tern of magnetic anomalies (*21*), but there is serious conflict between recent convective spreading and the recovery of Miocene fossils from the rift valley unless we allow the possibility that "patches of older sediment were left behind in the crestal area rather than being completely swept away from the axis" (*11*).

4) Some of the larger pockets of sediment on the flank of the mid-Atlantic ridge contain a very prominent internal reflector, raising the possibility that these are uplifted horizon-A areas. Alternatively, if these pockets contain only pelagic sediments that have been ponded by local turbidity flows, there is still the possibility that the prominent reflector is synchronous with horizon A and that there is a distinct change in the acoustic properties of the sediments at about the Mesozoic-Cenozoic boundary as was reported for the Pacific sediments (*8*).

Although we have no direct information about the composition or age of this reflector, it is mentioned because, if it should prove to be uplifted horizon A or a deposit synchronous with this horizon, its presence as close to the crest as 100 miles would impose serious restrictions on the amount of permissible spreading of the sea floor during the Cenozoic.

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Diversity

More diversity in our science, our patterns of living, and our education would enrich us all.

John R. Platt

I celebrate diversity. Our research, our lives, our goals, our pursuit of excellence are all too homogeneous. La Rochefoucauld writes: "God has put as differing talents in man as trees in Nature: and each talent, like each tree, has its own special character and aspect. . . . The finest pear tree in the world cannot produce the most ordinary apple, and the most splendid talent cannot duplicate the effect of the homeliest skill."

I think he means that other men are not like him in being able to produce maxims of this kind. But what he says is true. How many of us have gotten D's and F's in apple-tree courses simply because the teacher was too narrow to see that we had to be nurtured as pear trees? Progress would be faster and life would be more interesting if we pursued more diverse goals, goals of excellence to be sure, but goals of our own, different from what everybody else is pursuing—and if we tolerated and encouraged the same sort of individuality in others. I want life to be various. I want to see around me not only apple trees but pear trees, not only fruit trees but slow-growing oaks and evergreen pines and rosebushes and bitter but salubrious herbs and casual dandelions and good old spread-out grass. Let us be different, and enjoy the differences!

The Scientific Bandwagon

Nowhere are we as diverse as we might be. Science and technology today encompass thousands of specializations, yet it is easy to see that the specialists are probably overconcentrating on certain subjects while other subjects, of equal interest and importance and ripeness for development, are almost entirely neglected. A short time ago it was announced that there were over 400 government and industrial contracts and projects for studying the new device known as the optical laser, which is able to produce a peculiarly coherent and brilliant beam of light. Now this is an interesting field, but—400 projects! This represents several thousand scientists and engineers who have jumped, or been pushed, onto this bandwagon in the 5 years since the laser was invented. The motorcar was developed with less than 40 manufacturing and development teams, and the whole field of atomic spectroscopy was developed in perhaps no more than 40 research laboratories. One cannot help wondering whether everything important to discover in the field of lasers might not have been discovered just as fast with only 40 projects, with the other 360 groups doing something less repetitious. One suspects that many of the 400 projects might not have been started if their leaders had known in advance—before they got their grant money and could not back out—that they would be competing with 399 others.

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Over the past 25 years I have changed my own field from physics and chemistry to biology, and I think that, in every field of science I have seen, there are areas that are being overstudied in this way by men who might be doing something more valuable with their brains. There is not only bandwagoning, there is nitpicking, where a multiplying succession of scientists pursues more and more ingrown exercises in what were originally interesting and important subjects. I am polite and will not name all these areas. That is left as an exercise for the student. But I think there may be symptoms of overstudy in some parts of molecular chemistry, where even the insiders often admit that they are doing rather repetitious studies on rather repetitious series of molecules. And some nuclear physicists, in relaxed moments, will be heard to sigh that the research teams are too big and the apparatus too complicated and the results hardly worth the effort any more. Many physicists have changed to molecular biology, where there seems to be more novelty and more scope for individual creative achievement. But in that field also there are now complaints that too many hundreds have taken up "the DNA game" and that it is time to move on.

Many of the men in these areas will defend their studies, of course. They have ego-involvement, as they should have; and financial dependence as well. If there are many men in a subject, they can point quite accurately to many achievements, and can say quite truthfully that with more men and more money they would have had even more. The important thing they do not say is what other, perhaps more valuable, things they might have done instead. Perhaps only the broad administrator, or the student not yet committed, has the detachment to make a real comparison of this kind, judging the promise of different fields and their excess study or neglect.

