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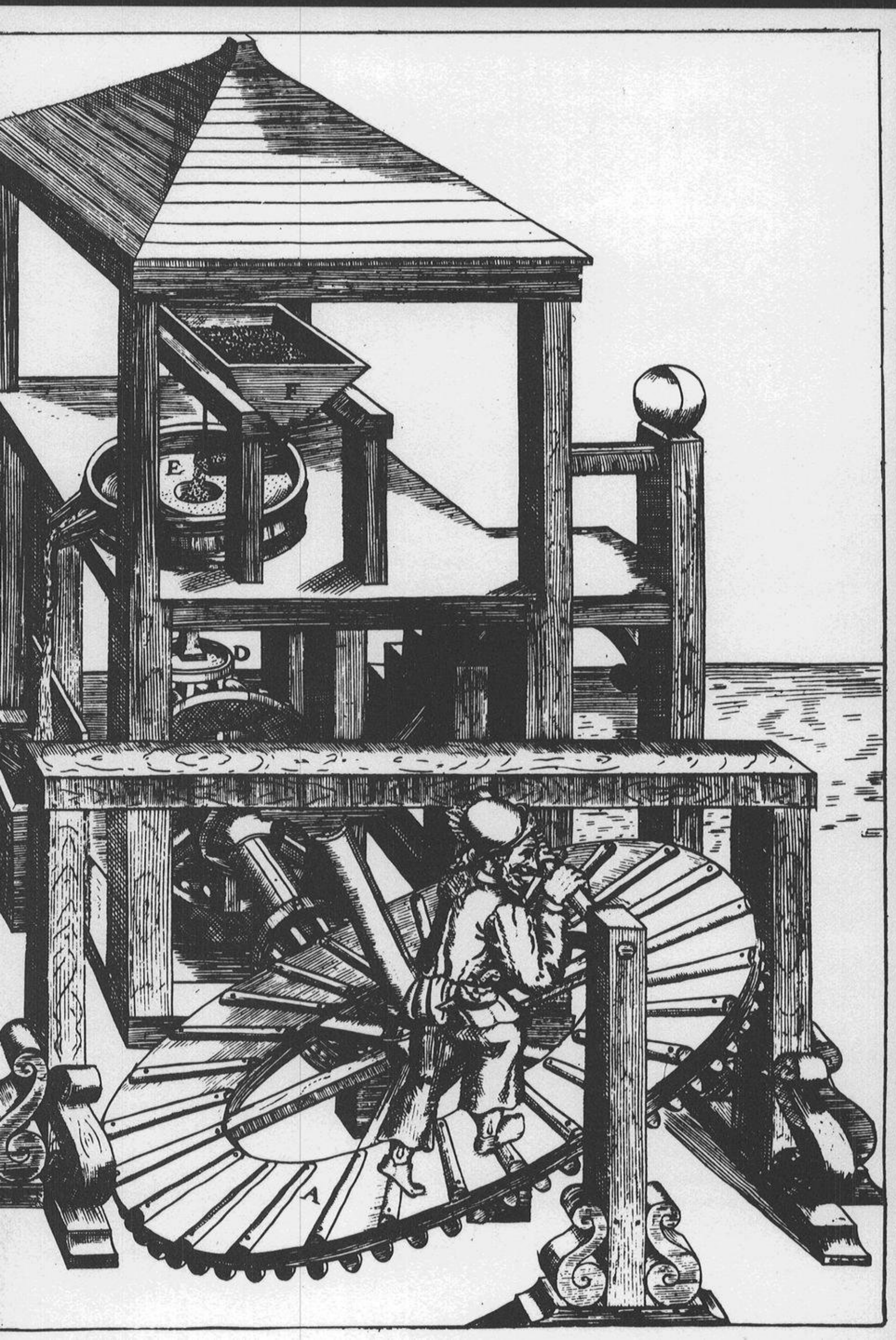
WISCONSIN ACADEMY REVIEW

Science, Technology & Human Values



Volume 21, Number 3
Summer 1975

In writing this short note, I feel like a stagehand who suddenly finds herself at center stage with the curtain going up and an expectant audience sitting on the other side of the footlights.

The stagehand plays an invisible role in production—setting the stage, shifting the scenery, and lighting the set. The managing editor has analogous roles—gathering articles, editing, and finally, displaying the text in print. Neither is accustomed to the spotlight.

Yet it is not without some delight that I introduce myself as a new member of the cast. I hope that you, the audience, find my first Review, *this special issue on "Science, Technology and Human Values," interesting and thought-provoking.*

Chris Beals

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Cover: a plate from Ramelli's *Le Diverse et Artificiose Machine*, 1588.

WISCONSIN ACADEMY REVIEW

Volume 21, Number 3
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The Authors...

Wayne Becker will spend the academic year 1975-76 at the University of Edinburgh, Scotland as a Guggenheim Fellow. The associate professor of botany at the University of Wisconsin-Madison received a Chancellor's Award for distinguished teaching in May, 1975. His research focuses on the developmental biochemistry of seed germination, the regulation of gene expression in plant development, and the role of chromosomal proteins in the regulation of transcription.

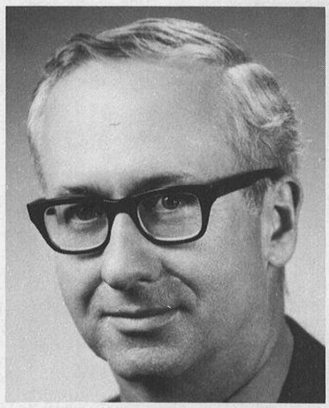
Through her work as editor for the Center for Engineering Research at the University of Hawaii and through her recent studies at the University of Chicago Divinity School, Gretchen Schoff has worked on interdisciplinary studies of the relationship between theology and nature, ethics in the technological age, and the impact of technology upon the humanistic perspective. She is a lecturer in the Integrated Liberal Studies program and in the College of Engineering at the University at the University of Wisconsin-Madison.

Marion Namenwirth, an assistant professor of zoology at the University of Wisconsin-Madison, teaches basic zoology for non-majors, developmental biology, and is planning a new course on the social implications of recent developments in biology and medicine. Genetic control of frog embryo development, as well as the biochemical basis of the specialized properties exhibited by different parts of the embryos, is the focus of her research.

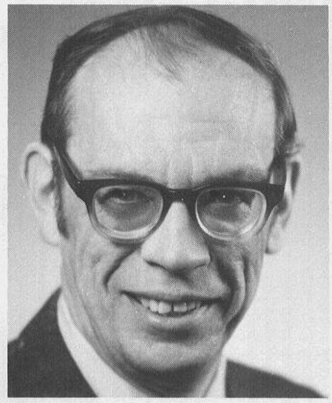
Robert Kimbrough, professor of English and chairman of the Integrated Liberal Studies program at the University of Wisconsin-Madison, teaches courses in Elizabethan drama, poetry, and prose and in European culture. He spent a year under the auspices of the Institute for Research in the Humanities on the Madison campus to complete a biography of Sir Philip Sidney and to edit Marlowe's *Tragedy of Dr. Faustus*, and he has published other critical works.

Charles Wedemeyer is William H. Lighty professor of education in the University of Wisconsin-Extension where he played an important part in the development of correspondence instruction for the Extension program. In addition to serving as a consultant to universities around the world, he received a Ford Foundation grant for European study; he was also a Kellogg Fellow in adult education at Oxford University, England.

As associate director of the Institute for Environmental Studies, John Ross has been concerned with long-term environmental analysis rather than crisis-oriented solution. Also a professor of agricultural journalism at the University of Wisconsin-Madison, Ross has studied communication problems in pesticide use and has helped to develop a communication studies curriculum for the School of Natural Resources.

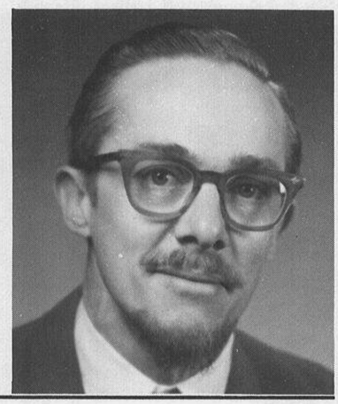


A course in the history of the occult and pseudo-science has been a recent effort of Robert Siegfried. The professor of history of science at the University of Wisconsin-Madison has devoted research time to study the development of chemical concepts—their relationships to and distinctions from those of physics. He wrote the chapter on Humphry Davy in the book *Great Chemists*.



A Leonardo Scholar at the University of Wisconsin-Madison, Van Potter, professor of oncology, was recently elected to the National Academy of Sciences. In addition to substantial contributions in the field of cancer research, he has participated in an interdisciplinary seminar to identify national resource policy needs, and, in 1971, wrote *Bioethics: Bridge to the Future.*

"Revolutionary Chemistry," the brainchild of Robert West, professor of chemistry, is an honors course for liberal arts students interested in the relationship of chemistry to social and environmental problems. West has received, in addition to enthusiastic student response, a Chancellor's Award for distinguished teaching.



Science, Technology & Human Values

What Wordsworth called "the still sad music of humanity" sounds through it all—through pulsars and lasers, fission and fusion; through Green Revolutions, organ transplants and genetic engineering; through all the test tubes and circuits and computer printouts that make up the terrible-wonderful brave new world of science and technology come yet the strains of human concern and questioning.

Earlier this year, a group of scientists and academic humanists joined together in Madison in an attempt to "tune-in" to some of these concerns and questions. The occasion was an eight-week public program on "Science, Technology and Human Values," sponsored by the Midwestern Center of National Humanities Series, an agency of the National Endowment for the Humanities.

The purpose of the program, according to Center Director Robert E. Najem, was "to provide a forum in which people of science could discuss with people of the humanities the moral and ethical implications of recent scientific and technological developments." A secondary purpose was "to demonstrate the continuing need for such dialogues if we are to bridge the chasm between what author-scientist C. P. Snow once referred to as the 'two cultures' of science and humanities."

Because the Wisconsin Academy of Sciences, Arts and Letters, throughout its century-long history, has attempted to further the interrelationship of science and the humanities, and because the subject is of crucial and contemporary importance, this special focus issue of the Wisconsin Academy Review is devoted to a presentation of the highlights of the program, "Science, Technology and Human Values." The responses of members and friends of the Academy are invited and encouraged.

Science and Technology:

Hero of the Past, Villain of the Future?

by Robert Siegfried

A rather abrupt change has taken place in the public attitude toward science and its contributions to our culture. This change, a basic distrust of the scientific establishment, seems to have accelerated within the past fifteen years far beyond the public shock at the dropping of the first atomic bomb.

Perhaps negative feelings toward science are not so much widely held as they are loudly expressed. Science and technology still contribute so pervasively to our well-being that for a large majority there is no thought of challenge and, science is still a hero. What science has brought in gains to our material comfort and welfare are so obvious that they are taken for granted: increased life expectancy, better health, freedom from diseases which only a generation ago were long and uncertain of cure; reduction of drudgery, and escape from the debility of long hours of heavy labor.

The gains that science and technology have added to our stock of human values are perhaps less obvious, but no less real. The wealth and affluence made available by a technological society have provided the fulfillment of many social ideals, universal education, and leisure time for the pursuit of individual goals. Not only does the eradication of poverty and slavery now seem possible, but it becomes a public shame that they continue to exist. Furthermore, as Jacob Bronowski demonstrates in his 1956 book, *Science and Human Value*, science has become one of the more active grounds for human creativity, the most unassailable bastion for the habit of truth, and the principal ground for man's irresistible need to explore.

The justification for viewing science as hero is clearly so impressive that we must ask: What has brought about the disillusionment of those who now see it as potential villain? There are two sets of charges—against science's material effects and against its human values. The atomic bomb has brought the capacity for total destruction of the human species, possibly of all life on the earth. In the fifteen years since Rachel Carson called our attention to what we were doing to our environment in her book *Silent Spring*, the ecological movement has grown enormously in response to ever wider awareness of the possibly irreversible changes we are producing in the atmosphere, the sea, and the land. We are creating a world we were not selected to live in.

These physical threats of ecological disaster, energy crises, mass starvation, etc., have shaken attitudes toward science's values as well. Nearly every anti-establishment movement—whether or not it is openly anti-scientific—justifies itself by crying out against "materialism" and calling for humane values. Alternatives to the scientific, materialistic view are being actively sought, whether through the study of the religious mysticism of the Far East, or the revived interest in the occult arts of astrology and Tarot cards. Anti-scientific attitudes are also frequent in science fiction where the coldly calculating scientist who has no humane understanding is a familiar figure. The mad scientist is a traditional character in western literature, from Dr. Frankenstein to Dr. Strangelove.

I shall not dwell on the revival of the occult nor on new styles of pseudoscience, but I do wish to meet the challenge as presented by the most intellectually serious critic of science, Theodore Roszak, a professor of history at the University of California, Haywood. Roszak has written several books and papers developing his thesis that scientific influence is inherently destructive, and I shall refer particularly to thoughts expounded in his short paper, "The Monster and the Titan: Science, Knowledge and Gnosis" which appeared in the summer 1974 issue of *Daedalus*.

Roszak sees science as having come to dominate present society through its chief characteristic of objectivity, which has become "the commanding life-style of our society . . . . The mentality of the ideal scientist becomes the very soul of society." He adknowledges science as "the fairest child of the Enlightenment" and recognizes that its practitioners are motivated by a "strange intellectual passion." But whatever its virtues to the professional, the "cult of Objectivity" has fostered the abandonment of meaning.

Roszak sees the meaninglessness created by science as a *moral* issue, for

> meaninglessness breeds despair, and despair, I think, is a secret destroyer of the human spirit, as real and as deadly a menace to our cultural sanity as the misused power of the atoms is to our physical survival.

These are serious criticisms whose general validity I will not challenge, but what does Roszak offer as a remedy? The answer is "Gnosis," a revival of "an *older* and *larger* kind of knowledge," a mystical view of nature that transcends and encompasses by a higher order of understanding, the informational knowledge of science. In searching for this kind of knowledge, Roszak says,

> it is a certain texture of intelligibility we first and most decisively seek, a *feeling* in the mind that tells us, "Yes, here is what we are looking for. This has meaning and significance to it." (Emphasis and quotation marks in the original.)

How like Descartes's method for finding truth within oneself! But where Descartes found truth where he could not doubt, Roszak finds truth where he feels good.

Now I willingly support the necessity of feeling good about what I believe in, but to accomplish that by making the subjectivity of feeling the test for a higher order of "knowledge" simply will not do. To subsume the objectivity of science under the subjectivity of gnosis is to destroy science itself, along with that great intellectual passion to know, which continually creates science. This passion is as much a part of our humanity as is our need to feel in harmony with the world we live in.

