie-talkie triggered a receiver hidden in the
goal posts that released rocket streamers and flags...

On this past New Year's trip, the rumor mill had it that Caltech had outdone themselves by actually managing to replace the president of one of the competing institutions with one of their own... a Caltecher...a "mole" planted many years ago in a leading Big Ten university, programmed to surface on New Year's Day and thrash USC!!!

How to Give a Commencement Address

Well, whether Caltech actually managed to engineer this feat or not... it is indeed both an honor and a pleasure to be able to return to Pasadena for some reason other than beating a Pac Ten team!

Except, now, rather than preparing a bunch of speeches for pep rallies and sports reporters and alumni, I have been faced with the intellectual challenge of preparing a commencement address for perhaps the smartest graduating class in the nation!!!

But not to worry. Because I have learned that it is far easier to prepare a commencement speech than it is to listen to one!

Because you see, there is really only one commencement address...

And although it has been given thousands of times...
in thousands of different ways...

The basic message is still the same...

First you tell the graduates that their education has prepared them to go forth into a world in which they, and they alone,

will have the power to control their
own destiny.

Then you throw in some advice on how to
go about doing this...

although, of course, it is traditional for graduates to
totally ignore this advice...

The only real challenge is to figure out how to
say this once again...in yet another way...
and to keep it all under 15 minutes!!!

So here goes (*glancing at my watch*)

Some Personal Memories

I should note that this task generates a certain nostalgia
since it was exactly a quarter-century ago that I
graduated.

In fact, last week I experienced the trauma of my
25th Year College Reunion back at Yale...

When I think back to that time, I remember a
time of great optimism in America...
the glow of Camelot of the Kennedy administration...
still lingered with us.

There were great causes to take up such as
...world peace...
...the conquest of space
...the Civil Rights movement

My Class of '64 graduated with feeling of boundless confidence in
ourselves and our country.

But there were already clouds gathering on the horizon even during my
senior

year that suggested that things would be not quite so simple,
that dramatic changes were coming...

John F. Kennedy was assassinated during the fall of my senior year...

The Cold War had begun to heat up with the Cuban Missile Crisis

A few people were talking about a distant war in a place called Viet
Nam

The Free Speech Movement at Berkeley was revealing a new
spirit of student anger and activism on the campuses.

But even with these warning signs, we were not prepared for
the dramatic crises and confrontations, the great changes
that Americans and their institutions would face in the years
immediately following our graduation...

- the war in Vietnam that so profoundly affected all of our lives...
...both those who served and those who protested...
- the eruption of assassination and terrorism which robbed
us of our heroes
- the racial turmoil that tore apart our cities
- the emergence of the drug culture...
as more people turned on and tuned out...
- Watergate, and the crisis in confidence in our leaders

In a sense, during the decade following my graduation

America lost its innocence...

In many ways, my class may have represented the last generation of

Americans to be truly optimistic about the future...

to welcome its challenges and to feel equal to them.

I can't say whether my own choice of a career would have

been different if I could have foreseen the future...

but it seems appropriate this morning to engage in

some futuring...to speculate a bit about the
world you will be entering...

Possible Futures

The French poet Paul Valery once said that

"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...

Yet you will be spending the majority of your life in the
next century...in the 21st Century.

And while it is always risky to speculate about the future,
three themes of the next century seem clear...

1. Demographic Change: The New Majority

America is changing rapidly...

When we hear references to the demographic changes
occurring in our nation, our first thought probably
focuses on the aging of our population.

It is indeed true that the baby boomers are now entering middle
age,

and their generation has been followed by a baby bust...

in which the number of young adults will be declining over the

remainder of this century by roughly 20%.

Indeed, today there are more people over 65

than teenagers in this country, and this situation will

continue for the remainder of your lives.

Further, the growth rate in both our population and workforce is declining to the lowest level in our nation's history.

America will simply not be a nation of youth again in your lifetimes.

Yet, there is a far more profound change occurring in the population of our nation.

America is rapidly becoming the most pluralistic, multicultural nation on earth.

Women, minorities, and immigrants now account for about 90% of the growth in the labor force.

By the year 2000, they'll represent 60% of all of our nation's workers!!!

Those groups we refer to today as minorities will become the majority population of our nation in the century ahead...just as they are today throughout the world.

And women have already become not only the predominant gender in our nation and our institutions, but they are rapidly assuming their rightful role as leaders of our society.

In this future, the full participation of currently underrepresented minorities and women will be of increasing concern as we strive to

realize our commitment to equity and social justice.

But, in addition, this objective will be the key to the future strength and prosperity of America, since our nation cannot afford to waste the human talent represented

by those currently underrepresented in our society,
this human potential, cultural richness, and social leadership.