One reason why some fields are overstudied these days is our present system of government grants. If the grand old man in a certain field was skilled in "grantsmanship" just after World War II and got large grants or contracts for a few years, he was able to feed numerous undergraduate and graduate and postdoctoral students. As a result, within a few years he produced a dozen more trained scientists in the same field, specialists who had published papers and who knew how to apply for grants and who, as established experts, would recommend each other's grants and might even become agency officials. And, from these trained scientists, a new generation of students has of course multiplied again, and international conferences must be held in this area of rapidly growing importance. It is a chain reaction. Even the undergraduates can see how important the subject is, with all those visiting lecturers passing through and praising each other.

Meanwhile, that poor old area where the senior scientist lagged in applying for his first grant a few years ago is still trying to catch up, but is falling farther and farther behind in money and manpower, regardless of its importance or equal promise of success.

I am exaggerating slightly, of course. Students do change subjects, and new discoveries are made which open up new fields. But the tendency is clear, and some fields will be overstudied and others will be neglected, as long as government granting agencies refuse to make value judgments between areas, and say, in effect, that whatever many scientists want to do—that is, whatever they were supported for learning to do as students 20 years ago—must be the thing most worth doing and worth supporting.

I think there are thousands of scientists who would like to change to less crowded and more interesting fields if they thought the move would not be disapproved and if they could see how to make a living and how to get research support while making the change. I think such moves would be a good thing. Mobility spreads the skills in a labor market, and mobility would spread the skills in science. Kant, Helmholtz, Pasteur, all changed fields. Enrico Fermi once said that a scientist should change fields every 10 years; that, in the first place, his ideas were exhausted by then, and he owed it to the younger men in the field to let them advance; and that, in the second place, his ideas might still be of great value in bringing a fresh viewpoint to a different field. If government agencies do not want to point the finger at some areas as being overcrowded, they might at least consider giving wide publicity to the relative numbers of men and projects in different areas and to the ranking of the importance or promise of these areas by experts from nearby fields; and they might be able to take the lead in pointing out *under*studied fields and in soliciting grant applications in such fields.

Understudied Fields

Are there understudied fields? There certainly are, and interesting ones too. In the field of the colors of molecular compounds, in which I have done some work, there must be hundreds of scientists studying the spectra of diatomic gases for NASA and the Air Force, and thousands of scientists studying the spectra of benzenes and petroleum compounds and dyes for the oil and dye and photographic industries, but only one or two laboratories have made systematic studies of the spectra of the flower pigments, and I have been able to find only one paper in English on the absorption spectra of the irises of our own eyes. These subjects are difficult, but no more so than many others which are avidly pursued, and they are of considerable biological and genetic and human interest.

Much of the work on visual pigments and on the biochemistry of vision has been done in a single laboratory, that of George Wald at Harvard. And, in spite of the journalistic excitement that was produced a few years ago by the curious color demonstrations of Edwin Land of the Polaroid Corporation, the number of scientists working on the physics and chemistry and anatomy of color perception, or indeed of any aspect of perception, is still only a handful. The molecular basis of memory—what molecules are involved in the growth of nervous connections between brain cells when we learn something—is the subject of articles in the New York *Times* every week or two, but there are scarcely more than a dozen laboratories where such studies are being pursued. And the mechanisms of photosynthesis, in spite of their human and biological and economic importance for feeding the world, are probably being studied seriously at no more than about 20 laboratories, and the subject is still almost untouched by the powerful methods of the DNA revolution.

Marine biology—the problem of understanding the odd creatures of the sea and their development and cycles and diseases—is something done at only a few centers on the coasts, many

of them poorly staffed, although its importance for the life of the world should make it a matter for basic study by the best physicists, chemists, and biologists everywhere. I once heard the president of a Midwest university say that this was not a proper subject for emphasis at an inland school—even though his astronomers were working in both hemispheres, his cosmic-ray men had networks around the world, and his engineers were readying apparatus for solar system orbits from what is now Cape Kennedy. He was not "inland" except to marine biology.

In a more technical direction, we badly need new tools of research that almost no one is working on. A recent theoretical study has suggested that it might be possible to make improved electron microscopes that would permit one to see individual atoms or to identify a molecule directly just by looking at it. The importance of this for organic chemistry or biology may be imagined. It might be as great as the importance of the original electron microscope. But the number of qualified investigators who have applied for grants to try to develop such improved microscopes can be counted on the fingers of one hand. The development of research tools is not a traditional business of biology as it is of physics, and this and many other types of tools—such as new types of centrifuge, new methods of sectioning and staining and visualizing tissues, new methods for automating genetic studies—are lagging because of the lack of scientists who will turn aside to develop them and the inability of our laboratories to assign task forces to these important projects, as they could easily do if it were a matter of military or space studies.