I believe that these two aspects of our humanity are separate and distinct: rational versus intuitive; analytical versus holistic; scientific versus poetic. The aspects exist side by side in each of us, and do not truly mix, though like oil and vinegar of a good salad dressing, if properly shaken before being used, they make a fine combination whose proportions are determined by individual taste.

In responding to Roszak's claims, I am going to measure his position by an historical example in which we can remain less emotionally involved than we are in the present day arena. I therefore turn now to a brief account of the rise of modern science as background to the romantic movement of the early nineteenth century.

The rise of modern science meant not only enormous growth of knowledge about the natural world, but a basic change in the way in which western intellectual man viewed nature. Before the seventeenth century the universe was alive, an organism which had to be dealt with in personal terms; prayers, incantations, and ritual practices were the characteristic ways of dealing with unseen, often whimsical forces and supernatural wills.

The seventeenth century saw the rise of the mechanical philosophy, most extremely held by Rene Descartes, but made operationally effective by Isaac Newton. Nature was seen as a machine, for like a machine, nature appeared to seventeenth century man to be precisely predictable, inalterable and inexorable in its workings. The central theme of the new philosophy was precision, and one of Newton's focused arguments in his major work, *The Mathematical Principles of Natural Philosophy* (1687), was directed against the cosmic scheme of Rene Descartes who had created an ingenious and highly plausible scheme from first principles derived from introspection, not from nature. Newton, starting from the experiences of nature itself, demonstrated that Descartes's system could not be factually true. As the historian Westfall has expressed it, "The universe of precision had replaced the world of more or less."

The eighteenth century saw a long sequence of detailed challenges to the Newtonian law of universal gravitation, challenges always of precision. Each challenge, more demanding than the one before, was met with ever more precise success, until by the beginning of the nineteenth century, the French astronomer and mathematician La Place, who did so much toward the perfection of Newtonian astronomy, was moved to say that Newton was the most fortunate of all men, for it is possible only once to discover the fundamental laws of the universe, and Newton had done it.

The consequences of Newton's triumphs were enormous and form the basis for the spirit of the enlightenment, by which term we characterize the century which followed. Basil Willey in his *Eighteenth Century Background* refers to "the sense of relief and escape, relief from the strain of living in a mysterious universe, and escape from the ignorance and barbarism of the Gothic centuries."

Note that the term "Enlightenment" is not one invented by retrospective historians; it is a term invented and used by those who lived in the period. Its spirit is evident in the motto of the Royal Society of London, the oldest existing scientific society, founded in 1662, "Nullius in verbo" which freely translated means "Take no man's word for it." The most mature statement of this spirit of the enlightenment is perhaps that of Immanuel Kant written in 1784.

> Enlightenment is man's emergence from his self-imposed nonage. Nonage is the inability to use one's own understanding without another's guidance. This nonage is self-imposed if its cause lies not in lack of understanding but in indecision and lack of courage to use one's own mind without another's guidance. *Dare to know! (Sapere aude.)* "Have the courage to use your own understanding" is therefore the motto of the enlightenment.

But the spirit of the enlightenment involved not only abstract delight in knowledge but also faith that knowledge could be put to good use for the *physical* benefit of all mankind. Man's lot was difficult and his burden was heavy; knowledge could be useful in relieving that burden. Francis Bacon had seen that vision in the early seventeenth century long before any hope of achieving it was apparent. The eighteenth century thought the time had come, and optimism forms one of the motivating themes of Diderot's great *Encyclopedia* whose hundreds of woodcuts illustrating machinery of manufacture and the arts, are aimed at enabling men to educate themselves for self-benefit and usefulness.

This enlightened optimism extended even to the study of man himself and the eighteenth century saw the beginnings of nearly all the social sciences. John Locke provided the epistomoligical assumption which underlies new studies of human behavior: in contrast to the Cartesian view that knowledge is innate and knowable by careful introspection of one's own mentality, Locke thought that at birth a man's mind was a *tabula rasa*, a blank slate on which his unique life experiences write and determine what he is and is to become. From this view the environment becomes all important, for to make better men all we need is a better environment, better education, happier experiences. Studies of the philosophy of law and of government fill the eighteenth century with the inevitable challenges to existing laws and government. The American Revolution seemed to give hope and justification to those who believed in "the perfectability of man," a phrase still in use at the end of the century, but the French Revolution, which promised even more when it began, became the vehicle of disillusionment when it degenerated into terror.

William Wordsworth in poetry written long after the event, speaks passionately of the high hopes nourished by the French Revolution and of the bitter disillusionment that followed it. And others of the poets share Wordsworth's view of the French Revolution's evils as something spawned by Reason and pursued in her name.

Although various factors entered into the Romantic reaction, the revolt against reason was central, and science, as Reason's most visible and successful practitioner, received the poets' scorn. Wordsworth reviled one who "would botanize upon his mother's grave" and who in search of knowledge must "murder to dissect." But beyond his contempt for particular scientific sins, Wordsworth challenged the basic activity of scientific inquiry.

> . . . Go, demand
> Of mighty Nature, if 'twas ever meant
> That we should pry far off and be unraised,
> That we should pore, and dwindle as we pore,
> Viewing all objects unremittingly
> In disconnexion dead and spiritless:
> And still dividing, and dividing still,
> Break down all grandeur, still unsatisfied
> With the perverse attempt, while littleness
> May yet become more little; waging thus
> An impious warfare 'gainst the very life
> Of our own souls.
>
> (William Wordsworth, *Excursion*)

Perhaps my quoting of Wordsworth's negative comments on science somewhat distort his overall philosophic position. Yet he did

I believe that these two aspects of our humanity are separate and distinct: rational versus intuitive; analytical versus holistic; scientific versus poetic. The aspects exist side by side in each of us, and do not truly mix, though like oil and vinegar of a good salad dressing, if properly shaken before being used, they make a fine combination whose proportions are determined by individual taste.

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write these lines, and they are paralleled by the lines of many other poets of the time, in a widely held attitude. Reaction against reason was not confined to the poets and artists of the era; there was for a time an active philosophical development which through the writings of Friederich Schelling in Germany entered into the scientific community, a movement known by the German name of *Naturphilosophie.*

The fundamental theme of *Naturphilosophie* was the unity of all things in nature (in opposition to the analytical separation of things as found in the practice of science) and the need to find one's own resonance and mystical identity with the world of nature. Its chief intellectual tool was the recognition of polarities in natural phenomena and their mystical combinations into a single holistic unity that transcended human reason. The claims of *Naturphilosophie* are very much like those of Roszak's Gnosticism, offered up in times very much like our own when the "world is too much with us."

Historians of science have recently become greatly interested in this movement and its relation to the development of science during this period. Only one scientist of first rank has been unequivocally identified as a true believer in *Naturphilosophie*, though others have on rather tenuous evidence been claimed as adherents. The one is Hans Christian Oersted, the Danish physicist who in 1820 discovered the magnetic effects of a wire carrying an electric current. According to his own testimony, it was his belief in the unity of nature that led him to persist in his experiments to make this discovery. But he does not explain how that faith led to the *particular* experimental set-up which produced the discovery.

Here again we have the universe of precision and the world of more or less. The broad philosophical frame that claims the unity of nature is so vague and loose in its intellectual structure as to allow almost any empirical discovery to be interpreted in consonance with it. It may well satisfy the personal preferences of the researcher, but it seems inadequate as a guide to experiment, which must be particular.

The only other historical figure of significance who can be called an advocate of *Naturphilosophie* was Johann Wolfgang von Goethe, and though he had great interest in certain phases of science, particularly in optics where he developed a theory of vision in conformity with his *Naturphilosophische* views, he cannot be seriously considered as a scientist.

As my chief example of a scientist's response to the early nineteenth century's situation, I wish to dwell at some length on Humphry Davy, a self-educated Cornishman who won fame as a chemist before he was thirty. A personal friend of nearly all the English romantic poets, he had ample opportunity to understand both the scientific and the poetic views of nature, and he was able to accommodate the two views in a personal dualism rather than by requiring that some unity should subsume them.

Davy was born in 1778 in Penzance (yes, Gilbert and Sullivan lovers, there really is a Penzance), about 300 miles from London and less than ten miles from Land's End, the southwestern-most tip of England. His formal education was intermittent and ended before he was fifteen. At sixteen, shortly after the death of his father, he was apprenticed to a physician-surgeon in the town and there he remained for just under four years. Davy's efforts at chemical experimentation brought him to the attention of an Oxford graduate in the community who recommended him to a physician in Bristol then seeking a director of the laboratories of his Pneumatic Medical Institute. This physician was the optimistic Dr. Thomas Beddoes (father of the poet, Thomas Lovell Beddoes) who was dedicated to the idea that respiratory ailments, especially consumption, might be treated by some of the new gases that were just then being discovered. Since oxygen had been shown to have essential physiological properties, perhaps other gases did too. Davy's task was to explore this possibility. Needless to say, the great hopes with which the enterprise was undertaken were not realized, and no cure for consumption was found. But Davy's experimental efforts led him to the discovery of the properties of nitrous oxide, or laughing gas, in 1800. He also discovered its anesthetic qualities and even suggested that it could be used to eliminate pain in small operations. Unhappily neither he nor Dr. Beddoes nor anyone else put the suggestion into practice for another forty years.

Having achieved fame, even notoriety, as laughing gas parties became quite popular for a time, Davy moved to London as chemical lecturer in the Royal Institution. Here he added to his fame with chemical discoveries, and preparations of new metals (sodium, potassium and half a dozen others) and with the invention of the miner's safety lamp in 1815. He became even more famous locally for the inspiring and informative lectures which he delivered to public, non-professional audiences. The sense of excitement and the poetic style with which he delivered his scientific information enthralled his audiences.

Davy had written poetry from the age of seventeen, and his poetic qualifications go beyond those of fashionable verse-making. During his 2½ years in Bristol, he became closely acquainted with many members of the literary world of England. Dr. Beddoes' wife was the sister of the novelist Maria Edgeworth, and the Beddoes home was open house to such other figures as Joseph Cottle, a publisher of Wordsworth and Coleridge, and Robert Southey, later poet laureate. Davy met Coleridge in the summer of 1799 and they became great mutual admirers. Coleridge once told Cottle that ". . . there is an energy, an elasticity in his mind which enables him to seize on and analyse all questions, pushing them to their legitimate consequences. Every subject in Davy's mind has the principle of vitality. Living thoughts spring up like turf under his feet." Coleridge also once said that he attended Davy's lectures in London "to increase his stock of metaphors." (Davy corrected the proof sheets for the second edition of the *Lyrical Ballads* during the absence from Bristol of both Coleridge and Wordsworth.)

In spite of the great respect and mutual admiration between Davy on the one hand and Wordsworth and Coleridge on the other, there were deep philosophical differences between them. Both poets saw analytical activity as the work of an inferior faculty of the mind. The work of the experimental scientist may be useful, they believed, but it is superficial. Davy took public issue with his two friend's position in an early lecture given at the Royal Institution in January 1802, with Coleridge in the audience. Davy's basic position was that scientific—that is, experimental—inquiry not only produces useful knowledge, it also provides deep stimulation to the imagination. Davy continuously elaborated this position throughout his career as a lecturer, and in 1807 he published a brief paper on "The Parallels Between Science and the Arts," in which he expressed the idea that the creative aspects of imagination and of reason are similar and that both are equally important.

At one other time, he described the similarity thus:

> The contemplation of the laws of the universe is connected with an immediate tranquil exaltation of the mind, and pure mental enjoyment. The perception of truth is almost as simple a feeling as the perception of beauty; and the genius of Newton, of Shakespeare, of Michelangelo, and of Handel, are not very remote in character from each other.

Clearly the imagination and the reason were for Davy distinct and separate attributes. They relate to each other and reinforce each other, but one is not higher, more important than the other. "Imagination, as well as reason," Davy other, but one is not higher, more important than the other.

> Imagination, as well as reason, is necessary to perfection in the philosophical mind. A rapidity of combination, a power of perceiving analogies, and of comparing them by facts, is the creative course of discovery. Discrimination and delicacy of sensation, so important in physical research, are other words for taste; and the love of nature is the same passion, as the love of the magnificent, the sublime, and the beautiful.

Davy made the relations more explicit between imagination and reason in later lectures.

> Words alone must never be suffered to satisfy or fill the mind, and their relations to facts must be ascertained before they can be considered either of importance or of use. We may be always safely entertained by wit,—we may be always safely delighted by eloquence,—for they are the life and organs of the mind; but never let us consider wit as argument, or eloquence as truth, till we have coolly examined them by the test of right reason.

The dangers of forgetting the discipline of "comparing analogies by facts" he frequently warned against. In science which is concerned with nature, the imagination is used in framing hypotheses, but these

> should be considered merely an intellectual instrument of discovery, which at any time may be relinquished for a better instrument . . . . To be attracted to mere speculation, is to be directed by a dream. Knowledge can only be acquired by the senses. Nature has no archetypes in the human imagination.

Or, at another time,

> It is of great importance to the progress of science, that facts should be separated from what is imagined; that the nature of knowledge, and the grounds of our opinions, should be strictly defined.

In one lecture he spoke of a particular theory concerning the nature of heat, then a fundamental question of the day, saying that "it satisfies the imagination, but not the reason."

Lest from these extracts we gain the idea that although Davy understood the distinct roles of imagination and reason, he did not experience anything akin to the mystical identification with nature so characteristic of romanticism and *Naturphilosophie*, I add the following excerpt from his personal notebook.

> Today, for the first time in my life, I have had a distinct sympathy with nature. I was lying on the top of a rock to leeward; the wind was high, and everything in motion; the branches of an oak tree were waving and murmuring to the breeze; yellow clouds, deepened by grey at the base, were rapidly floating over the western hills; the whole sky was in motion; the yellow stream below was agitated by the breeze; everything was alive, and myself part of the series of visible impressions; I should have felt pain in tearing a leaf from one of the trees.

Following this he wrote in a more philosophical mood—

> Deeply and intimately connected are all our ideas of motion and life, and this, probably, from very early association. How different is the idea of life in a physiologist and a poet!

From this passage written early in his friendship with Coleridge, we can safely assume that Davy understood something of the romantic poet's mystery and awe, the sense of identification with nature. Yet he saw it and felt it with a difference. Two poetic passages will illustrate further. The first, from Coleridge, is quoted by Roszak at the end of his *Daedalus* paper to climax his argument for the higher cosmic unity which gives life and meaning to man.

> And what if all of animated nature
> Be but organic Harps diversely fram'd
> That tremble into thought, as o'er them sweeps
> Plastic and vast, one intellectual breeze
> At once the Soul of each and God of all.

Davy, in lines probably written in response to the above, starts with the primary existence of man and projects human characteristics onto the cosmos.