If we do not create a nation that mobilizes the talents
of all our citizens, we are destined for a diminished
role in the global community, increased social turbulence, and
most tragically, we will have failed to fulfill the promise of
democracy upon which this nation was founded.

But there are other important challenges associated with
such demographic change.

In particular, it is important to realize here that 21st Century
America will NOT be a melting pot in which all
cultures are homogenized into a uniform blend --
at least not during our lifetimes.

Rather, it will be pluralistic...composed of peoples
of vastly different backgrounds, cultures, and
beliefs...peoples seeking to retain their cultural
roots...to maintain their differences.

Our challenge will be to find the common bonds and
values that unit us, even as we learn to respect and
value our differences.

The growing pluralism of our society is perhaps our greatest
challenge as a nation...yet it is also among our most important
opportunities, since it gives us an extraordinary vitality
and energy as a people.

2. The Internationalization of America

The second theme is triggered by an image that comes
from almost exactly two decades ago...when
Apollo 11 set down on the Sea of Tranquility to

put man on the moon.

The image is that extraordinary photo of the earth taken by Lunar Orbiter as it circled the moon...
...an image that dramatically revealed how nations and peoples are passengers together on spaceship Earth.

It was a portent of today, a time in which all aspects of American life are becoming increasingly "internationalized", in which our nation has become a member of a truly global community.

Whether through travel and communication, the arts and culture, the internationalization of commerce, capital, and labor, we are becoming increasingly dependent on other nations and other peoples.

The world and our place in it have changed.

The fact is that a truly domestic US economy has ceased to exist.

...It is no longer relevant to speak of the California economy or the American economy...or the competitiveness of California industry or American industry.

Our economy...our companies...are truly international, spanning the globe...and intensely interdependent on other nations and other peoples.

In slightly more than 5 years, US trade deficit has taken us from the world's largest creditor to its largest debtor nation.

We are no longer self-sufficient or self-sustaining. We are not immune to the shocks of the world society.

As the recent events in China and the Soviet Union

make all too clear.

But beyond commerce and national security, there is an even more important reason to pay attention to the trends of internationalization...

The US has become the destination of about half the world's immigrants

Probably 10 million this decade alone...

With falling fertility rates, immigration will soon become the main determinant of the variability in our population.

Our nation continues to be nourished and revitalized by the extraordinary diversity of our immigrant population-- as it has been throughout our history.

Yet today, in a very real sense,

America is evolving into the first true "world nation", with not simply economic and political but also ethnic ties to all parts of the globe...

From this perspective, it becomes clear that understanding cultures other than our own has become necessary not only for personal enrichment and good citizenship, but indeed, necessary for our very survival as a nation.

3. The Age of Knowledge

Looking back over history, one can identify certain abrupt changes, discontinuities, in the nature, the very fabric of our civilization...

The Renaissance, the Age of Discovery, the Industrial Revolution

There are many who contend that our society is

once again undergoing such a dramatic shift in
fundamental perspective and structure.

Today we are evolving rapidly to a new post-industrial,
knowledge-based society, just as a century ago our
agrarian society evolved through the Industrial Revolution.

In a sense, we are entering a new age, an age of knowledge,
in which the key strategic resource necessary for our
prosperity, security, and social well-being has become
knowledge--educated people and their ideas.

Industrial production is steadily switching away from
material and labor intensive products and processes
to knowledge intensive processes:

A fundamental transformation is underway in our economy that
is reshaping virtually every product, every service, and every
job in the United States.

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 the America of the 21th 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

actually the

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...

(In fact, the brave new world I have been describing as

America of the 21st Century is California of today!!!)

But these themes of the future 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 is the fourth theme 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,

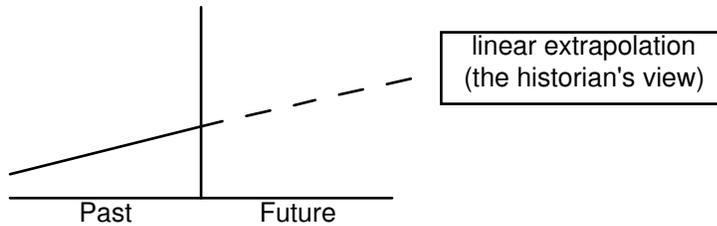
it seems apparent that we are entering a period in
which permanence and stability become less
valued than flexibility and creativity...

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.

Models of Change

Linear growth

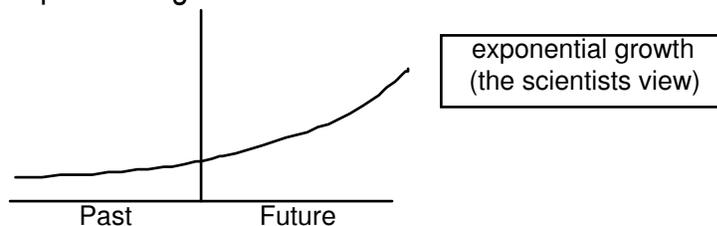


Here we face a particular challenge, since most of us have been trained to think in terms of change from a historical perspective...