Some of the scientists who have been studying the design of automatic vehicles for the scientific exploration of the surface of Mars have hoped that such a vehicle would require the development of a completely automated chemical and biological laboratory for analyzing small samples of material. Chemistry and biochemistry have lagged behind other fields in applying computers and automation methods to laboratory analysis and synthesis. Students still pour liquids back and forth by hand and sit watching flasks boil, as they did in the time of the alchemists. An automated lab might change all this, with incalculable consequences in making our chemical and biochemical studies faster and simpler and more accurate.

In many fields of science there are lags and understudied subjects, just because of the narrowness of training in the fields themselves. In astronomy, many of the great developments of the last century have come from outside the field, including the analysis of ionization in stellar atmospheres; the hypothesis of nuclear reactions in the stars; radioastronomy; astrochemistry; magnetohydrodynamics; and the discovery of synchrotron radiation. Astronomers have tended to be ingrown, trained only by other astronomers and isolated away from the flux of new ideas in physics and chemistry, and they have often resisted such innovations.

Similarly, in medicine, many of the most fundamental advances have been made, not by doctors, but by physicists and chemists and biochemists. Witness the germ theory, the development of many antibiotics, and the DNA story, not to mention technical tools like x-rays and other radiation, the electron microscope, and radioactive tracers. There are exceptions, but all too often the training of young medical research men is a training in repetition rather than in the important new methods and ideas of biology and the other sciences. As one wit has said, "We learn exactly what we are taught. Send a man to jail for four years and he becomes a trained criminal. Send him to medical school for four years and he becomes self-important and incurious." It is an overstatement, but it has a core of truth.

Outside the sciences, philosophy is another field which is too ingrown. It suffers from being taught by philosophers. Many of the major new philosophical ideas of the last hundred years—creative evolution, pragmatism, empiricism, logical positivism, personalism—have come not from philosophy but from the sciences, biology, psychology, mathematics, and physics. Diversity, diversity! There are probably many other areas which I have not mentioned where the narrowness of training by the professionals is evidently an actual handicap to progress in the field.

On the technological side, we develop some things well and other things not at all. We send men into orbit and we can fly faster than sound, but our clothes are inferior to those of a bird in many ways. The technical design of clothes is still prehistoric, in spite of synthetic fibers and sewing machines. The fibers must still be drawn out like animal or plant fibers, then spun, then woven or knitted, and then cut and sewn more or less to fit, just as fibers and cloth have been spun and sewn for thousands of years. And then these threads do not protect us against rain or cold, or ventilate or shade us in the hot sun, unless we put on and take off many layers, which we must carry around in a suitcase. Why should someone not make us a single suit that would shed rain and that we could ruffle up for comfort in any weather, as a bird ruffles its feathers? A bird needs no suitcase. The reason is that no one—not even the Army, which might be expected to have the greatest interest in it—has put a task force on the problem of designing clothing material of variable porosity and variable thermal conductivity that could be molded to the body. Not everybody would want a single universal suit, but it would be nice to have the option. It might not even be very hard to invent. But we still have prehistoric patterns of thought in what touches us most closely. Helicopters, *si*; clothes, *no*.

It is the same story with shoes, which are still sewn of pieces of leather or plastic. And again with housing, which lags far behind automobiles in technology and still has piece-by-piece assembly and leaking roofs and windows and no standard modular connection to the needed city services.

It is as though we had collective taboos against certain types of development, like the taboo against work on oral contraceptives before about 1950, or the refusal to consider or finance Buckminster Fuller's geodesic dome buildings until the Army used the principle for radomes, or the reluctance of psychologists and physiologists to study sleep before the work of Nathaniel Kleitman and his coworkers made it respectable. Scientists are not really innovators, and neither are industrial companies and government agencies and their research-and-development teams. They all shrink, like other men, from unheard-of projects for which there is no precedent, even obvious and important projects, because they are afraid they will be laughed at or cut off from support.

As psychologists once backed away from the study of sleep, so biologists and doctors today back away from

the study of regeneration and rejuvenation, although the central importance of these studies to human welfare is obvious. Such studies sound too much like science fiction—as though every development today did not!—and they have often been given a bad name by sensational reports like those of the "monkey gland" studies of the 1920's. But lower animals can regenerate parts of their bodies. Lobsters can regenerate claws; and newts, which are vertebrates much farther up the scale, can still regenerate eyes and optic nerves. It would seem that the power to do this is not lost in the higher animals but is only "turned off" or economized somehow, since we still have the full information for our embryological development preserved in every cell of our adult bodies. A concentrated study of "tissue inducers" or of the restoration of embryonic biochemistry might permit a useful measure of regeneration, and the discovery of how to do it might take only a fraction of the biologist-years now being spent on minor studies of DNA. A man who had lost a finger or a hand might find it very useful to grow, not merely skin over the stump, but bones and muscles, even if it took just as long as growing the original finger or hand. But we will never know whether it can be done until a few dozen scientists get to work on it.