> What if the stars themselves
> Be but a different animated world
> Of which our narrow intellect can form
> No just conception; what if each bright orb
> In the act of pouring forth its flood of light
> Should feel intensest pleasure, and the globes
> That dance in everlasting circles round
> Should in the attractive power which moves them
> Feel a holy glow like that of purest love.

I have dwelt at some length on the life and thought of a rather little known scientist whose work has long been superseded, because it is often easier to understand our own problems if we see them objectified in a situation outside of ourselves. And though I firmly believe the historian's familiar adage that "historians make poor prophets" I equally believe Santayana's warning that "those who do not learn from the mistakes of the past are condemned to repeat them."

So I have offered you the description of a man of science responding to challenges similar to those we face today, living at a time when, as now, active and persuasive voices were raised demanding that he make a choice between reason and feeling, between mind and soul. Humphry Davy, with grace and full understanding, refused to make that choice. So should we.

* * *

Selected Readings

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Daedalus, Summer, 1974. "Science and Its Public: The Changing Relationship."

E. A. Havelock, *Prometheus*, paperback edition, 1968, published originally under the title, *The Crucifixion of Intellectual Man,* 1950

Peter B. Medawar, *The Art of the Soluble*, 1967

____________, *The Hope of Progress*, 1973

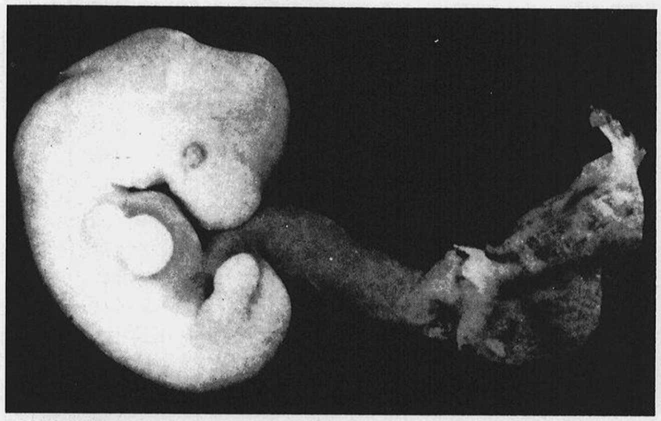
Theodore Roszak, *Science*, 1972, 178:961

Lynn White, Jr., *Dynamo and Virgin Reconsidered (Machina ex Deo)*, 1968

Reproduction in the Twenty-first Century

by Marion Namenwirth

Photograph taken through a microscope of a living human embryo several days after fertilization. By this time the fertilized egg has divided itself into 32 cells, each of which has a complete set of human chromosomes.



Six-week old embryo in side-view. Actual length of embryo from head to seat is about 3/4 inches.

The phrase, "the twenty-first century," has a curiously faraway ring in our ears, rather like "once-upon-a-time" in reverse. But the century itself is not far away, and what it proves to be will depend very much on what we are doing in various fields of research today. In our present century there has been a remarkable expansion of biological research, leading to an almost explosive knowledge about cells, genes and biochemical interactions. This knowledge in turn has led to new concepts and techniques in human biology and medicine whose further development, especially in the area of prenatal medicine, could effect enormous changes in the century ahead.

I wish to discuss some of these possible changes, realizing that the threat of severe overpopulation may condition the choices and decisions human beings make.

How a single human egg cell, only 0.1 mm in diameter, manages, after fertilization, to develop into a being which at birth consists of over 200 billion cells specialized for multiple functions is not thoroughly understood. But one major point about this process is already clear: the mammalian embryo, which normally develops inside a uterus, is basically a self-organizing, self-developing system. It depends on the mother's body for food, oxygen, waste disposal and protection from physical harm. But if this nourishing milieu can be supplied outside of the uterus, the fertilized egg by itself contains all the genetic information and all the cellular structure needed to make an entire organism. In fact, portions of the human embryonic and fetal periods have already been sustained outside the uterus in various kinds of incubation set-ups, resulting in seemingly normal development of the embryos. Further research on human development *in vitro* could mean revolutionary changes in human reproduction. Before exploring this matter further, I should like to discuss some less startling, but still major, techniques in prenatal medicine which have evolved out of cellular and molecular biology.

Human embryo, inside its chorionic sac, at about 2 months of development. At this stage the embryo is about one inch long from head to seat.

Amniocentesis

Approximately 1 infant out of every 200 born today has a serious abnormality in its chromosome constitution. Chromosomes are the long, threadlike structures on which our genes are located. The nucleus of each human cell normally contains twenty-three pairs of chromosomes. When the chromosomes of an embryo are present in abnormal numbers, the resulting imbalance in the dosage of genes leads to a variety of physical and mental disabilities, the most widely-known syndrome being Down's Syndrome, or Mongolism.

The condition of the chromosomes in a developing fetus can now be diagnosed during the fourth month of pregnancy using the technique of amniocentesis. In this procedure, a needle is inserted through the abdominal and uterine walls of the mother, directly into the amniotic sac of the fetus, and a small volume of amniotic fluid is withdrawn for examination. This amniotic fluid is centrifuged to separate out the floating cells. The fluid, which contains enzymes and other cell products manufactured by the fetus, is analyzed directly, whereas the cells are incubated in a nutrient medium for several weeks to allow growth and cell division to occur until there are large enough numbers of cells to permit study of the fetal chromosomes and performance of a variety of biochemical assays.

Almost 100 different hereditary abnormalities can now be diagnosed by study of the amniotic fluid or of the fetal cells found within it. As research on cultured cells yields more information about the characteristics of normal chromosomes and the biochemistry of normal cells, we can expect that our ability to diagnose unusual genetic conditions will steadily increase.

Although most of the disabilities detectable by amniocentesis cannot now be corrected by medical intervention, future research may change this situation. A physician then could give corrective treatment at birth or, since many deleterious genes exert their damaging effects very early, even before birth.

At the present time prenatal diagnosis is most often valuable because it gives parents the option of aborting a pregnancy that would otherwise result in a seriously defective infant. This seems to me to be a great benefit where severe physical or mental disabilities are concerned. Of course there are persons who will disagree, holding that the condition of the fetus cannot justify abortion. Moreover, there will be a great diversity of opinions on which conditions would justify an abortion. Presumably, parents will continue to decide whether to abort a pregnancy and will make this decision for diverse reasons. If large numbers of people in the twenty-first century were to become very selective as to what characteristics they wanted in their offspring, prenatal diagnosis followed by selective abortion could significantly alter the range of characteristics found in the human population.

Choosing Gametes

So far we have tacitly assumed that parents will always choose to have children genetically related to themselves. One instance in which this might not be the case is where study of the family history, or medical examination of the parents, reveals the presence of deleterious genes that could be passed on to the children.

Every individual has two genes for each characteristic. A complete set of genes is present in the nucleus of each cell in the body. When sperm and eggs (gametes) are formed, a special type of cell division takes place which sorts out the genes so that each gamete carries only one gene for each characteristic. Thus when an embryo begins development after the fusion of a sperm with an egg, the embryo has two genes for each characteristic, one obtained from its father and one from its mother. Together these genes direct development of the new organism, and oversee its functioning throughout life.

So far we understand the pattern of inheritance of only a small number of the genes operating in humans. The ones we have information about are primarily genes that can cause drastic changes in our health. Usually these genes must be present in two doses in order to exert their effect. If only one such deleterious gene is present in an individual, while the other gene for that characteristic is normal, then the individual will appear to be normal even though he is a carrier of the deleterious gene. Parents who are concerned about passing harmful genes on to their offspring are usually in this situation—having one normal gene which makes their own physiology normal, but carrying the harmful gene on the other chromosome, so that there is a fifty-fifty chance that a gamete carrying the harmful gene will take part in fertilization.

Until recent years, prospective parents who felt anxiety about transmitting undesirable genes to their offspring had to depend solely upon statistical probabilities in deciding whether to have their own children. Now that prenatal diagnosis by amniocentesis is possible, parents may begin a pregnancy and then have the fetus examined. If the amniocentesis tests show the presence of the undesirable condition, the pregnancy can be terminated by abortion and a new pregnancy begun.

Alternatively, if a feared deleterious gene is expected to come from the father, the problem can be solved by artificial insemination, a procedure that has been used in medical practice for many decades (though it has more commonly been used to initiate pregnancy in cases of male infertility). Sperm to be used in artificial insemination can be frozen and stored for long periods without loss of function. A sperm bank is used, for example, when an individual who has decided to have a vasectomy wishes to have sperm available in case he should later decide to have more children. Now that human eggs can be obtained from the top of the oviduct, it may be only a matter of time until techniques are perfected for preserving them also, with full potential for future development. Sperm banks will then become co-ed institutions, and both eggs and sperm might be selected systematically for their genetic characteristics.

Except to avoid transmitting unfavorable genes, why would anyone bother to carry out such a selection? Well, people might desire offspring who are very strong physically, or resistant to disease or to smog. They might wish to have children who are very intelligent, or gifted musicians, or perhaps unusually adaptable. Nobel Prize-winning geneticist H. J. Muller thought that it would benefit mankind to set up a system in which many individuals would donate gametes to be preserved until after their deaths. Then society could make a reasoned judgment on the value of each person's lifetime achievements and, on this basis, could decide whose gametes should be chosen as starting material for future generations.

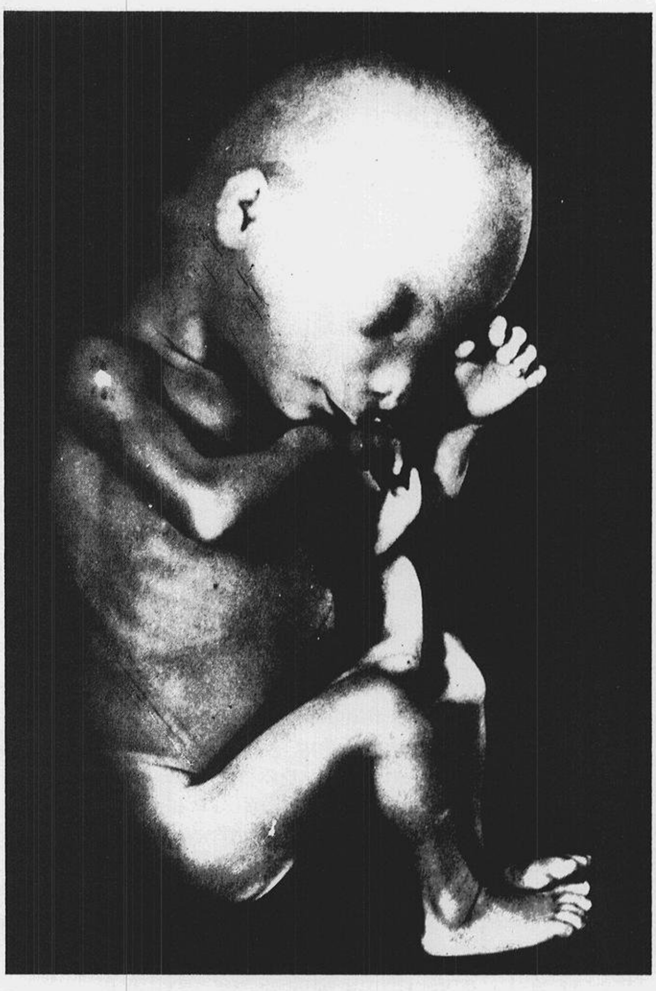
Actually, a systematic genetic program of this sort is not feasible at this time for two reasons: first, traits like artistic talent, intelligence or adaptability appear to be controlled by so many pairs of genes acting in concert that it is exceedingly difficult to work out exactly which genes are involved. Geneticists have so far focused their attention primarily on traits controlled by a single pair of genes simply because such conditions are much easier to analyze. Furthermore, even if we succeeded in discovering which genetic combinations determine a trait, pairs of genes within this complex would probably sort out independently during the formation of gametes so that, as an example, only some of the eggs of a very intelligent woman would carry gene combinations for high intelligence.

Second, genes do not produce behavior automatically, but through interaction with the environment. Substantial differences would occur between identical twins if their environments were different. It is certainly apparent that we don't understand what factors in the environment modify the expression of genes or there would be much more agreement on the best patterns for education, creative training, etc.

Nevertheless, repeated artificial selection for complex traits in plants and animals has resulted in markedly changed species. If we selected systematically for some complex human trait, within several generations we would surely change the incidence of that trait in the population.

Understanding and Modifying Early Development

Human eggs for use in biomedical research have been available during the last several years through the cooperation of women who are preparing to undergo hysterectomies. Hormones are administered to trigger the release of many eggs into the oviducts just before the operation. When the oviducts are removed, these viable human eggs can be retrieved for use in research.



Human fetus at 3½ months of development. Actual length is now 4½ inches from head to seat.

It has proven possible to fertilize human eggs with human sperm successfully outside the body, and thus to initiate the development of human embryos *in vitro*. A British physician has reported that three infants born in England during 1973 began their development by means of an *in vitro* fertilization. To overcome a block to fertility in the mothers, medical researchers used hormone treatment to induce the release of eggs from the ovary. These eggs were removed from the oviducts surgically and were fertilized *in vitro* with the father's sperm. After several days, when the resulting embryos had reached the proper state of development for implanting in the uterine wall, they were introduced surgically into the uterus. Successful pregnancies resulted, and apparently normal and healthy children were born. Undoubtedly the previously infertile couples are enthusiastic that this technology was available to them, but of course it has much broader implications than the circumvention of infertility in a few.

Our ability to culture human embryos in the laboratory makes those embryos available for study and experimentation. At present, only the very young embryo is accessible because development outside the body cannot be sustained for more than a few weeks. However, it is probable that this line of research will lead to a gradual prolongation of the time during which human embryos can be kept alive *in vitro* until the entire nine-months' gestation can occur outside the body. When this is achieved, it will still take several more decades to determine whether *in vitro* development produces healthy, normal, well-balanced individuals.

Ought we to continue doing research along the lines I have been describing? First, is it reasonable and proper to initiate embryonic development, use the resulting embryos in experiments, and then allow the embryos to die? I think this procedure is acceptable as long as we are dealing with young unconscious embryos which have no experience of their existence in the laboratories; experimentation with human embryos under these conditions involves no cruelty. Yet we are talking of issues that must be decided by society as a whole and not by individual opinion.

Does further research on embryos *in vitro* portend dangers and abuses that would outweigh the benefits? Could there be devastating results if scientists were mistaken about the ability of their methods to promote normal development? This is a serious problem but not, I believe, very different from that entailed in any new medical procedure. We work out an experimental method using animals as models and finally, if all goes well, we test the method on humans. Sometimes mistakes are made. We have made serious mistakes in prescribing drugs for pregnant women, in the care of premature babies, and sometimes in our methods of delivery. Yet most of us feel, on balance, that medicine is beneficial to human well-being.

