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THE ARROW OF TIME--BEGINNING AND END

Commencement Address

California Institute of Technology

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M. Delbrück

to ask questions, the heart  
of teaching.

Ladies and Gentlemen:

So, here I have the privilege of addressing this convocation of graduates and their families, of colleagues and friends of the Caltech community. A lively and festive occasion, cameras ready to record this punctuation mark in the lives of you, the graduates, <sup>for me,</sup> and, <sup>or, perhaps, the final question mark?</sup> the final period mark, ~~for me,~~ And I am supposed to make a speech, say something; something appropriate, not necessarily memorable--who remembers a commencement address?--but something to heighten the mood. I feel divided between impulses to talk to the few of you graduates I have known and befriended during your sheltered sojourn at C.I.T. and impulses to give them a broader scope, relating more to my relation to Caltech, four decades of it, to my general sense of what Caltech amounts to or ought to amount to within the framework of our general culture. This is a subject on which I never had occasion to express myself in public so the temptation is great to take advantage of the fact that somebody made the mistake to invite me to give this address.

I understand that this graduating class has a certain feeling of uniqueness above other graduating classes of Caltech in having come here four years ago when the relative calm of our social

and political life got into some momentary jitters--jitters provoked by the oil crisis, jitters that disrupted normal life to the shocking extent that the candidates for freshman admission were not interviewed personally!! I imagine this commotion might have given to some of you a faint inkling that our society is not quite as stable and totally sheltered as it could appear otherwise, from the inside of a student house where you can live embedded in a world of courses and exams where major decisions revolve around whether or not to cut the morning class, whether to protest the abominable food, or what fun activities to organize or participate in. With its excellent offerings in HSS Caltech does try to teach you that, besides the physical universe, there is a human world outside, three-fourths of which is starving; that there is an arms race which may bring the world to ashes; that there is a history of civilization ranging over thousands of years; that our institutions indeed have grown out of this history; that science, too, is not merely a matter of the latest results discussed in Science, Nature, and Physical Review Letters, but that it is an immensely greater effort, a cultural effort ranging through the centuries and millenia. About all this greater human world Caltech's HSS gives you offerings that more often than ~~that~~ not must seem tantalizing for lack of time to avail yourself, constraining you to be content with a glimmering. Perhaps, for some of you the concern with man's history and man's destiny, with the powers that shaped man's consciousness of himself, amounted to not more than an amusing diversion, feebly

competing for your attention with science fiction and fairy tales. Nothing wrong with that! Thank God the true ivory tower man can still slip by at Caltech. The true egg-head is well-rounded, creative, too.

As far as I am concerned probably ~~as few of~~ you know <sup>as little</sup> of me as I know of you, and for good reason. We all divide time three ways: real time, the time we have lived through; hear-say time, before we were born; and future time, a matter of fear and hope. I was born and had my childhood in a different country in a different language and at a vastly different historical time, before the First World War, worlds removed from your world. Thus, from your point of view, a specimen like me belongs to hear-say time. I might as well be a relic from the time of the Crusades. Perhaps, though, I can make myself more concrete to you if I mention that Max Planck lived down the street, and that my brother and I <sup>picked</sup> ~~harvested~~ and ate the cherries from his garden. Concrete or not, the distance is vast. Indeed, it could be argued that we now live too long, compounding too many layers of cultural change. Perhaps modern medicine did the wrong thing, prolonging our lives. Perhaps it should aim to shorten our lives, so as to keep the living better tuned to the fast-changing times. But the compounding has its merits, too, and it is on these merits that I would like to capitalize in reflecting on Caltech.

At this point it may be appropriate to insert an aside on my identity. When President Christy, some months ago, approached me as to whether I would do this job, I asked him,

"Why me! Who suggested it?" "Well," he says, "your name was suggested by a committee and I liked the suggestion. The committee added that the students had again suggested Woody Allen." "Well," I said, "<sup>he would give a much better speech than any of us,</sup> that is a splendid idea, why don't you try him first." So he said, "Who is Woody Allen?" "Oh," I said, "he is a marvelous comedian, he just got a prize for a movie, which he wrote, directed, and played in, about his unsuccessful marriage." "Well," he says, "I am successfully married, so that's why nobody told me to go, but if you say he is so good I'll let the students have a try at him, if you don't mind." "By all means," I said.