So it is also with rejuvenation, or the preservation or restoration of sexual activity and enjoyment and of other youthful functions after the age of 50 or so. About 20 percent of the people of the world are in this age group, so this is a problem affecting the health and marital happiness of more than 600 million people. Some of the processes of aging that cause us to run down may be programmed innately into our genetic apparatus, while others may be due simply to the breakdown of certain repair mechanisms. Could these genetic programs be reversed or delayed? Or could the repair mechanisms be replaced? We do not know, but there are many avenues to try, and it seems to me quite possible that the work of a few hundred biologists in this important area might do more for the daily happiness of hundreds of millions of people than even a successful solution of the terrible problems of cancer and heart disease; yet the number of researchers in this field is probably not 1 percent of the number in the cancer field. We are driven by the fear of death, not by an interest in living more abundantly. Who would have the courage and love of humanity to try to organize an American Rejuvenation Society as rich as the American Cancer Society for the support of research? The jokesters would have a field day. And so the important thing does not get done.

There are other possible experiments that use the same biological principles and that would be extremely interesting to try, even though they are still more "far out." Since the nucleus of every adult cell in the body contains all the genetic information necessary for copying the complete adult, could we not take out some of these nuclei with a micropipette and insert one of them in a fertilized egg cell in place of the egg's own nucleus, letting the egg cell then develop and grow up into an identical twin of the original adult?

J. B. Gurdon of Oxford has already succeeded in doing this with frogs. If this procedure will work for higher animals, it could be the basis of a new animal-copying industry. One can imagine cells being taken from a prize cow or from a champion racehorse, and the nuclei from them being transplanted into newly fertilized egg cells and the egg cells reimplanted into a foster mother or into several foster mothers, producing several calves or foals which would all be identical twins of the champion. It could be a very profitable business! And it would be the fastest method of breeding enough superb stock for the developing countries.

For human beings, successful development of this method offers the possibility of giving babies to many couples who are unable to have children—babies which in this case could be genetic copies of the husband or wife. Many would find such a method infinitely preferable to our present method of artificial insemination from anonymous donors, with its genetic risks, or our method of adoption of babies from anonymous parents. And perhaps someday many mothers might want to try bringing up new copies of some of the great individuals of the world—great actors or athletes or musicians or thinkers or statesmen. Identical twins of this kind, reared in different homes, might enable us to find out for the first time how much of human achievement is due to heredity and how much to environment. If the genetic component is the determining factor, then in 25 years we might have the most remarkable collection of violinists or scientists or educators in the world!

It would also be useful to try animal-copying with the nucleus taken from one species and the egg in which it was implanted taken from another. Donkey and horse can be mated; will a donkey nucleus in a horse egg cell give a donkey—or something more like a mule? This might teach us something about the developmental embryonic differences between species. If it would work, we might be able to save some vanishing species by transplanting their cell nuclei into the egg cells of foster species. Is the DNA that carries heredity destroyed immediately when an animal dies? If the meat of woolly mammoths locked for thousands of years in the Arctic ice is still edible, perhaps their DNA is still viable and might be injected, say, into elephant egg cells to give baby mammoths again. By some such methods, perhaps we might achieve "paleo-reconstruction" of the ancient Mexican corn, or of "mummy wheat," or even of the flies that are sometimes found preserved in amber. One man has devoted his life to reconstructing creatures like the ancient aurochs, by backcrossing modern cattle. May not these other genetic methods of paleo-study also be worth trying? Success is uncertain, but the rewards would be great.

Biological Technology

There must be dozens of other areas of study that contain such families of unconventional experiments just waiting to be tried. In biological technology alone there are the experiments required for the selective breeding and herding of sea animals and "farming the oceans"; experiments on animal development, in which our new knowledge of embryonic growth would be used in attempts to develop larger brains or stronger muscles; experiments on the closer shaping of animal behavior, not just to make trick animals for the movies, but to make more versatile pets or better dogs for the blind; and experiments on electronic transducers to bring animal sounds into our range of hearing and our sounds into their range of hearing, so as to learn whether dolphins or chimpanzees or Siamese cats might

learn to use signals and symbols more as we do if we made it easier for them. This might give us a better understanding of the origins of our own communication and linguistic development over the last few hundred thousand years.