...as a linear, causal, and rational process.

We have been taught that by looking back to the past, we can simply linearly extrapolate to predict the future.

Exponential growth



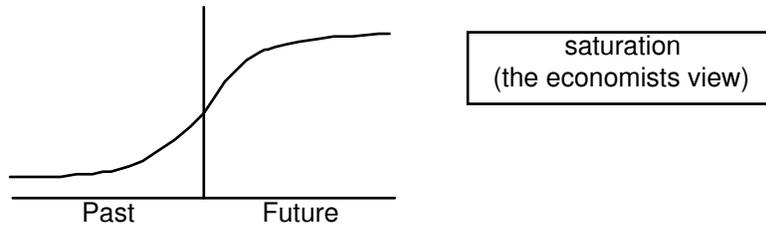
Of course, the scientist has a much different view of change...

...a view that is much more disturbing.

The scientist notes that most change in our natural world does not occur linearly with time, but rather exponentially, at every increasing rates.

From this view, the challenges that face us, challenges such as the growth in 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.

Saturation



Enter the economist, who says "not to worry"...

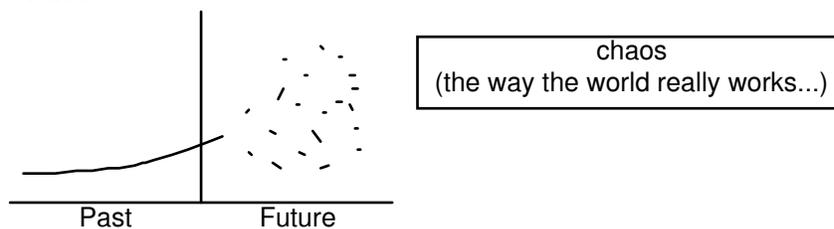
Sooner or later every exponential phenomenon eventually reaches a limit, a saturation, as a Parkinson's law of diminishing returns sets in.

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 40 trillion people on Earth with only one square yard per person!

Chaos



Ah, but we have learned in recent years that the world really doesn't work like this either!

Instead, 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 are linear, exponential, and perhaps even saturating, at later stages, change frequently occurs in far more dramatic and unpredictable ways.

In this view of the world, systems become unstable and undergo dramatic and often chaotic change to create new levels of order and complexity.

Ex: Witness the complex evolution of 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:

- i) First, from this modern view, change is not simple and gradual and linear. Rather it is characterized by nonlinearities that lead to complex behavior frequently to dramatic rather than gradual change... to revolution rather than evolution.
- ii) 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 of Newton or such modern determinists as Freud or Marx or Skinner.

That's the bad news. Now for the good news!

- iii) Chaotic change depends far more sensitively on small disturbances than we had ever thought possible.

To mathematicians, chaotic systems are "ill-posed"...

But the popular press has a more picturesque term...

known as the "butterfly effect"...which arises from the suggestion that the even the disturbance in the air caused by a butterfly's wings could cause major changes in weather halfway 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 preparation for a career...
as scientists or engineers...

or doctors, lawyers, or teachers...

or even investment bankers...

I suspect that was not the real purpose of your education at Caltech.

The eminent philosopher 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 morning that perhaps you did not learn as much of "the art of life" as Caltech as you might have wished... (I certainly didn't when I was an undergraduate!!!)

Not to worry...

Your college education was intended only as a the 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 relearn-- and relearn yet again through self study and returning to school on occasion, as you attempt to adapt to a world of change.

Just look at my example! Who could have predicted that a Caltech graduate would end up a president of a

university that won both the Rose Bowl and the NCAA national basketball championship in the same year!!!

Daring and Venturesomeness

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

Caltech is really a very, very special place.

A few weeks ago I had the privilege of being present when one of your most distinguished former faculty members, Linus Pauling, received the Vannevar Bush Award for outstanding achievements as a scientist-statesman.

In his acceptance remarks, Dr. Pauling first paid tribute to Caltech, which he characterized as the most outstanding institution in the world for scientific research and education. But, even beyond that accolade--which I agree with, incidently-- Caltech has achieved distinction because of its ability to attract a very special type of person to its faculty and its student body...

The type of person, who prefers to operate on the "exponential part of the knowledge curve"...

Let me explain...