So, what happened? Well, it's up to you to decide. Is it Max Delbrück as advertised, talking to you, or is it Woody Allen, impersonating a Senior Academic Citizen, <sup>ls</sup> scurrilous (named Max Delbrück, or is it Max Delbrück, scurrilously pretending to be Woody Allen impersonating Max Delbrück?

Having been trained in critical thinking for so long at Caltech I am sure you will enjoy pondering these alternatives while I, whoever I may be, go on with my talk.

The motto on the seal of Caltech says, "The truth shall set you free." Like any motto, it lends itself to jokes, crude ones and subtle ones, biting ones and gentle ones. My joke will be to take it straight. The motto and the emblem were chosen <sup>our founding father</sup> by Millikan in 1925, <sup>half a century ago</sup> and in the charge to the artist who designed the seal Millikan put down that the seal should show an older man passing the torch to a younger one, both of them in the clouds. Millikan wanted to symbolize the handing down of truth

from one generation to the next. He wanted to symbolize scientific truth and the progress towards enlightenment, towards liberation from superstition, towards a better, more rational society.

Many intellectuals of Millikan's generation believed that science would outpace and largely displace all other intellectual and spiritual endeavors, as indeed it has done. No question about that. They also believed that science would lead to a better world and most of them believed that it would displace religion by the end of the century. We now know that our age is not a golden age and, indeed, that it is a most unstable age. We also know for a fact that the scientific culture has in no way eliminated the strength and intensity of the religious needs, the religious fervor, the power and appeal of the churches.

Indeed, we can take it for granted that science is intrinsically incapable of coping with the recurrent questions of death, love, moral decision, greed, anger, aggression. These are the <sup>questions</sup> ~~questions~~ that determine man's values. <sup>They</sup> ~~and~~ constitute the greatest forces

<sup>can</sup> that shape man's destiny. You symbolize all these forces in <sup>and that may help you in solving up by other decision making institutions</sup> nice mathematical systems, <sup>that</sup> but it is a <sup>limited</sup> hollow victory. It <sup>constitutes medium</sup> ~~simulates~~ hard science but its <sup>probes neither the biological nor the cultural origins of these values.</sup> ~~predictive value is zero.~~

When I first saw the motto "The truth shall set you free" it thrilled me. It made a strong impact on me. Why the emotional response? Perhaps because in science the name of the whole game is truthfulness. If you cheat in science you are simply missing the point. You defeat yourself. So, whatever sense of exhilaration and liberation the scientist does derive from the exercise of

his profession, it is deeply connected to his ~~commitment~~<sup>commitment</sup> not to cheat. This ~~connotation~~ seems to be more of a religious than of a rational nature. I wondered where the motto came from. Had Millikan coined it? Far from it. A nephew of mine, a student of theology, put me right. It comes from the Fourth Gospel, the Gospel according to St. John, Chapter 8, Verse 31. It occurs as a punch line in one of a series of heated discussions between Jesus and the Pharisees. These discussions, together with the description of the miracles performed by Jesus, form the body of this Gospel, the strangest and the strongest of the four Gospels. The writer of this Gospel, an impassioned, speculative thinker, a highly poetic symbolizer, uses these heated arguments as a deliberate literary device. The parties (Jesus and the Pharisees) grossly misunderstand each other all of the time. He uses these misunderstandings in order, step by step, to unfold and clarify his theological doctrine. The passage containing our motto is one in which the parties display an extreme degree of frustration; they throw intemperate insults at each other. At one point Jesus, turning aside to his followers, says, "If you continue in my word, then are ye my disciples indeed and ye shall know the truth and the truth shall set you free." The Pharisees promptly misunderstand "free" as "politically free". They think that Jesus wants to propose himself as a political liberator, the Messiah, so they say, "How so? We be Abraham's seed and were never in bondage." And Jesus elaborates that he does not mean political freedom but freedom from sin. Earlier

he has made it apparent that by "truth" he means faith in him, Jesus, as the Son of God. He does not mean<sup>a</sup> "scientific truth" or "rational truth" in the Greek sense of the word. Not that at all. Comparing this meaning with that of Millikan's interpretation of the motto you will note that an extraordinary perversion of the original meaning has taken place. Yet as it stands on the seal the reader is free to interpret the motto as he pleases. Each of us can be his own Supreme Court, responding according to his predisposition. I would not be surprised if the evocation produced in Millikan himself was more of the religious kind than of the rational progress kind. Millikan was artful in choosing this highly ambiguous motto, satisfying both his scientific clients, the faculty, and his other clients, the friends of Caltech, often of a religious bent.