Finally there is an important set of experiments and developments needed for devising more sophisticated machines that would serve biological functions. Not just artificial kidneys, and pacemakers, and artificial hearts, which are all now under study, but things like balancing machines, to help the paralyzed to walk, with motors as compact and powerful and fast as our own muscles, and with feedback circuits as clever as our own balancing. Should these be so hard to devise, for men whose electronic circuits have flown past Mars transmitting pictures? Perhaps not; but the amount of scientific and engineering effort devoted by the nation to such problems is probably less than a ten-thousandth of the space effort.

The balancing problem is part of the interesting problem of making self-guiding automata—artificial cybernetic organisms, or "Cyborgs" as someone has called them—with pattern-perceiving sensory systems, communication systems, and control programs, and with self-contained power sources and motor motions. Such devices will be needed for exploring the hostile surface of the moon and Mars and sending back data, but they would also be useful for exploring sea bottoms and volcanoes and for fire-fighting and other dangerous operations. We are on the edge of understanding how to make such automata, but the problem is still being studied at only a half-dozen centers, and still does not enlist the hundreds of trained and inventive minds that will be needed to make such devices work cheaply and well.

These things I have been talking about are the science fiction of a few years ago, but they are now on the verge of being technically possible, even though they are still "long shots." Many scientists, of course, would be embarrassed to admit that they are professionally interested in such things, and many others might insinuate that if they were not embarrassed they should be. Experiments like these, that touch on our fundamental assumptions about life, encounter a kind of collective unconscious scientific censorship that makes them almost more taboo than the taboos of sex. But, when a few scientists around 1950 broke the taboo on the study of oral contraceptives, the results turned out to be of immense value for the whole human race. Perhaps it is time for some new scientific leaders to break some more taboos in some of these areas and see what further valuable results can be achieved. And perhaps they would find more support today from administrators and granting agencies than they would have found even a few years ago.

It is time for more scientific diversity. The question to be asked is no longer, what does physics have the apparatus and the equations for? It is, rather, what are the curious things in the world? And what are the needs of man?

Patterns of Living

Science is not the only area of life where we pursue some lines excessively while neglecting others. It happens throughout our economic and social and political life as well. Just to give one social example here, I think we neglect many important alternatives in our patterns of housing and living. We have automobiles in plenty—and I am no longer one of those who complain about their design; they are remarkably functional and economical and satisfying, and some day they may even be safe! But why should not our magnificent economic and social system be able to give us a similar level of technological skill and competitive cost in the construction of our houses? And why should we not be able to have more diversity and choice in our patterns of houses and lots? Again, there is a coupling of money to conventional patterns of tradition and taboo. If we were to put our houses at the edge of the streets, facing inward on the block, the houses could all look onto a sizable little park in the middle of the block, with trees and a fountain and swings and a place for oldsters to sit and for children to play safely away from the street. Given the pleasure of facing your very own park, who would prefer all these separate private lots with their wasteful driveways and unused areas? Very few, perhaps; but most of us will never know, because our system is focused on a different image and is not flexible enough to give us the option.

In fact, I think there are many different family and neighborhood patterns that we should explore. Try asking people who have traveled and lived in many different types of communities where in their lives they have enjoyed life the most. Surprisingly often the answer is in some form of group living. Many Englishmen say it was in their student days at Oxford. For others it may have been a hitch in the Navy on a good ship. Physicists and chemists still reminisce about the wartime colony at Los Alamos; they learned to share life there because they could not talk about their work. For many University of Chicago graduates, it was the old Howarth House cooperative, with its intellectual explorations and its taste of freedom.

Listening to these recollections, one begins to wonder whether our conventional pattern of life today, with its separate households and its separated age groups, is really giving us the full satisfactions of human living. Are we not basically tribal creatures? Good living is with a tribe. At the Marine Biological Laboratories at Woods Hole, Massachusetts, where I have spent several summers, the boundaries between the generations seem to disappear, as well as the boundaries between work and play and between indoors and outdoors and between man and environment. Children and students and teachers walk barefoot in and out of the laboratories, arguing science and studying the odd creatures brought up from the sea. All night they watch the fish embryos developing in the dishes, and they go out before dawn together to catch the big striped bass. The 4-year-olds solemnly examine frogs, the 10-year-olds sell their catch of dogfish to the labs, the 15-year-olds listen to the DNA arguments on the beach or play savage tennis with the senior scientists. No wonder they all want to turn into marine biologists!

Why should we not make environments for ourselves where we can have this kind of diversity and human satisfaction and pleasure of living all year around, instead of just in a student community or a wartime colony or a summer laboratory? I think that many universities and laboratories are neglecting one of their greatest potential attractions, in not trying to arrange environments so that living in-

tellectual communities of this sort could spring up around them. Make a good faculty center for easy and informal interactions, with faculty apartments and guest houses and conference rooms and lounges and terraces and recreation facilities and dining rooms and theaters, and the intellectual dialogue would never stop.