If an *in vitro* method of procreation should prove wholly successful physiologically, would it pose psychological problems in child-parent relationships? If we consider, as models, families in our own society who have adopted children, this possibility does not look particularly bleak.

But suppose that a governmental or private group decided, for some purpose of its own, to "manufacture" people? This is a potential danger, although an unlikely one: there would be almost a generations's delay before the product became useful.

Let us consider what the positive results might be if research on *in vitro* development is continued. What can we expect to learn? Study will probably reveal the causes of birth defects and ways to prevent them. We may learn a good deal about human physiology and basic biological mechanisms that can be applied to many fields of medicine. In the long run, experiment might lead to the invention of methods for modifying development. Some of these methods might be only remedial while others might be used to alter development in novel ways, to create human beings with some new characteristics, or else to create many individuals possessing psychological or physical characteristics now found in only a few. These changes, of course, could be for the benefit or the detriment of man.

To give some examples, we might test the effects of adding various chemicals, drugs or hormones to different parts of the embryo at different stages of development. It has been reported, for example, that rat embryos exposed to growth hormone at a stage when the brain cells are undergoing rapid multiplication develop into unusually intelligent rats with markedly enlarged brains.

We might learn how to repair a defective gene or how to add a new gene to the genome of an embryo. Such a treatment would best be carried out in a young embryo where the gene need be introduced into only one cell, or into a small number of cells. If the gene was functional, it could then reproduce itself during the subsequent cleavages and so be distributed throughout the body.

We might be able to introduce genetically different cells into the embryo. If introduced early in development, foreign cells would not be rejected by the immune system; the acceptance would probably be permanent and the foreign cells would multiply and become part of the developing organism.

Finally, methods might even be devised for cloning people. Implanting copies of the genetic material of one individual into many human eggs whose own genetic material had been destroyed would result in a number of genetically identical people, like identical twins. Alternatively, subdividing an embryo at an early stage of development and allowing each embryonic cell to develop as a separate individual might achieve similar results.

At present these are only theoretical possibilities. It would take a great deal of time, effort and expense to make them realities, and I think society must soon decide whether these roads of exploration are desirable. We cannot foresee what medical challenges we will face in the future, but we can be fairly sure they will be substantial. The world's population is enormous, food is in short supply, the ecosystems in which we evolved are taking a terrible battering. It is entirely conceivable that we will soon have to adapt to conditions and challenges that we have never had to face before. Our continued survival might depend on our knowledge of biological systems and our ability to preserve and nurture them under adverse conditions.

Will research with human embryos provide a technology which we shall *need* in order to deal with the future? If it is developed, can we control its application and prevent its misapplication? If we outlaw this area of research, will it be carried on nevertheless, in secret, by an elite government or a private organization, leaving society more defenseless against its misuse than if public research had been allowed to continue?

These are all exceedingly difficult questions. Our answers will be little more than guesses, and we won't know whether we have guessed right until well into the twenty-first century.

Ethical Implications of Nuclear Technology

by Robert West

In his message to Congress on the Energy Crisis, President Ford recommended speeding the construction of 200 large nuclear power plants, to be added to the approximately 40 already in operation. However, some environmental groups are pressing for a total moratorium on nuclear power plant construction and, in California, have succeeded in scheduling the moratorium question on the 1976 ballot. Recently two groups of eminent scientists have issued statements, one supporting and the other condemning rapid development of nuclear power.

Here in Wisconsin the lengthy hearings concerning the proposed construction of a nuclear power reactor at Lake Koshkonong have been well publicized. There have been lectures and spirited debates at the Madison campus of the University on nuclear power and on the safety of nuclear compared to coal-fired power plants. It is evident that the issue confronting us is complex, controversial and unresolved.

Let us examine some of the ethical and human questions associated with nuclear technology. In doing this in limited space we shall have to accept some limitations. First, I shall not deal specifically with technical and engineering questions, except as they affect the ethical decisions. Second, I shall only raise questions, not propose answers. Finally, I wish to separate the issue of nuclear power from the more general problem of growth in energy use. However the fact of continued growth may be a good place to begin, for it also poses problems in human values.

We in the United States are certainly wasteful of energy. On a per capita basis we consume about twice as much energy as residents of industrialized countries in Western Europe, whose living standards are in many ways as high as ours. Vigorous measures to curb wastefulness and to conserve energy are clearly desirable, although it is difficult to see how a *rapid* reduction in energy use can be achieved without creating economic disruptions even more serious than our present problems.

The recent Energy Policy Study of the Ford Foundation lists, as one of three possible future scenarios, a plan called "zero energy growth." However, what is actually meant by this term is a slow increase in energy consumption until the year 2000, then gradual cutback. Even this slowdown in energy growth has been bitterly attacked by corporation spokesmen as damaging to our economy.

For the moment, I shall assume that the use of energy and the generation of electric power in the United States will continue to grow during the next twenty-five years at least, although probably at a slower rate than in the past. Under this assumption, what options do we have? It is now clear that natural gas and petroleum are going to be too expensive to use for generating electricity. New energy sources, of which solar energy and nuclear fusion seem the most promising, are unlikely to be competitive in yield for the next two or three decades at least. The choice that must be made, that is actually being made, is between coal and nuclear energy. Only these two technologies offer promise of meeting needs for electrical power during the next few decades. On what grounds, other than purely economic ones, should the decision between these technologies be made?

Let us consider first the environmental and health hazards. For coal these are severe. Strip mining of coal is damaging to the environment, deep mining is dangerous and unhealthy. Current annual compensation payments to coal miners who have contracted pneumoconiosis, "black lung" disease, are about a billion dollars a year. Uranium miners face some additional health risk from exposure to radioactive materials, particularly radon gas, but by best estimates the hazards per unit of energy produced are about one hundred times fewer in uranium mining than in coal mining.

Likewise, the health hazards to the general public from coal-burning are certainly more serious than from nuclear power generation. Sulfur dioxide formed from combustion of the sulfur in coal is known to cause emphysema, bronchitis, and chronic lung disease. The particulate smoke emitted from coal plants is carcinogenic and is probably a major cause of lung cancer. These emissions can be reduced, but not eliminated, by the use of pollution control equipment, but utility companies are reluctant to install and to use this equipment.

Nuclear power plants emit small amounts of radioactivity, mostly in gaseous form. The annual radiation dose per U.S. resident from this source is on the average only 1/50,000 of the whole-body dose received by a U.S. resident from medical x-rays. It is only 1/1000 of the amount of additional radiation which a passenger receives in a *single* cross-country flight in a jet aircraft. Even with a fully-developed nuclear energy economy the risk from release of radioactivity *during normal operation* would, in my opinion, be negligible.

So far, the environmental and health considerations favor nuclear power over coal. But note that we have specified normal operation. With nuclear power plants there is a small but finite chance of catastrophic accident in which coolant carrying heat from the reactor would suddenly be lost. Emergency core cooling systems (ECCS) are then supposed to spray water on the reactor core, to minimize damage. However, the ECCS has never been tested and it is hard to imagine how a full scale test could be carried out without risking destruction of a half-billion dollar reactor. If the coolant were lost and the ECCS did not function, the intensely radioactive reactor core would surely melt and the hot mass would probably penetrate the concrete footings of the building and the ground below, possibly releasing a large amount of radioactivity. The consequences would depend on the siting of the reactor, weather conditions, etc. Assuming the worst possible combination of circumstances, the number of people endangered could be in the thousands or tens of thousands.

How likely is such a major catastrophe? The Rasmussen report, a major study of this question carried out over the past several years, was released last fall. The report consists of thirteen volumes, which raises this question: How can individuals, even those with technical knowledge, evaluate reports of this complexity? Professor Norman Rasmussen, the chief author, defends the general conclusion that such an accident is extremely unlikely and well within the risks that society commonly accepts. However, both the Environmental Protection Agency and certain environmental groups have questioned the methodology and the detailed estimates of consequences in the report. In fact, it is most difficult to predict the likelihood and consequences of a type of accident which has never occurred.

Intentional sabotage of a nuclear power plant is also a possibility worth considering. A determined and knowledgable group of extremists could conceivably gain entry to a nuclear power reactor and damage both the ECCS and the main coolant pipes, causing a core meltdown. The scenario may not be a very likely one, but in order to prevent it, nuclear plants would have to be heavily guarded.

We can now begin to focus on human values. Coal power technology will surely lead to increased deaths and injuries from mine accidents, black lung disease, bronchitis, emphysema and cancer. Nuclear power avoids or minimizes these problems, but presents the

. . . the nuclear breeder reactor and plutonium economy imply a trust in the continuing stability of human institutions . . . .

possibility that a catastrophic accident might occur, causing great loss of life. How can one balance these hazards and decide on the best—the most ethical—power policy?

Threat of catastrophic accident or sabotage are not the only problems in the nuclear fuel cycle. Nuclear fuel must be removed from the reactor after only partial "burnup" of the fissionable uranium-235, because accumulated fission products interfere with the nuclear chain reaction. Considerable quantities of plutonium are present in spent fuel rods; at present such fuel rods are simply being stored, but within two years, a recycling plant will be in operation and others are being planned. A fateful decision will soon have to be made: Will the plutonium be purified and recycled as a reactor fuel? Recycling of plutonium presents special risks not only because of the intense toxicity of this element but also because purified plutonium oxide could be diverted and used for the construction of a crude nuclear weapon, an atomic bomb. Once plutonium recycling is under way, very elaborate safeguards will be necessary. Already plans are being made for armed guards to accompany shipments, for security clearance of nuclear workers, for intelligence activities against groups which might attempt to steal plutonium, and so on. We were willing to accept stringent security measures during World War II. Are we prepared to accept such measures during peacetime? Some people feel that our very freedom will be threatened. In a recent article Professor Abrahamson of the University of Minnesota says:

> Nuclear power presents to the alienated minority and the poor nation alike a means to greatly amplify their political power. It is obvious that society could not tolerate disruptive nuclear events. The response to nuclear power will be the garrison state.

Plutonium recycling would lower fuel costs by 10 or 15 percent. This is not essential with the present generation of nuclear power reactors; however, use of nuclear power for more than a few decades will require that breeder reactors be developed to convert essentially all of the abundant uranium-238 into plutonium. In a fully developed plutonium economy, the amounts of this material being shipped around the country would be very large.

The final problem with nuclear power is that intensely radioactive by-product wastes are produced, and no fully satisfactory disposal method has yet been found. The wastes are small in volume but very large in radioactivity. Most of the radioactivity dies away quickly but substantial amounts of isotopes with long half-lives are also produced. These include isotopes such as strontium-90 and cesium-137 which will be dangerous for hundreds of years, and worse yet, actinide elements, plutonium and americium, which would have to be isolated from the environment for many thousands of years. In generating these nuclear wastes we are passing on to future generations the problems of storing them and isolating them from the environment for thousands of years. Are we morally justified in doing this? Of course it can be argued that we have already burdened the future with the nuclear weapons program, and that nuclear power will not create a new problem but will increase the magnitude of a present one.

One person in favor of nuclear power, who has thought quite carefully about these problems, is Dr. Alvin Weinberg, the former director of Oak Ridge National Laboratory. He states his conclusions in a now classic article in a 1972 issue of *Science:*

> We nuclear people have made a Faustian bargain with society. On the one hand, we offer—in the catalytic nuclear burner—an inexhaustible source of energy . . . .
>
> But the price that we demand of society for this magical energy source is both a vigilance and a longevity of our social institutions that we are quite unaccustomed to. . . . In a sense, we have established a military priesthood which guards against inadvertent use of nuclear weapons, which maintains what *a priori* seems to be a precarious balance between readiness to go to war and vigilance against human errors that would precipitate war. Moreover, this is not something that will go away, at least not soon. The discovery of the bomb has imposed an additional demand on our social institutions. It has called forth this military priesthood upon which in a way we all depend for our survival.
>
> It seems to me . . . that peaceful nuclear energy probably will make demands of the same sort on our society, and possibly of even longer duration.

In other words, the nuclear breeder reactor and plutonium economy imply a trust in the continuing stability of human institutions, a commitment to a continuing social order so that these materials will be protected. Is society willing to make this kind of institutional commitment for the indefinite future?

Humility with Responsibility: The Basic Bioethic

by Van Potter

With the separation of church and state, there seems to have been acceptance of the idea that teaching ethical behavior was not the responsibility of the state's educational system. Neither the elementary nor the secondary schools, and certainly not the state universities were assumed to have any role in the development of an individual's moral commitments. Even in the professional schools such as law, medicine and engineering the teaching of moral behavior was never a formal concern. Perhaps it was assumed that students in professional schools were already gentlemen, already members of a select group adequately exposed to moral principles.

Today the picture has changed radically, partly because of the attitudes of those students who have become aware of certain failures attributed to previous generations of professionals, and partly because of society's changed view of the professionals and of the world. These changes are forcing the professional schools to reevaluate their obligation to include ethics in the curriculum. Unfortunately, a substantial number of students still regard the professional school as a kind of escalator on which they can move up to affluence and power in a world no different from that of their fathers. Despite that attitude, continued consideration of the role of ethics in professional training seems mandatory.

The Survival Imperative

In a widely quoted paper on the "Purpose and Function of the University," a group of Wisconsin professors emphasized the need for multidisciplinary efforts for human survival. They affirmed the views: (1) that the survival of civilized man is not something to be taken for granted, (2) that governments throughout the world are experiencing great difficulty in planning for the future while trying to cope with the present, and finally (3) that the university is one of the institutions with a major responsibility for the survival and the improvement of life for man. In response to the question, "What are the purposes of higher education?" the committee wrote:

> The primary purpose of the University is to provide an environment in which faculty and students can discover, examine critically, preserve, and transmit the knowledge, wisdom, and values that will help ensure the survival of the present and future generations with improvement in the quality of life.

In this University manifesto we see for perhaps the first time an emphasis not only on knowledge to help ensure survival and improvement, but also on values and wisdom, defining wisdom as the knowledge of how to use knowledge for the general good. To further emphasize that biological knowledge and human values together play an important part in achievement of this desperately needed wisdom, I have coined the term bioethics.

The Specialist's Dilemma

How to harness the talents of the specialist is the great dilemma of modern society; how to develop his talents in a rapidly changing world is the dilemma of the modern student. Until recent years, society's problem has seemed soluble by dividing knowledge into disciplines to form an intellectual free enterprise system subject to the laws of supply and demand. The product is weighed and measured and the industrial, agricultural, medical, or political recruiters enter the knowledge supermarket with a reasonably clear shopping list. The student has not fared so well. Because society measures the professional product by academic degrees, a student usually becomes highly specialized. Unfortunately, as he focuses his interests, he not only loses flexibility, but he also may lose sight of the overall significance and applicability of his work. Contrary to this, in cross-disciplinary studies, his specific competence may be sacrificed to gain competence in a broader area.