If science, as I said ~~above~~ <sup>before</sup>, is so limited an enterprise, so one-handed a tool to hold the world together, where does that leave Caltech as a whole, and where does Caltech stand in relation to the needs of our times? In which direction might it have to move? Or should it stand pat, on the platform of 50 years ago?

In the late Middle Ages when universities first came into being, they were loosely attached to cathedral schools. They then had the lower curriculum, the trivium (grammar, rhetoric, and logic) and the upper curriculum, the quadrivium (arithmetic, geometry, astronomy, and music). The trivium dealt with the arts of the word, the liberal arts. It uses language in its widest ranges of possibilities, in poetry, myth, divine revelation

down to the crudest <sup>brain</sup> ~~basin~~ washing to which the media subject us. The quadrivium dealt with measurement and calculation, the sciences.

The sciences severely limit the use of language, attempt to eliminate ambiguities, right down to the bizarre excesses of the mathematical logician. <sup>the schools of</sup> In our Western World the quadrivium has taken ascendance over the trivium and you might say that Caltech represents the ultimate faith in the quadrivium. At Caltech we know how to do science, and those who do science here by and large have no qualms whatever about its intrinsic value and are willing to bat for it.

This attitude has turned out to be a viable and indeed immensely successful one over the last five decades. How valid will it be in the future? Will its continuation make Caltech and its cohort of similar schools empty shells, a sounding brass, a tinkling cymbal? Will people of later times look back at Big Science as we look at Stonehenge or the Pyramids, grandiose creations, but what was the point of it?

When Science was discovered and came into bloom he was a beautiful youth, like Tithonus of the Homeric myth. The goddess, Aurora, the morning dawn, fell in love with Tithonus and requested of Zeus that he be granted immortality. The request was granted by the great Zeus but an unfortunate situation arose when it was realized that Aurora had failed to include in her request for eternal life of her beloved lover also a request for eternal youth. Tithonus aged and shriveled and talked incessantly. Since <sup>his im-</sup> ~~mortality~~ <sup>inded</sup> cannot be restored (time's arrow does not fly backward), a compromise solution emerged according to which

Tithonus <sup>was</sup> ~~has been~~ transformed into a cricket, and put away in a box.

Science does chatter <sup>and chirp</sup> away incessantly. Its chirping, on black holes, on the big bang, on neutrinos, on recombinant DNA's, is sweet <sup>music</sup> to those few who are tuned in to it, but does it satisfy <sup>Aurora's</sup> the yearnings <sup>Aurora</sup> of the morning dawn?

The question is not what science can do for us, it can do a lot, ~~but~~ the much more important question is: what can science not do for us. Science orders our external world. It does so in a marvelously coherent way, or almost coherent way. It develops a universe of discourse or, let us say, a few universes of discourse with very large overlaps between them, enough to move back and forth from one to the other without too much jarring. While primitive man developed theories about the universe which he formulated in terms of myth, science rejects myth. The myth may have talked about the creation of the universe <sup>about</sup> or the end of the world, <sup>indeed about</sup> a divine intervention, at every thunderclap.