Diversity in Education

The area where there is perhaps the greatest need of all for more diversity today is the area of education. Students nowadays can hardly realize how much the alternatives available to them have been closed up by the zealous professionalism of the professors in the last 30 years. In the 1930's the colleges knew they had been liberalized by John Dewey and they offered what is now sneered at as a "cafeteria system" of education. Yet what an enriched program it permitted us! When I was an undergraduate physics major at Northwestern University I not only took physics and math courses but I had time for electives that included 2 years of French and 3 years of German (Goethe and Schiller), plus astronomy, economics, philosophy, public speaking, music, and a seminar on the origins of war.

Our present survey courses are more thorough and systematic but not so well tailored to each individual's curiosity and enthusiasm. Many colleges have pushed electives almost out of the curriculum, in favor of so-called "honors programs." All too often these should be called "narrows programs," for what they make is one-dimensional men.

It particularly worries me that physics and chemistry majors and other science majors have now lost most of their free electives. Scientists are now rising to executive positions in business and industry and are becoming advisors on major international and military matters. About one-third of all physicists eventually become administrators. I do not want—and I do not think any sane person wants—a world in which the major decisions on technological and military and international affairs are made by one-dimensional men, men who have never had time to explore art or music or history or philosophy or literature or the nontechnical achievements of mankind!

The only thing that saves us is the fact that the good students learn many things outside the curriculum. I think that in many cases the reputation of the hard-driving schools, both the high schools and the colleges, is not due to the courses or the staff at all, but is due to the quality of the students they are able to get. If you have hot-shots, it makes little difference what you teach them—or whether you teach them at all; they will find out from each other (as the whole human race did!) how to be great contributors to society. The importance of this initial student selection factor has never been sorted out in assessing our schools. Many a school has good graduates not because its education is good but because its students were good when they came in and have not been much damaged.

Even so, the hot-shot dimension is not the only one to be emphasized. Why should we assume or insist that our students have only one important coordinate of variation? This is the fallacy of exams and I.Q. tests. Yes, I want those fast-growing pines, but I also want rosebushes in my classes, and persevering oaks, as I said earlier. It is good that Jacob Getzels and Philip Jackson and others have emphasized recently that there is a dimension of "creativity" in students that has little relation to I.Q. How many other such dimensions of achievement are still to be explored?

We do not even allow for the physiological variations in students. Students, like professors, are not all wakeful or sleepy at the same time. We often start by trying to teach them things when they—and we—are half-asleep; and then we try to get them to go to sleep when they are wide awake. Would it be impossible to have classes at one time of day for the skylarks and at another time for nightingales? Even professors might like it. Some of the world's greatest leaders napped in the daytime and worked around the clock. Classes in the evening might lead to the best discussions of all if you could sleep in the morning. I have never understood why these possibilities are not seriously examined by educators, who are supposed to know something about the psychology and physiology of learning.

While we are speaking of the right to physiological diversity, let us not forget the right of some of the students to be women. It is easy to show that prejudices and handicaps to women's education still abound. Fathers send sons to college rather than daughters; and not only fathers but deans will cut off a college girl's financial support if she gets married, where they would not cut off a boy's. I have known professors in several departments who refused to take girls as graduate students on the grounds that they would probably get married and not use the education. The "nepotism rules" of many schools result in failure to hire good women teachers if they have the misfortune to be married to good men teachers, so the image of the woman intellectual that the student sees is almost always that of a woman who has renounced marriage. One great university lost a great woman scientist in this way, through refusing to pay her a salary separate from her husband's—until she became famous.

What is worse, however, is the fact that the colleges and counselors do nothing to combat the double standard of the college men, who may learn far-out things in biology or anthropology but are never shaken out of their conventional station-wagon images of what marriage should be. They go on assuming that the college wife, or the graduate-student wife, is the one who shops and cooks and cleans, even if she is carrying courses and trying to do equal work. The result of this conventional image—which the girls have often picked up as well as the men—is that American women are concentrating on conventional and subordinate jobs and that, compared to women of other countries, they are making fewer and fewer contributions to our national life, either as educators or editors or scientists or doctors or lawyers or judges or legislators or political leaders. We are only getting half-power out of our educated and intellectual women, and it impoverishes us all.

Poverty, Austerity, and Overwork

To come back to the narrowing pressures on student life in general, I think it is not at all clear that the intellectual and the economic pressures on students today are either good education or good economics. Students are probably the most overworked and underpaid class in our society.