Frankly, I'm worried that relatively few of our best minds are able to expend significant energy on the major problems of our time, and that, though they might agree on some things, they are unable to influence society in any profound way. Virtually every talented person is occupied in a daily routine of detail; the really major decisions are made without time to consider all of the relevant information.

As a scientist and a biologist, I want to emphasize that the future cannot be foretold; no single path can assure success. Therefore, our course of action should not be bound to dogma; we should avoid positions of no-return, and we should hedge our bets on the future by encouraging pluralistic approaches to social problems. Of course we should set up some priorities based on existing knowledge and should not assume that the future will take care of itself.

Optimism has been defined as a belief that the future is uncertain; pessimism, that we are headed for certain disaster. I am calling for neither optimism nor pessimism, but an informed realism that includes *the ethical ingredient of humility*—a humility in which we admit that none alone knows how society should proceed; a humility that causes us to listen to the thoughts of others. We need a humility that is not merely a mask for incompetence but rather a humility that is willing to step over the disciplinary boundary, willing to criticize and be criticized, and willing to modify and evolve a cherished personal insight into an effective working hypothesis or an action policy.

In my opinion, "humility with responsibility" is the first rule of professional ethics and is "the basic bioethic." The freedom of the isolated specialist or group of specialists to ignore the needs of society is rapidly disappearing. I am thus advocating interdisciplinary groups composed of competent and responsible members who also have humility about their limitations. Of course, the nature, size, and orientation of the groups in which an individual operates will continue to vary. Additionally, in different groups, any individual may have different roles: leader, team member, or student. Such a person can develop a "pluralistic personality," to use a concept developed by Michael Novak.

The Pluralistic Personality and The Basic Bioethic

As the associate director of the Humanities Program of the Rockefeller Foundation, Michael Novak has seen many proposals that seek to bring the sciences and the humanities together. His own interests have been imprinted with the ethnic and symbolic aspects of American culture. In a collection of articles devoted to "The Future of Individualism," Novak discusses his concept of the communal "pluralistic personality" as an antidote to the individualistic "liberal personality," Novak supplements his concept with the phrase "passing over," by which he means "to enter empathetically into the sense of reality, story, symbols, and words of another." He says that "passing over" does not require abandonment of one's own position; it does require the tentative assumption of the other person's standpoint, for purposes of understanding and communication. When two persons successfully "pass over," each into the other's point of view, they can sometimes invent a new shared "third" world. Thus, long interdisciplinary or intercultural inquiries sometimes result in new forms of shared discourse. To me, the "pluralistic personality" represents the ideal of "humility with responsibility" that I refer to as the basic bioethic, balancing the needs of the individual and the needs of the society so that people can *be* individuals.

The Ideal-Contractualist Ethical Theory

Humility has long been a topic of religious and scholastic discussions on what constitutes a moral life. Ronald Green has published a penetrating article in the Journal of Religious Ethics entitled, "Jewish Ethics and the Virtue of Humility."

He writes, "If humility and meekness are singled out for special attention by the Rabbis, it is because their opposites, pride and arrogance, are viewed as the gravest threats to the moral life. The Rabbis continue the prophetic tradition in identifying the tendency of the strong to exploit the weak as the source of man's undoing, and in recognizing the moral danger of unchecked power, splendor, or success."

He continues, "The moral man lacking in humility strikes us as not completely good. But in what sense is humility a precondition of even being moral in the first place? Why is humility required to attain even the most fundamental moral attitudes and capacities?"

We need a humility that is not merely a mask for incompetence but rather a humility that is willing to step over the disciplinary boundary, willing to criticize and be criticized, and willing to modify and evolve a cherished personal insight into an effective working hypothesis or an action policy.

To answer this question, Green turns to the "ideal-contractualist ethical theory" developed, over a period of time, by Rawls, Gert, and Gewirth. This viewpoint looks upon morality as "a rational instrumentality for ordering and settling social disputes."

According to the ideal-contractualist ethical theory, Green continues, "It is assumed that human beings have at hand at least two methods for resolving conflicts of will, the method of coercion and the method of relying upon principles to which all parties to a dispute might freely agree. Only this latter method is truly moral. Clearly, for any long-term state of society the method of principled, moral settlement is most advantageous." But he questions the ability of pure reason to lead to a rational, ethical order: "How are principles to be generated which really represent the free and uncoerced choices of all parties to a social dispute? The problem becomes sharp if one notes that in any social conflict, a moral means of settlement might clearly disadvantage those who possess the power (whether physical, economic or intellectual) to order the dispute by coercion. . . . The individual who in his self-estimate cannot separate himself from his social or natural advantages will not likely be willing to submit his behavior to rules upon which he would agree if he knew nothing more about himself, or valued nothing more about himself, than what was common to him and other men. Lacking in this elementary humility such an individual will not prove to be moral."

He proposes that, "Humility, on the other hand, as the curious excellence in which one's own excellence is denied, admirably supports this rational, ethical construct."

"The excellence in which one's own excellence is denied" is a complex definition of humility as it pertains to professionalism. In the medical field, with which I am familiar, three behavioral models have been discussed. The Engineering Model portrays the physician as scientist, dealing only with facts. The Priestly Model portrays the physician as a frankly paternalistic agent, making the decisions, both factual and moral. Finally, there is the "Contractual Model" which calls for a sharing of decision-making responsibility between physician and patient.

We can project these models onto a more general level. Certainly, the potential exists for the professional to exploit the ignorance of the nonprofessional. I am advocating that professionals, in their contacts with the rest of society, should make every effort to be competent and responsible, but that they should habitually think in terms of dialogue. In other words, professionals must see the virtue of "humility with responsibility" or "the curious excellence in which one's own excellence is denied"; that is, is not exploitative. This brings us to another aspect of professional ethics.

The Morality of Benevolent Intervention

Science and technology have vastly enlarged the scope of professional intervention in human affairs, providing new choices of action which present ethical problems. How does the professional make his decisions when asked to intervene in the life of an individual client or in the life of a community?

In the area of human intervention in human affairs we all understand that malevolent intervention is evil. The real problem lies in the area of benevolent intervention, in which the professional can intervene to almost any extent within the financial capability and willingness of the client and still take the position that the client's welfare is being served. But, the issue of benevolent intervention goes beyond the matter of avoiding harm to the client. It involves the propriety of one individual or of society intervening in the life of an individual or group of individuals, even with the best of intentions, and even when requested to do so. Society is going to have to develop guidelines of intervention, to find the line that divides professional service from a custodial relationship that destroys human dignity. There remains the fact that, under some circumstances, the professional use of technology will seem totally dehumanizing. I suggest that such use of technology (as with an unconscious patient in an intensive care unit) is appropriate if two conditions are met: (1) the situation is assumed to be temporary, and (2) the individual has a good chance of living out a substantial fraction of his life span as a person after recovery. No doubt more guidelines could be formulated. The point is that the professional needs humility to receive the guidelines and to share the burden of decision with others, including the nonprofessional. How can professional education be modified to promote this ethical development?

Ethics in Professional Education

Recently, a group headed by Dr. Robert E. Cooke, now Vice-Chancellor for Health Sciences at the University of Wisconsin-Madison, called for informal inquiry "to explore the options which growing knowledge of man's biology and of human society have made possible, and to consider the standards and the legal and social frameworks by which the choice among these options should be guided." I have discussed the problem of professional ethics in my field of medical education with Dr. Cooke. In his opinion, and in mine, casual and informal ethical training will no longer suffice for the medical student. Instead formal presentation of the principles involved must be a part of the curriculum. Dr. Cooke specifically proposes organization of a Clinical Ethical Conference that would operate retrospectively. This weekly or monthly conference would be a powerful educational device and would foster development of new ethical appreciation for both students and mature professionals.

Studies in professional ethics will promote organized efforts to diminish the dehumanizing aspect of technology and professional detachment. We can look forward to a new era of professional service on behalf of survival and of human dignity.

* * *

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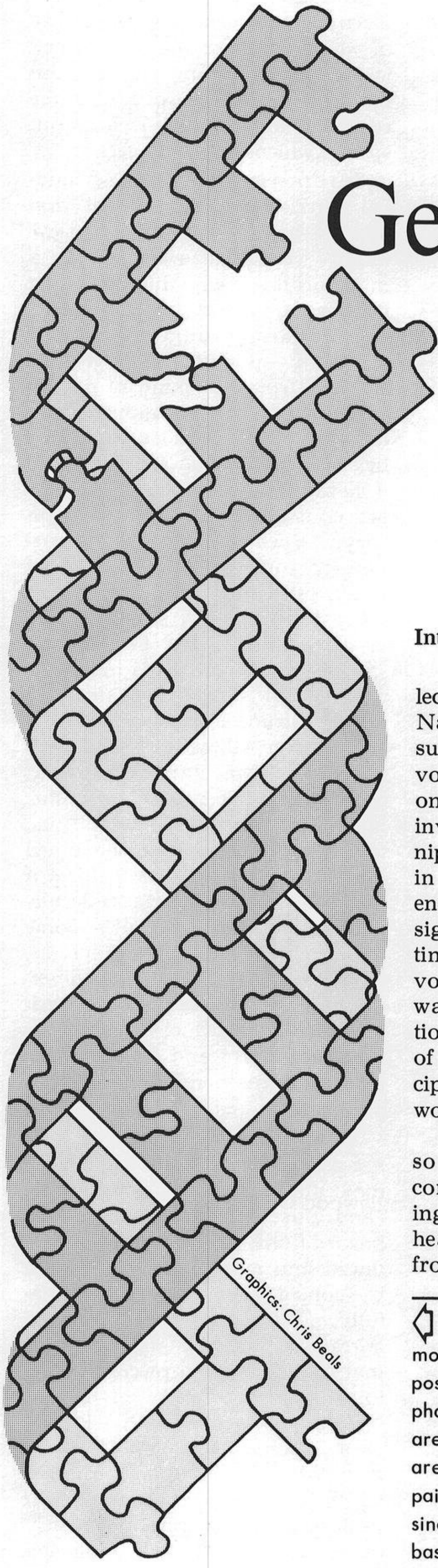


Genetic Engineering:

Research That Shouldn't Be Done?

by Wayne Becker

Introduction

In July, 1974, a group of molecular biologists sponsored by the National Academy of Sciences issued an unprecedented call for a voluntary worldwide moratorium on an area of biological research involving the kind of genetic manipulation frequently referred to in the popular press as genetic engineering. The statement was signed by eleven of the most distinguished American scientists involved in this type of research and was widely circulated by publication in *Nature* and *Science*, both of which are respected multidisciplinary science journals with worldwide readership.

The group was concerned not so much with long-range social consequences of genetic engineering, but rather with immediate health hazards which might result from the genetically altered bacteria that can now be produced in the laboratory. These scientists' proposals take the form of an appeal to colleagues throughout the world to follow their example in voluntarily and temporarily deferring two related kinds of experimentation and in exercising due caution before proceeding with a third type. In addition, the group, headed by Dr. Paul Berg, chairman of the Biochemistry Department at Stanford University, has suggested that the National Institutes of Health (NIH) appoint a committee to give practical guidance on the situation, and that an international meeting of scientists be convened early in 1975 to discuss appropriate ways of dealing with the potential biological hazards posed by these three types of research.

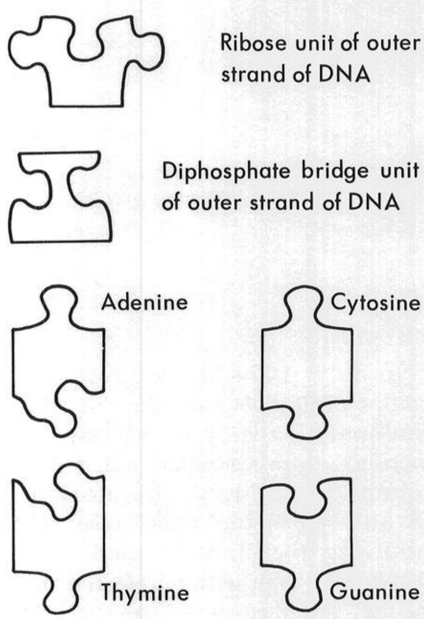
Before looking at the actual researches that have triggered the moratorium, we should note two important features: it is only *temporary*, an effort to buy time for careful thought before the research area gets out of hand; and it is *unique*, as a first time that researchers have ever voluntarily suggested that their own work ought to be stopped to allow contemplation of its social impact and potential hazard.

Artist's conception of the DNA molecule. The outer strands are composed of alternating sugar and phosphate units. The "rungs" of the ladder are composed of four base units which are complementary—adenine is always paired with thymine, guanine with cytosine. The variable sequence of these base units makes up the genetic code.

What Is It That's Being Banned?

To appreciate the implications of the ban, it is necessary to recall that all of the genetic information that specifies how an individual will look, function, and develop is stored in the DNA molecules of the chromosomes present in each of the cells of that individual. Specifically, the genetic information is encoded in the particular linear sequence of component molecules of the DNA just as the information in a sentence is encoded in the particular linear sequence of component letters. Thus, the color of your eyes, the height of a pea plant, and the nutritional preferences of a bacterial cell are all genetically controlled, and are all traceable to specific sequences of subunits in the long DNA strands that make up the genes of these organisms. In fact, the elucidation during the past fifteen to twenty years of the so-called genetic code and of the mechanisms for storing, copying, and expressing genetic information has been one of the most exciting chapters in the entire history of science. Beginning with the announcement of the double helical structure of the DNA molecule by Watson and Crick in 1953, our understanding of the molecular basis of heredity and gene expression has unfolded with a breathtaking rapidity, an elegance of technical advances, and a potential relevance to human health unparalleled in the history of science. And indeed, it is exactly these features—of the unfolding—that have now led to some qualified misgivings among those most intimately acquainted with the work.

A basic two-part principle of heredity has emerged from the past two decades' work. First, the genetic code is universal: the same DNA-based information-storage system or genetic alphabet is used by all forms of life—plant, animal, and microbial. Second, all organisms also use strikingly similar mechanisms for replicating, transmitting, and expressing DNA-stored information. This universality is very reassuring, because it allows molecular biologists and geneticists to carry out a wide variety of experiments on organisms like bacteria and fruit flies which are very amenable to laboratory manipulation, while still confidently expecting their findings to be broadly relevant to other organisms, notably man. However, this basic principle has also made possible a kind of research that is now giving at least some scientists cause for concern. For if the DNA molecule is the common vehicle for storing genetic information in all organisms, then chemically it becomes very easy to envision "hybrid" DNA molecules in which genetic information from two different organisms is present in the same piece of DNA.