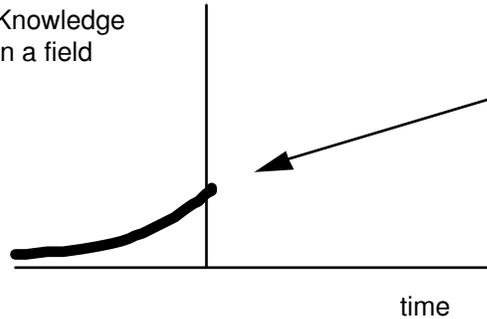
This term comes from a discussion I had with one of your faculty members, Carver Mead, a number of years ago in which he characterized the growth of knowledge in a field over time as a familiar S-shaped curve.

In the early stages, the growth of knowledge is exponential with time, since the more you learn,

the more rapidly the rate of knowledge

increases...

Knowledge
in a field



Exponential growth
of knowledge...
a few people with
extraordinary intellectual
span...

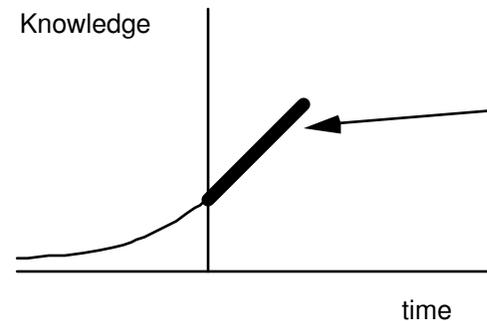
At this early stage, a few individuals of exceptional ability and great intellectual span can have truly extraordinary impact, essentially stimulating and defining entirely new fields of knowledge...

This is the "high risk" area...since it can frequently take years (in addition to great talent) to achieve something...

As a field matures, the growth in knowledge

becomes linear with time....

Knowledge



Linear growth...
Safe scholarship...
Lots of people and
lots of dollars...

In this stage, the more resources you throw at an area...the more people or dollars...the more you learn...

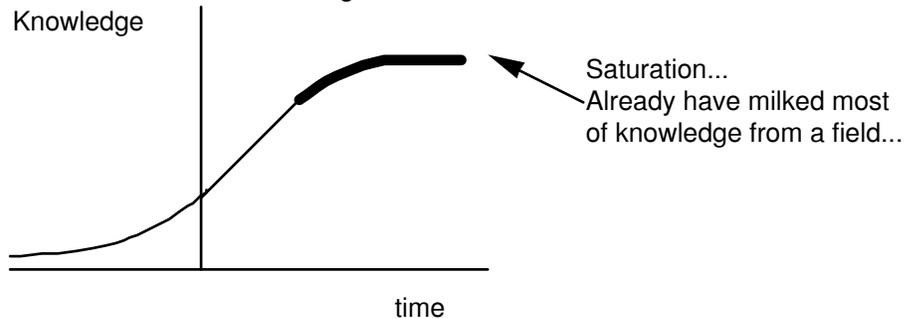
(I usually refer to this as the Michigan region of the knowledge curve...you might prefer to

call it the MIT region instead...)

This is where it is "safest" to work...

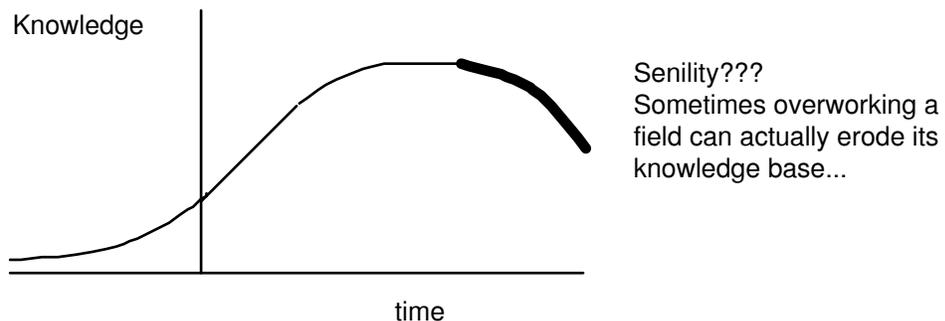
easiest to get grants and to achieve tenure...

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



All too often people...and institutions... tend to regard their role more as the keepers and transmitters of existing knowledge than as the

creators of new knowledge...and chose to work
only on the safe problems.

But you, as a Caltech graduate, not only have the talent...
but also presumably 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 traditionally been 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 societies...
...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
to mind...

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!"

Concluding Remarks

Emerson once noted that the wisest council 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 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...

But whether you accept my optimistic perspective or not, one thing is clear to me.

Whether we like it or not, change, massive transformations,
in our society,
in our culture,
in our way of life,
is what you can expect.

The fear or denial of change isn't going to keep it from happening.

It just will keep you from influencing the direction it will take.

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!

Congratulations...

...God-speed...

...and go get 'em!...