Their training has now been shown by many studies to be the most important element in the economic development and prosperity of a country, and yet they are not paid as well as their brothers who became plumbers' apprentices. The 18-year-old brother or sister who works in a factory or a store gets off at 5 o'clock and has enough income to have an apartment and a car and books and records and recreation and a paid vacation. He can have guests in and can come in or go out at any hour. But the student is treated, not like his brothers or parents or teachers, but like a monk with a vow of poverty, austerity, and overwork—a vow which is not even his own vow but has been taken for him. He often works until midnight or later at subjects his brothers might never master, and he is supposed to get money from his family, or borrow it, or be grateful for a fellowship that still leaves him below the poverty level. He is frequently locked in at night and forbidden to have a car or an apartment, and has little money for his own books or for good meals or concerts. He is given cafeteria fare in cinder-block buildings and never learns to live like a human being. It is an affluent-society parody of medieval monasticism, with the universities—the primary sources of new economic development today—treated as priestly beggars, and with the professors themselves, who have grown up in the system, approving this treatment of the students and feeling, always, that they have too much money and do not work hard enough.

It is an odd 4-year gap in our economic scheme. Students are overworked and underpaid undoubtedly because they are the only group in our society who are too old for child labor laws to protect them and too young to have the support of a union or of professional-market competition—as their parents and their professors have—to help them get more civilized hours and treatment.

And, oh, how long are those hours that we are forcing on ambitious students in good high schools and colleges today! You professors who have measured the rates of learning, have you measured the optimum number of hours for intellectual work? Do they agree with the standard homework assignment? It is estimated that a medical student is expected to learn 30,000 bits of information in his first year, or 100 bits per day, if he obeys every demand of the instructors. Is it actually possible to learn at this rate, or does this not simply overload the brain and block any real organization of the material? No wonder the drop-out and failure rates are high. No wonder the suicide rate is high.

Men do not become wise and full by studying 14 hours a day, or 10 hours a day, or possibly even 8 hours a day. This is not education for the good life or the good society. There is a limit to human capacity to pack in new knowledge just as there is a limit to the capacity of a stuffed goose. The limit may be no more than a few hours before we need a change of pace for the rest of the day—a period of exercise or recreation or idleness, eating and chatting—if we are really going to assimilate new information and fit it together.

The Narrow Faculties

The trouble is that the faculty itself still thinks this is the only way of education. The student is not taught how to be broad and human because the faculty frequently does not know how to be broad and human. *Nemo dat quod non habet.* No one can give what he does not have. The student is overloaded with information because the professor is overloaded with information, with a piled-up desk and a bulging briefcase. He does not know how to handle it himself, so he passes it on. And many a professor equates education with judgments and grades. I have heard of one man, a kind man in his personal life, who gave out seven F's in a class of 25 undergraduate majors because some students either were not prepared for his 3-hour course or were unwilling to spend 20 hours a week on it, and because he had not the perception or the humanity to tell them earlier that they should not be in the course. This little piece of righteousness will cost these unfortunates hundreds of thousands of dollars in lost fellowships and graduate education and potential job opportunities over their lifetimes. In any other line of work, a man who did such a thing could be sued. In a university, he tells his colleagues it shows how poor the students are today, and they cluck sympathetically. Sometimes such men mellow as they mature, but all too often these black-and-white academics only get more and more self-righteous all the way to retirement.

The student comes for teaching and what he gets is grades. We are hypnotized by grades. They seem so exact and discussable. I have seen departments where one-quarter of the teachers' time and energy was spent in making up exams and grading them. If any administration doubts this, let it measure the ratio. This amount of time spent with individual students could have pulled many of them over the borderline; but we prefer to retreat to written questions. It gives us renewed proof that our students are one-dimensional. What Montessori said should be written on every bluebook in letters of fire: "The business of a teacher is to teach, not to judge." The business of a professor is to give, not grades, but intellectual contagion.

Do not misunderstand my criticisms here. I think the academic life can be the most varied and imaginative and interesting life in the world, and I love it. But I am talking about its distortions and about how they narrow it from what it might become. Its great men are so very great and its little men are so little. And it pains me when I see one of those academic men who has deliberately narrowed himself to an intellectual pinpoint and has cut off all that life might be. Emerson must have been thinking of such men when he said: "The state of society is one in which the members have suffered amputation from the trunk, and strut about so many walking monsters—a good finger, a neck, a stomach, an elbow, but never a man."

The academic world is perhaps no worse in this respect than the world of government or the world of business, but it is sad all the same. The teacher is the one man who most needs to know what it is to be a complete man with wholeness and diversity and humor. When his vision is distorted, the vision of a whole generation may be warped.

I think it is time to say loudly and clearly that the interval of higher education should be an interval of learning to live like cultured human beings instead of like monks and academics. Instead of overload and punishment let us have excitement and leadership. Along with excellence let us enjoy diversity. Let us try to find ways in which students can be given the mon-

ey and leisure they ought to have as valuable apprentices in an affluent society. Let us bring up a generation of young adults full of the delight of living, interested in many things, and knowing not only how to be intellectual but how to be full and creative men.