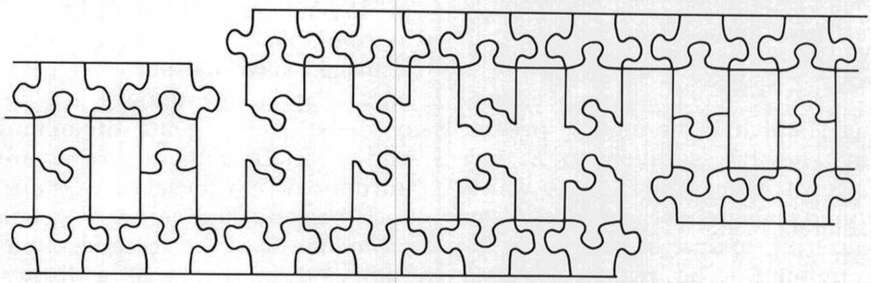
The exchange and rearrangement of genetic information is a routine phenomenon in nature, resulting in the appearance in offspring of traits that were not found together in either parent, but which occur together on the chromosomes of the offspring because of an exchange of DNA between two chromosomes. The crucial feature of such natural recombination of genetic information is that it almost always occurs only between individuals of the same species, and although it results in the rearrangement and continued mixing of genetic information within the species, it does not provide for the introduction of new genetic information from other species. Even the bacterial viruses, many of which can carry pieces of genetic information from one bacterial cell to another, are usually quite restricted in the range of bacterial species which they can infect.

It is precisely these strong natural barriers between species that are threatened by the new techniques which led to the call for a moratorium. For within the last two years, means have been discovered to move genes between species by splicing a piece of DNA isolated from one kind of organism onto the DNA obtained from another kind of organism. In brief, the technique makes use of a newly-discovered class of cellular constituents called restriction enzymes, which can snip the enormously long DNA molecules of living cells into manageable gene-sized fragments. Furthermore, these enzymes cut the double-stranded DNA molecule in such a way that a short single-stranded piece protrudes, creating a "sticky end" which will selectively adhere to the complementary "sticky end" of another molecule cut in similar fashion by the same enzyme. Thus, two DNA molecules can be joined together in a test tube to form a new and unique hybrid molecule. And if the two molecules come initially from two different species, the resulting hybrid or *recombinant* DNA molecule is an experimental novelty which could never occur in nature and whose genetic properties are therefore not readily predictable.

One further technical note is necessary. Such recombinant DNA molecules are of biological interest (and pose a potential biological hazard) only if they can be introduced into a cell in which they will be copied and transmitted faithfully. For bacteria, this criterion is readily met by making sure that one of the two pieces of DNA joined together in the test tube is a piece of bacterial DNA known as a *plasmid*. A plasmid is a segment of DNA in a bacterial cell which is not a part of the regular bacterial chromosome, but which, once inside the cell, replicates in synchrony with the bacterial chromosome, with copies passed to each daughter cell at every cell division. Plasmids (or *episomes* as they are also called) are natural, though dispensible, components of many bacterial cells. They are infectious, in the sense that extra copies can be passed readily from a plasmid-containing bacterial cell to a cell which did not previously contain such an element. The existence of plasmids has been known for more than twenty years, and naturally-occurring plasmids, especially those referred to as *sex factors*, have played an important role in the study of bacterial genetics. Sex factor plasmids are useful because they can be reversibly integrated into the bacterial chromosome itself, and when such an integrated plasmid returns to its autonomous form, it may bring a small piece of the bacterial chromosome with it, to the considerable delight of bacterial geneticists, who have found numerous ingenious ways to exploit this property in their studies. That plasmids can carry additional genetic information with them when they infect bacterial cells is not especially noteworthy. What is noteworthy is that the extra information need no longer come from other cells of the same bacterial species—the restriction enzyme technique now allows scientists to attach almost any kind of genetic information onto such a plasmid. For example, the introduction into bacterial cells of genes from frogs and from fruit flies is already an accomplished fact.

A valid question at this point might well be *why*—why would anyone want to make such hybrid DNA molecules and then contrive for the deliberate introduction of foreign genes into a hapless bacterium? The immediate answer, of course, is that such experiments are likely to facilitate greatly the answering of fundamental questions of interest to geneticists and molecular biologists. Potentially, however, there are great practical implications to such experiments, for they suggest a possible means for the amplification of rare but desirable biological molecules. Consider the case of insulin, for example: if it were possible to isolate the gene for insulin from human DNA, link it to a bacterial plasmid and infect bacterial cells with it, it should be possible to grow up vats full of bacterial cells, all containing the gene for human insulin. And if such foreign genes could be expressed in a bacterium, then, in theory at least, one would have vats full of cells all making harmful to man. Ominously enough, new genetic techniques offer a theoretically possible way of accomplishing precisely that end.

However, it was not such hypothetical misuses of their knowledge that prompted the scientists to set an embargo on their work. The ban was motivated by and directed toward certain experimental programs already in progress. In the opening paragraphs, the Berg



The "sticky end," created when the DNA molecule is cut using restriction enzymes, is composed of adenine-thymine units—two adenine units followed by two thymine units on one strand; two thymine followed by two adenine on the other.

insulin, which would almost certainly revolutionize the commercial production of this critical substance. In a similar vein, Dr. Donald Brown of the Carnegie Institution of Washington already has plans to put into bacteria the set of silk moth genes that govern the synthesis of silk proteins, an experiment which is likewise not without considerable commercial significance.

Unfortunately, the same stretch of imagination which allows us to envision vats full of bacteria making insulin or silk can also conjure up more sinister applications, since these techniques could with equal ease be used to transfer genes for the production of deadly bacterial toxins or for antibiotic resistance or for pathogenic viruses into bacteria already known to infect man. We dare not forget, for example, that the same country which supports the work of most of the signatories of the moratorium proposal also has invested millions of dollars at the U.S. Army's biological warfare laboratory at Fort Detrick, Maryland, in attempts to improve upon the lethality of viruses and bacteria

proposal speaks of the introduction of genes from frogs and fruit flies into bacterial cells and states:

> Several groups of scientists are now planning to use this technology to create recombinant DNAs from a variety of other viral, animal, and bacterial sources. Although such experiments are likely to facilitate the solution of important theoretical and practical biological problems, they would also result in creation of novel types of infectious DNA elements whose biological properties cannot be completely predicted in advance. There is serious concern that some of these artificial recombinant DNA molecules could prove biologically hazardous.

This concern for the biological hazards of such experiments is heightened because the standard bacterial species used experimentally in genetics laboratories is the bacterium *Escherichia coli*, whose native habitat is not the geneticist's test tube but the human intestinal tract. The average healthy human routinely carries around with him a flourishing intestinal culture of *Escherichia coli*, which is normally quite an innocuous guest. What concerns the Berg committee is the possibility—remote but finite—that bacteria endowed with hybrid genes for experimental purposes might escape the test tube and inadvertently infect the human population, with unknown and possibly catastrophic results. From this point of view, the Berg committee sees two types of experiments as especially risky, and their self-imposed moratorium is restricted to these two cases:

Type 1. The first type of experiment which is banned at present involves the addition to *E. coli* cells of bacterial genes which would confer either ability to make bacterial toxins or resistance to antibiotics. The reason for this trepidation should be quite clear: if a bacterial species which is a normal but nonpathogenic inhabitant of the human gut were suddenly able to make some sort of potent poison, the effect could be an epidemic of bacterial infection which might run like wildfire through the human population, especially if such bacteria had also been experimentally endowed with genes conferring resistance to the antibiotics that represent our first line of clinical defense against such infections. The threat of antibiotic resistance genes is especially great, since heritable resistance to drugs such as penicillin, streptomycin, chloramphenicol, and sulfonamide is already known in bacteria; such genes can in fact be carried and transmitted by special plasmids. Because *E. coli* is capable of exchanging genetic information with other types of enteric bacteria, some of which are known human pathogens, the deliberate experimental introduction of drug resistance genes into *E. coli* cells raises the specter of the accidental escape of such cells and eventual transfer of the drug resistance genes to known pathogens, thereby creating "superstrains" of pathogenic bacteria which would be invulnerable to the usual drugs employed in clinical chemotheraphy. Thus, the Berg committee recommends voluntary deferral of experiments which involve the "construction of new, autonomously replicating bacterial plasmids that might result in the introduction of genetic determinants for antibiotic resistance or bacterial toxin formation into bacterial strains that do not at present carry such determinants."

Type 2. The second type of experiment included in the voluntary moratorium involves the linkage of DNA from animal viruses to autonomously replicating DNA elements such as bacterial plasmids. Again, the danger is quite obvious: if the genes of animal and especially human viruses are introduced into bacterial cells and such bacteria inadvertently escape the confines of the research laboratory, there would be a distinct risk of increases in the incidence of diseases caused by such viruses, including cancer.

In addition to outright bans on these two fields of experiment the proposal also urges that experiments which link animal DNAs to bacterial plasmids (such as those involving the genes for insulin or silk protein) "should not be taken lightly."

It is important to keep in mind that the committee's appeal was not for a permanent prohibition on these specific types of experimentation, but rather for a voluntary deferral of such work "until the potential hazards of such recombinant DNA molecules have been better evaluated or until adequate methods are developed for preventing their spread." Toward that end, the committee called for two further actions: the establishment by the National Institutes of Health (NIH) of an advisory committee to evaluate the hazards of such experiments and develop procedures and guidelines to safeguard human and other populations; and the convening of an international meeting of scientists in February, 1975, "to review scientific progress in this area and to further discuss appropriate ways to deal with the potential biohazards of recombinant DNA molecules."

Reaction to the Ban

Reaction of the scientific community to the recommendations has been quite favorable. The temporary deferral of Type 1 and 2 experiments seems to be firmly endorsed by most scientists, but there is less general accord on the cautions about insertion of animal genes into bacteria. Some feel that such experiments should also have been covered by the ban; others believe that such experiments present no health hazard. Dr. Wallace P. Rowe, of the National Institute of Allergy and Infectious Diseases, feels that these experiments should be done only when bacteria are found that are unable to infect man. On the other hand, Dr. Donald Brown, who wants to insert the silk protein genes into bacteria, was quoted as saying, "I can't see how this could cause any conceivable danger to anybody," though he has been confronted with the objection that someone infected with his silk gene-containing bacteria might end up with a "gutful of silk!"

A more fundamental objection to the ban was voiced by Dr. Joshua Lederberg of Stanford University, himself a Nobel laureate in genetics, and, incidentally, a former member of the Wisconsin faculty, who fears that the formalization of such proposals will lead to further impediments on research and remove the ultimate decision from the hands of scientists. Countering this viewpoint was the reaction of Dr. Jonathan Beckwith of Harvard Medical School, who is "happy to see this precedent set because it will raise a debate about academic freedom to pursue research one wishes."

Beyond the Ban

The immediate consequences of the ban seem clear-cut and commendable: selected research, of potentially hazardous biological nature, has been temporarily postponed, and creation of possible "bad molecules" of DNA has been delayed and perhaps prevented. Of far greater potential significance are the broader issues raised in the comments of both Lederberg and Beckwith, which begin to touch upon the sovereignty of the scientific investigator and the possibility of restriction, self-imposed or otherwise, on the freedom to research. Viewed in this framework, the discussion quickly transcends the narrow issue of specific kinds of genetic experiments and the particular hazards they may pose, and encompasses instead a broad sphere of research activities which impinge, directly or indirectly, upon society.

It was to this broader concern that Dr. Beckwith and his colleagues at the Harvard Medical School spoke in both the scientific and the popular press in late 1969, following the publication of an elegant paper describing the first isolation, in Beckwith's laboratory, of an actual gene, the so-called *lac* operon of *E. coli*. Beckwith and his colleagues used the occasion to give public expression to their concern about the potential for the misuse of genetic manipulation and of science in general. Their pronouncements were given wide, almost sensationalistic publicity, evoking the following comments from the editors of the British journal *Nature* the week after their paper had appeared:

> This week has seen a great deal of excited speculation about the meaning of the report, published in *Nature* last week, that Dr. Jonathan Beckwith and his colleagues at the Harvard Medical School have been able to isolate the so-called *lac* gene from the genetic DNA of the similar *E. coli* bacterium. A part of the trouble seems to have been a confrontation between the authors of the research and newspaper correspondents in Boston at the weekend; what seems to have caught the popular fancy is the awesome prospect of what might be done with genetic engineering if ever such a practice were possible. The same theme seems to have been seized on elsewhere as well—the London newspapers at the beginning of the week were also preoccupied with the false assumption that it could only be a short step from the isolation of a gene to the manipulation of human inheritance . . . . So why are people anxious to read sinister messages in this new development? The question is perplexing because it reflects an implicit change in the public mood. Indeed, the tendency to seek sombre consequences for scientific discoveries is a comparatively recent event, a thing of the sixties and not simply of the nuclear world. Two dangers lie concealed in this. First, the progress of science itself may be interrupted or even halted by excessive fears of the consequences. Second, as in the tale of the shepherd boy who cried wolf too often, exaggeration may dull the sensibilities of society to real dangers. It is for scientists to help distinguish between a responsible concern for the social consequences of what they do, and an exaggerated fear of them.

That editorial comment was followed four weeks later by a rejoinder from the Beckwith group, which read in part:

> We wish to reply to your comments on the publicity surrounding the appearance of our article on the isolation of pure *lac* DNA. To a certain extent, your comments were perfectly correct. The press greatly inflated the importance of our particular piece of work. This was due in part to some of our own statements, which were misleading. It is true, however, that progress in the field of molecular genetics in the last few years has been extraordinary. We felt that the isolation of pure *lac* operon DNA was a graphic, useful, and easily understood example of that progress. We did not publicize our work in order to add to our own or Harvard's prestige or to make a plea for more money for basic research . . . . On the contrary, we tried to make the following political statement. In and of itself, our work is morally neutral—it can lead either to benefits or to dangers for mankind. But we are working in the United States in the year 1969. The basic control over scientific work and its further development is in the hands of a few people at the head of large private institutions and at the top of government bureaucracies. These people have consistently exploited science for harmful purposes in order to increase their own power . . . . Let us simply point out to those who feel we have ample time to deal with these problems that less than 50 years elapsed between Becquerel's discovery of radioactivity in 1896 and the use of an atomic weapon against human beings in 1945. As to the specific issue of genetic engineering, we cannot predict the future. But who in 1896 could have foreseen the weapons of mass destruction which now threaten us all? . . . As we see it, scientists are obligated to inform the public about what is happening in their secluded fields of research so that people can demand control over decisions which profoundly affect their lives. If our arguments mean that "the progress of science itself may be interrupted," that is an unfortunate consequence we will have to accept. It certainly should not inhibit us from speaking out on crucial issues.