<sup>In contrast,</sup> the aims of science are always, by the nature of its methods, partial aims. Science cannot say anything about the creation of the universe, so it just does not make any statements about the creation of the universe. If science cannot extrapolate the state of the universe backward beyond the big bang, it refuses to extrapolate backward or does so only in the most tentative and conditional way. <sup>Most astonishingly</sup> If physics cannot incorporate the arrow of time in its <sup>basic</sup> theories, <sup>and</sup> it admits that it cannot do so (see Feynman--Physics). <sup>Moreover,</sup> Science has recognized that in quantum physics the discourse contains a break: the objective world isn't that

objective. The observer and the observed cohere in a bizarre way which limits the clean separation between actor and observer. Moreover, biology has taught us that we, the observers, are products of our evolution, our cognition filters reality in a massive way. *Physics copes with the arrow of time in an awkward and contained fashion.* This arrow of time is much more of the essence of things in biology than in physics. In physics birth and death of particles are processes which can be looked upon as strict reversals of each other. In biology this is never so. Birth and death are totally different phenomena, future and past are radically different directions, the essence of life is <sup>of an individual organism</sup> development, indeed, development according to a plan. This feature of life, development according to a plan, which so strongly colored Aristotelian philosophy and through it the whole of western culture, its science, its art and its theology--this feature we can now tie up, through our proud new knowledge of molecular biology, with the physical universe. This directionality ~~of the arrow~~ of time where life is concerned has thus become part of our understanding of the physical universe, it is the hallmark, the specialty of biology.

How do they view time in the humanities? How does the historian view reality? In primitive society he, too, starts out with myth. Faith in miracles, in divine intervention have colored man's understanding of his own history throughout the ages. Along comes the historian of the 19th century, the positive historian, as proud as any scientist, wishing to describe objective reality. He ascertains the facts and forces, be they military, economic, social, or cultural, and tries to describe history as objectively

and even deterministically as any physicist tries to describe the events of nature. But in our times a critical reappraisal has gained ground, somewhat analagous to that in physics. Can you separate the historian from the history he describes? Is he, the historian, not himself a creature of history and does he not paint a picture that is as much a product of his own historically grown cognitive makeup as it is of the situations he aims to describe? What attitude should the historian take toward the myths of past centuries? Myths created by man, believed in by man, and constituting strong forces shaping the decisions of man. Surely no professional historian wants to admit miracles, divine interventions, immediate revelations of God, etc. But since a belief in these matters constituted the greatest forces of history, he must take full cognizance of them. For him, then, the myths of the past are historical facts. For him, paradoxically, the myths of past generations constitute part of the real historical past time. This past time he tries to order in a deterministic way.

Man, being an actor, an agent, a free though more or less rational agent, must deal with the past, recognizing that the persons in history were agents driven by their form of consciousness. They acted out of some knowledge of the past but most certainly out of ignorance of their future. For the historian, the tip of the arrow of time is even less determinate than that of the meteorologist.

Finally, for man, the individual man, the free agent, the

arrow of time takes its deepest meaning from the fact that the <sup>not even</sup> ~~only~~ <sup>we find ourselves in midflight without being asked, and</sup> beginning of the arrow is at hand, <sup>^</sup> but (to which end does ~~its~~ <sup>the</sup> tip of ~~the~~ <sup>arrow</sup> point? To some form of eternal life, if he has faith, or into nothingness? This alternative is surely the greatest force shaping man's value, finding its most powerful expressions in the arts, philosophy, and theology of all ages.

Our science, science at Caltech, ~~has~~ deals with time as simply a fourth dimension along which you move forward or backward at will. We know that science, this science, is immensely powerful and at the same time most severely and deliberately limited. It copes with the quadrivium, with measure and number, but it ignores the fact that both for mankind and for the individual man the arrow of time has meanings that vastly differ from those of physics or of biology. ~~I think~~ this realization is one that is powerfully needed and I think that Caltech is at a turning point where this need could and ought to be given the highest priority. ~~What Caltech needs is a realization that~~ Science is <sup>and by its best students</sup> doomed to mistrust by the public <sup>^</sup> if it remains self-serving, if it continues in the blind faith that what is good for science is good for mankind.

The essence of Caltech has been to be excellent and small. Small enough to avoid in large measure the schism into the "two cultures." In fact, the great "Court of Man" in which we hold this solemnity, flanked by the buildings to be dedicated to Behavioral Biology on one side and to ~~the~~ <sup>Humanities and to the</sup> Humanistic Social Sciences on the other is a symbol for the direction in which Caltech intended to and ought to continue its greatest thrust. Let us hope that the momentum will not get lost.