The Second Educational Revolution

I think that this goal I have suggested, of trying to make the college years more humane, more cultured, and more diverse, is just a part of a new educational revolution that will totally change the structure of our schools in the next 20 years. This revolution may be even more thoroughgoing than the revolution that was made by John Dewey and the other reformers 70 years ago, when they swept out the obsolete and stuffy classical education of the 19th century and redefined the goals of education as education for society and education for living.

Today our education has indeed become an excellent education for our society, so far as its professional content is concerned, but it is still obsolete and clumsy in its teaching methods. Since World War II, a revolution has occurred in information and communication and in our knowledge of the biology and psychology of the brain and the psychology of learning. It is beginning to be urgent for us to adapt our educational system to take account of these advances. Mass education up until now has been hard and punitive, with more of the stick than of the carrot. It has been hardest and most punitive in the colleges, where many departments and schools are actually proud to have standards so strict that they flunk one-third of their freshmen.

But it is now possible to move away from this traditional pattern. It has become clear that the psychology of positive reinforcement, of encouraged curiosity and reward, works much better than the psychology of negative reinforcement, as great teachers have always known. It is time to try out on a large scale the new discoveries and methods of this new educational psychology, discoveries such as the remarkable effect of early enrichment at ages 1 to 4, and methods such as use of the new phonetic alphabets and the programmed learning and teaching machines and programmed texts that promise to make spelling and geography and physics and anatomy and many other subjects easier and more quickly mastered.

The new ideas have already made a revolution across the nation in the teaching of high-school science courses, and efforts are well under way to create science programs with the same exciting immediacy all the way down to the kindergarten level. In fact it now appears that the whole difficulty with many subjects is that we have been teaching them too late. A 7-year-old can learn reading and writing more easily than an 18-year-old can, and we are now finding that he may also learn about sets and binary arithmetic and rates-of-change and the difference between mass and weight more easily than many college sophomores.

The difficulty today is that these remarkable new methods have not yet been drawn together into a unified educational approach. We have a better engine, a better transmission, and a better steering mechanism, but they have not yet been fitted together to make a complete car. It seems very likely that, when they are all put together, these new developments in education will reinforce each other and will make possible further gains that would not come from any one alone. Pre-school reading and writing would make room for beginning science in the early grades. Binary arithmetic in the second grade may make a child ready and eager for number theory and computer programming in the sixth. Rates-of-change at age 7 would permit introduction to economics at 13.

What is evidently needed now is to get out of the rut of our standard educational structure and to set up complete new kinds of pilot schools to try out this new personal and concrete and manipulative education in an integrated program all the way from age 1 to age 21 and beyond. We need to try schools of several different kinds, in different types of communities, in slum areas and rich suburbs, in company towns and scientific laboratory communities, to find out which kind of program under different circumstances produces the most alert and creative citizens. If we can find some educational leaders who will take the initiative in establishing private schools of this sort, or who can persuade some forward-looking school boards to try them out, this may be the most exciting educational adventure of the next decade.

I think that, if we put together all the speed-ups and simplifications that these new methods make possible, the children in such schools would no longer be overworked. The subjects we now teach them might be mastered in a much shorter school day, perhaps no more than 3 or 4 hours. There would be less boredom and resistance in school and more time for creative leisure outside. Some parents may shudder at this, because they do not want the children home half the day. But, with the new trends of productivity and automation in our adult life, perhaps creative leisure is one of the things we need to teach children earliest. And, if we let the adult's leisure enrich the children's leisure, homework might even become home play. The interaction between the generations might make for better relations than we have had for years. In fact the children, with their shorter hours, going home from school may soon meet the adults, with their new leisure, going back, hoping to learn in a more voluntary and serious way the subjects they missed in all their years of report-card education.

All this would change our stereotyped pattern of education in a remarkable way. The intense program of work now imposed across a few years in the late teens—where we have to study all day and all night because the earlier grades have taught us so little—might be replaced by an easier longitudinal pattern that would start with easy and fast learning methods at age 1 or 2 and would then go on all our lives for 2 or 3 or 4 hours a day. The children and the college students and the leisured adults might acquire a new attitude toward education. Formal teaching might blend inseparably into more individual and creative leisure-time activities, such as building boats together or learning music or ballet or skiing—or studying embryos and catching striped bass before dawn. Education would be by contagion and long discussion, and the generations might learn to talk to each other again.

A lifetime ago we made the transformation to education for living. It is time now to make the transformation to education for wholeness, for delight, and for diversity.