Nature then closed the debate with an editorial comment of its own, which included the following words:

> It is worth spelling out just why some of these gloomy prospects must not be taken too seriously. Where the horrors of biology are in question, one of the most simple truths is that there can be no simple assurance that the rudimentary manipulations with bacteria on viruses which are now possible or

within sight will certainly be applicable to mammalian systems. Even if they were, however, nobody can know what use would be made of them. It is possible to conceive of ways in which combinations of manipulations in molecular biology might allow compassionate medical people to make good some kinds of genetic defects but even this is not yet the kind of prospect which could be held out as a promise to those who might benefit. What justification can there be for supposing that there may be a more immediate threat in the perversion of an unknown technique in the hands of a medical profession which, for all its faults, has so far consistently worked in a beneficient direction?

There is, to be sure, quite a contrast between the cautiously worded appeal of the Berg committee for a temporary ban on specific genetic experimentation, and the highly political, almost inflammatory declarations of the Beckwith group, with the accompanying editorial exchange. Yet I juxtapose them here because each speaks, in its own way, to a question which scientist and humanist must confront together: is there research which should not be done, either because of the immediate technical hazard which it poses, or because of possibilities for misuse which its findings might present? And mere formulation of such a question immediately suggests two corollary questions: (1) if so, who is to decide, and what criteria should be used; and (2) could a ban on specific kinds of research, whether imposed by scientists or by society, really be enforced, and, if so, how?

This decision-making would seem to demand an insight, a foresight, and a Solomon-like wisdom which are not among society's most conspicuous gifts. To use the example raised by Beckwith: who —at the time of Becquerel's discovery of radioactivity in 1896—would have been able to predict the atomic bomb of 1945? And given the tremendous benefits which society has also derived from the exploitation of atomic energy, who would be prepared to say, even *ex post facto*, that Becquerel's work should or should not have been regulated or restricted? Similarly, we must inquire whether we possess, in the area of genetic engineering, the insight and wisdom to allow us to balance the benefits which might accrue from such research with the possible hazards and threats it might pose. Clearly, the signatories of the Berg moratorium have provided their own answer on a temporary, pragmatic basis. It remains to be seen what the eventual results of their proposal will be.

Of equal significance is the question concerning enforcement of restrictions on research. For the moment, the plasmid ban is apparently effective because it is clearly an interim measure, quite narrowly focused on the particular health hazards posed by specific classes of experiments, and framed so as to command the maximum possible agreement among the limited portion of the scientific community capable of conducting such studies. As Berg said last summer, "Anybody who goes ahead willy-nilly will be under tremendous pressure to explain his action." The real test of the embargo will come when and if the upcoming conference decides that the hazards are real and substantial enough to warrant an indefinite extension of the ban. An even more severe test of enforcement would come should the restrictions be established by an area of society distinct from the scientific community.

Clearly the questions are onerous, and do not admit to easy solutions, since only rarely has the sovereignty of the researcher been questioned or the relentless progress of scientific investigation been called into scrutiny. Yet both scientist and nonscientist will increasingly have to face these questions. As research impinges ever more directly on human welfare, the questions become in turn ever more relevant and pressing; we will have to form an opinion or to take a stand. To continue to avoid the issues is, of course, one response; indeed, it is an immensely popular response to a host of society's problems. As always, we must inquire soberly whether it is an intelligent or useful response.

There has probably never been a time in the history of human society when that society was more profoundly influenced by the research going on in its laboratories than we are right now. Further, there is probably no area of research with greater potential impact upon the fabric of that society than the area of molecular genetics. We ought therefore to follow closely the reactions to and outcomes of exploratory attempts at research regulation, such as the current proposals on plasmid engineering, for they may well portend much for the future.

Author's note: The international meeting of scientists (convened to review current research and experimentation with recombinant DNA molecules) was held in Pacific Grove, California, during the last week of February, 1975. Participants agreed on a system for classifying experiments by potential risk involved, with appropriate safety precautions to be observed at each risk level. Agreement was also reached on safeguards for selection of bacterial host cells and of carrier DNA molecules to minimize the risk posed by the new technology. Thus, the moratorium has been replaced by a series of guidelines which appear well-conceived and workable, and which should meet the needs of both science and society.

World Food Supplies:

A Technological Race with Population Growth

by John Ross

For millenia agriculture has been the thin green line of defense for mankind against starvation. There are a few hunters and gatherers, even today, who are independent of agriculture. But only a few.

From time to time, when agriculture has failed because of environmental change or social disruption, some portion of the population has starved. But food production has generally been able to match population growth, at least at subsistence dietary levels.

The last 100 years have produced three striking phenomena:

(1) A rapidly increasing world population, at an exponential rate.

(2) A rapid urbanization of population, detached from agricultural lands, with a lengthened food chain.

(3) A technical explosion in agricultural production in some, but not all parts of the world, with greatly increased manipulation of the agricultural ecosystem.

The technical explosion in agriculture has produced at least two subphenomena:

(a) A rapid trend toward mono-cultures with ever rising "dikes" built around the system to protect food production from the environment.

(b) The creation of a "world food supply," at least in the mind's eye, if not in fact. The net result of this is an increasing food interdependence between nations and regions, with some regions in surplus and some in deficit.

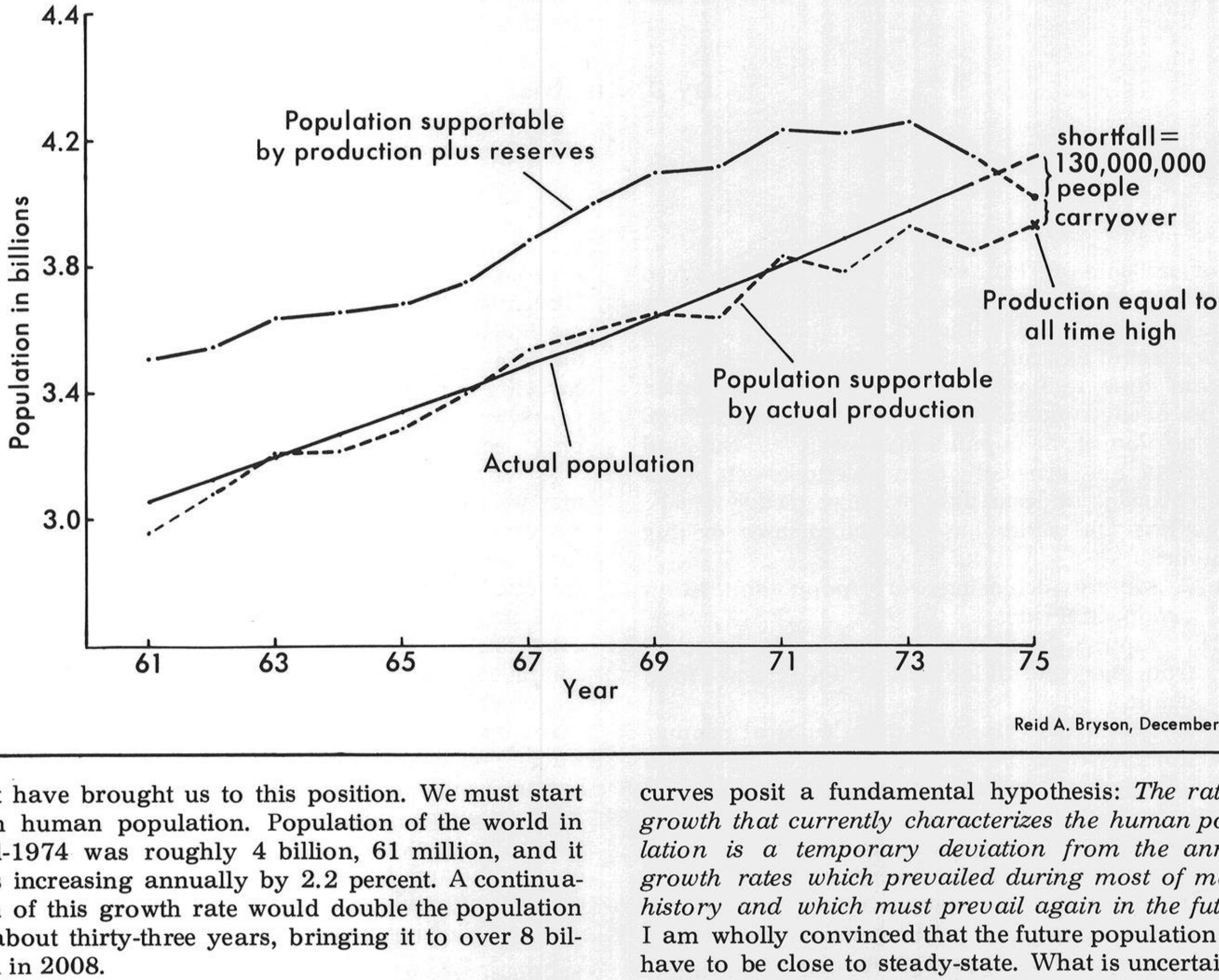
While these things have occurred, we have been blessed, or perhaps cursed, with the most benign climate for agriculture in at least the last thousand years and perhaps longer.

We must ask whether or not the world is approaching or has exceeded the earth's food carrying capacity. This concept of carrying capacity was assessed by a group of scientists in a Congressional Hearing on November 25, 1974, and the outlook was largely pessimistic. Grant Cottam, Professor of Botany from the University of Wisconsin-Madison, said, "The carrying capacity of the world is probably less than years we managed to survive without serious famine only because of the presence of a large food reserve. . . . With no reserves left at this time, there is no way that we can avoid massive famine." Garrett Hardin, University of California-Santa Barbara ecologist, said that "if the additional population is not to be subjected to ever increasing misery, money as well as food must be provided, and need for capital grows some three times faster than the population." He continued, "The right to have children implies the responsibility to feed them." Finally, Wayne H. Davis, a zoology professor from the University of Kentucky said, "You cannot solve a hunger problem by feeding hungry people."

These statements indicate that some people are beginning to think what was once unthinkable, they also imply that any policy concerning food distribution is linked to effective birth control programs.

The following chart, which covers the past ten years, shows that the world's population has increased from just over 3 billion to just over 4 billion. Annual food production wavered just above and just below the population until toward the end of the period when it fell off; the green line started to weaken. We entered this time period with strong food reserves. On the other hand, we entered 1975 with a grain reserve of under ten days' supply, and 1975 could end with a net shortfall of grain supplies equal to the needs of 130 million people. The immediate food situation is frightening, and it is improbable, I think, that policy of any kind could greatly alleviate the situation this year.

Such a gloomy scenario makes rationality difficult, but we must try to understand the events and trends



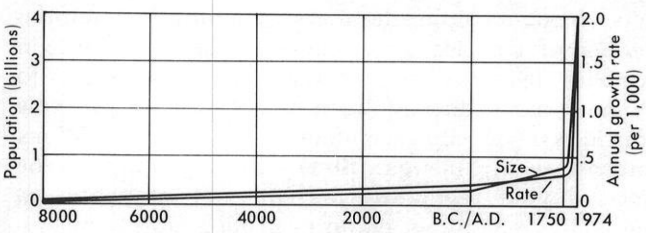
Reid A. Bryson, December, 1974.

that have brought us to this position. We must start with human population. Population of the world in mid-1974 was roughly 4 billion, 61 million, and it was increasing annually by 2.2 percent. A continuation of this growth rate would double the population in about thirty-three years, bringing it to over 8 billion in 2008.

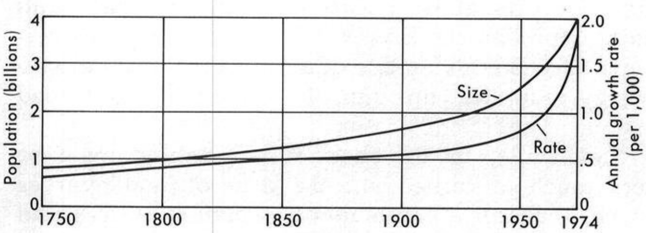
We can get a time perspective on this growth with the following charts. The first depicts a span of eight thousand years, the second, just over two hundred years. The scale on the left is the total world population in billions; on the right is the annual rate of growth as a percentage. The message of these graphs rings like a big brass bell: the current rate of population growth is an extremely recent phenomenon. The first graph takes off in pre-history roughly with the advent of agriculture, and some population increase registers, but it is not until much later, when some control of public health and the capture of energy occur that the exponential curve appears.

It seems to me that the sheer mathematics of these curves posit a fundamental hypothesis: *The rate of growth that currently characterizes the human population is a temporary deviation from the annual growth rates which prevailed during most of man's history and which must prevail again in the future.* I am wholly convinced that the future population will have to be close to steady-state. What is uncertain is at what level the future population will stabilize and what combination of fertility and mortality will sustain it. But fertility and mortality will vary together as we reach the food-carrying capacity limits. Note that, by implication, I have ruled out the possibility of unlimited increases in food production.

As we know, there is wide difference among fertility patterns in various parts of the globe. It shows up almost as a geographic difference—low fertility in temperate zones versus high fertility in equatorial regions, but the difference is pegged to questions of economic development. Starting in the nineteenth century, the death rate declined in countries whose "economic growth" enabled them to mount programs of



During most of the period since the introduction of agriculture the rate of population increase has been modest.



Period since 1750 is characterized by rapid and rapidly accelerating growth in the size of the world population. This period represents only about .02 percent of man's history, yet 80 percent of the increase in human numbers has occurred during it. Moreover, within this period the rate of increase has climbed most dramatically in very recent times: It has doubled in the past 25 years.

public health, and a decline in fertility has tended to follow the mortality drop, not rapidly, but within several decades. At present there are about thirty countries in the world that meet economists' definitions of developed, and virtually all of these have birth rates below the replacement level. As examples, the 1974 birth rate for the U.S. is 1.49; for West Germany (the lowest of any), it is 1.02.

By contrast, parts of the world that lag in economic development have an average birth rate of 3.8, and three-fourths of the countries on the globe belong in this category. As examples: the birth rate in Egypt is 5.0; in Mali, 5.0; in Bangladesh, 4.7; in India, 4.3; in Mexico, 4.5; in Peru, 4.2. The technology of death control—cutting down infant mortality and having some controls on diseases—has reached the underdeveloped lands, but a decline in fertility has not followed after. The great question is: how realistic is it to hope that economic development will come to major sections of the world in time to exert its historical effect of lowering fertility rates? As a theoretical exercise in estimating the hopes for rapid development, I have put together some figures for Italy and India, using energy consumption figures rather than income as the more significant index. Italy, with a birth rate of 1.6, consumes 20,000 kilowatt hours (kwh) annually per capita; India, with a birth rate of 4.3, consumes 1,500 kwh per capita. It would require a 1,330 percent increase for India to match Italy's present energy use, but the fact is that it has taken some seventy years for India to double its energy production. These two countries are an arbitrary choice; I might have paired various others to illustrate the same theme. If I had taken the U.S. instead of Italy as the developed country in this pairing, the contrast would be even more extreme: India would need to increase energy 5,700 percent per capita to reach the U.S. level of use.

If we pin hopes for solving the population-food equation solely on taking better agricultural techniques to underdeveloped countries, we must face the fact that there is no evidence whatever to indicate that improvement in food supply by itself brings about lower fertility rates. Instead, data of recent years seem almost to insist on this finding: *Population rises to the ceiling imposed by food supply.* Whereas there were strong gains in world agriculture between 1951 and 1971, the countries in Asia, Africa and Latin America barely kept food production ahead of population.

We entered the 1970s almost euphoric about food supplies. Grain production in the United States after World War II had increased spectacularly: between 1950 and 1973, U.S. corn production rose from 38.2 bushels per acre to 95.5 bushels, and wheat rose from 16.2 to 32.7 bushels. The idea of extending this improvement to other countries became a worldwide cause. At the same time the Western world was exporting antibiotics and insecticides for public health care, it was also exporting agricultural expertise. The former was successful in reducing death rates; the latter has been less successful in raising the total calories per person and unsuccessful in improving the protein diet of the hungrier peoples. Even the Green Revolution, which promised such miracles, seems to have been a disappointment. To be sure, the protein diet of the better fed, developed nations has improved markedly, and this is part of the general imbalance of food supplies. Although the overall world production of cereal grains doubled between 1951 and 1971, more than half the increase was absorbed by the richest 30 percent of mankind (much going into cattle and hog feed), while less than half was spread unevenly among the poorest 70 percent.

Now we return to our major dilemma: We shall have to double the amount of our present food production by the end of the century if we are to feed 7 to 8 billion people. Can we do this?

While there have been some technological advances in agriculture in the tropical areas, with possibilities for more, much of tropical food production is still not technically oriented. There are bright spots; for example, since 1951, India has increased the area of land under cultivation by 20 percent, doubled the irrigated area and raised fertilizer about 30-fold. However, despite a population three times that of the U.S., India uses less than one-sixth the amount of fertilizer used here, for fertilizer depends on ability to buy.

Massive industrial and capital inputs have really not been made in many countries. High technology agriculture requires vast commitments of fossil energy, and up to $2500 of capital to bring a "new" acre of land into production. It is clear that the differential energy consumption between the United States and some of these other countries is not entirely profligate behavior; a healthy slug of it is in agriculture.

There is a welter of conflicting information on aspects that will determine agricultural growth such as the amount of arable land or the land's capability to respond to either conventional or revolutionary technological or institutional improvements. I cannot make any authoritative prediction on the world's ability to greatly increase food production, nor can I be unguardedly optimistic. Recent charts on agriculture in the United States carry warning signals. For instance, the intensified use of complete fertilizers through the last sixty years now shows a leveling off, the classical curve of diminishing returns. A similar phenomenon appears in livestock reports, where both cattle and hogs show a declining efficiency in converting feed energy to food energy.

These warnings relate to conventional agricultural systems. Two revolutionary possibilities are worth noting. Work is under way at the University of Wisconsin to upgrade the availability to human beings of the rich and relatively untapped protein supplies in crops like alfalfa. The idea here is to skim proteins directly from a forage crop not now considered directly consumable by humans. Work under way at Michigan State University hints at the possibility of regulating the efficiency of photosynthesis by regulating photorespiration, implying optimal nutrient production by plants.

Both of these could be quantum jumps in environmental control of food production and might well be better strategies, with fewer environmental side affects, than the present strategies of control of plant and animal predators. However, these concepts are perhaps as nebulous as are quantum breakthroughs in energy supplies through, for example, controlled fusion.

Meanwhile, in the short run, mankind must be very much concerned with the issue of food reserves which, through a combination of natural forces and policy, have been gravely reduced. In early 1973 A. H. Boerma of the UN Food and Agriculture Organization proposed that all governments—exporters and importers—be asked to hold certain minimum levels of food stocks to meet international emergencies. In regular consultations, participating governments would review the food situation, judge the adequacy of existing stocks, and recommend necessary actions. International agencies such as the World Bank, the International Monetary Fund, and the FAO would help poor countries establish and maintain the reserve stocks necessary for self-protection against crop failures. The World Bank pledged support for the FAO plan. The United States is in the eye of the hurricane on this issue, as this chart demonstrates.

The Changing Patterns of World Grain Trade
Millions of Metric Tons
Net Exports (+) or Imports (—)

Region	1934-38	1972
North America	+5	+84
Latin America	+9	—4
Western Europe	—24	—21
East Europe & USSR	+5	—27
Africa	+1	—5
Asia	+2	—35
Australia	+3	+8

North America and Australia alone remain as net exporters in 1972. Recently I have seen conflicting figures on the world's food dependence on North America which range from 10 percent to 25 percent. Even taking the lower figure, North America's surplus is the food needed by 400 million people. A 10 percent decline in that surplus would spell starvation for 40 million. No wonder the eyes of the hungry are upon us. In the relatively short run, this means tremendous pressure on U.S. agriculture to increase its productivity.

One of the underlying assumptions in food production during the past two decades has been confidence in technological control of environmental parameters. We have focused on disease control, nutrition values, and genetic manipulation, paying little heed to the possibilities of climatic change.

It is now clear that we can ignore climate only at our peril. The past few years have demonstrated some climatic extremes. In 1970, 1972, and 1974 bad crops occurred in so many of the world's food-producing areas that stocks were run down severely, and grain prices rose to unprecedented levels. The events that caused bad crops were very mixed—drought in some areas, floods in others, frost in summer, late winter snows. These irregularities may well be a part of a series of step-like changes accompanying a general cooling trend that has gone on for about three decades. The most dramatic of these may have been the 12 percent increase, between 1971 and 1972, in the area of winter snow cover and pack-ice in the Northern Hemisphere.

It is a vital matter, from the point of view of world food production, to get answers to three sets of questions:

(1) What is the real nature of the recent climatic instability? Is it due to a major and persistent flip to a glacial mode, or is it something that will quickly correct itself?

(2) What is the probable crop yield for the next few years in the world's major granaries? Will 1972 and 1974-style extreme events repeatedly cause large-scale losses, or will it again be possible to assume that surplus conditions will follow each rise of prices?

(3) If the changed climate continues, how should scientists respond in devising an agricultural system that is optimally adapted to the new conditions?

The climatological view was summarized by an international group of scientists meeting in Bonn, Germany, in May of 1974. They said:

> A particular world climatic pattern, generally thought of as normal, has prevailed during the lives of most people now on the earth. During this time the population of the world has more than doubled; the resource demands of affluence have increased; the easily arable land has been occupied; and the barriers to migration have increased.
>
> The studies of many scholars of climatic change attest that a new climatic pattern is now emerging. There is a growing consensus that the change will persist for several decades, and that the current food-production systems of man cannot easily adjust.
>
> We believe that this climatic change poses a threat to the people of the world. The direction of the climatic change indicates major crop failures almost certainly within the decade. This, coinciding with a period of almost non-existent grain reserves, can be ignored only at the risk of great suffering and mass starvation.

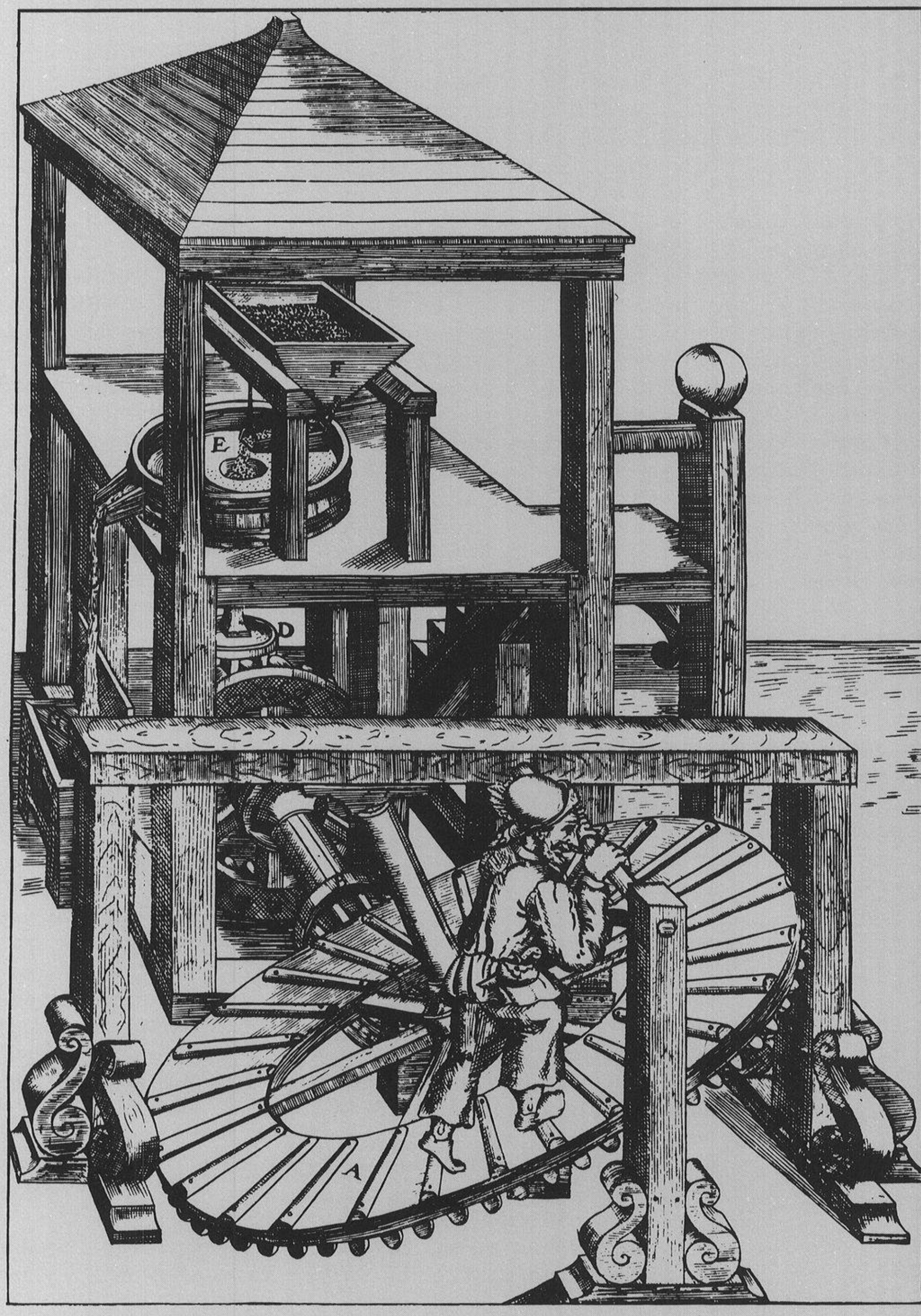
This report suggests a gloomy picture of sharp population drops from food shortages. Perhaps the worst will not happen, perhaps the world will show amazing resilience. But we cannot take a food status quo for granted; we must be steadily aware of these two points:

(1) The food system is not invulnerable to environmental change.

(2) We are entering an era of relative scarcities in food and related resources, whether that is arable land, nitrogen fertilizer supplies, oil to power farm machinery, or the calories available per capita. These scarcities are a function of increasing population, increasing per capita demands, and declining critical resources. Adjustments must be made: we must deal with the mechanics of production and the moralities of distribution.

I do not predict a debilitating decline of technological civilizations. I have great confidence in engineers and economists. But what seems inevitable to me is a change in growth rates: growth rates of population, and of energy consumption. De-escalation of these rates of growth is the critical sociological issue of our time.

The Humanists Respond--



Robert Kimbrough

When Bacon divided thinkers into Philosophers and Scientists, he advanced the cause of science, but did not, as he had hoped, encourage the advancement of learning. Because life is a totality and a continuum, we must live wholeheartedly and openmindedly within its processes in order to make life comprehensible and bearable. I should like to elaborate these assertions through my disciplinary specialty, literature.

John Donne, writing at the beginning of the seventeenth century, composed his poem, "The Ecstacy," as a satire on the Neoplatonic model of man as divided between body and soul—a yoking together of the earthly and the material with the heavenly and the spiritual. But, living in a moment of extremely dramatic theoretical shift within the scientific world, Donne had no sufficient model to work from, and had to exploit the old in order to say something significant about the nature of human life and instinctive endeavor. Toward the end of his poem Donne becomes quite serious for a moment when he talks about man and woman in the act of love; his words have both a literal and far-reaching allegorical significance:

> Our blood labors to beget
> Spirits as like souls as it can,
> Because such fingers need to knit
> That subtle knot which makes us man.

The image of persons laboring to beget something like fingers that can examine and understand, tie and untie, that incomprehensible thing called man is a dramatic concept; Donne catches both the organic thrust of life and the human attempt to comprehend, even direct, the process of life.

Thanks primarily to the so-called romantic rebellion or revolution, during recent centuries, we can almost accept the concept of the wholeness, the completeness of man; we can almost realize the entirely metaphoric nature of the phrase, "body and soul." But we are still prisoners of the old model. We have split the members of this group into Scientists and Humanists, assuming the one to be concerned with the material aspects of life, the other with the spiritual. But "body" and "soul" are merely labels for aspects of the whole—aspects which in function feed back into the whole.

Shakespeare's play, *The Tempest* (in many ways a general allegory of life in this world), contains a specific allegory concerning the question that we have been considering. The main character is Prospero, a product of European humanism—a bookish, scientific man so caught up in the life of the mind, in the mastery of knowledge, that he was quite easily cast out of his rightful place in society as the Duke of Milan and cast up with his daughter, Miranda, on a lonely island. The only native inhabitant is a creature of darkness, Caliban, an offspring of the devil and a witch. Prospero, with his mastery of the elements through the applied power of his learning (his books survived with him) symbolizes the spiritual, the intellectual; Prospero is a product of nurture. Pre-Darwinian Caliban is a product of nature, the ooze of nature—earthy, smelly, instinctive, merely existential—a symbol of man's bodily side. Prospero, white westerner that he is, immediately claims the island to be his, and pedant that he is, immediately sets about "the education of Caliban."

Caliban speaks:

> This island's mine, by Sycorax my mother,
> Which thou tak'st from me. When thou cam'st first,
> Thou strok'st me and made much of me; wouldst give me
> Water with berries in't; and teach me how
> To name the bigger light, and how the less,
> That burn by day and night: . . .

To name, the power of the word, to distinguish, to label, to sort out.

> And then I loved thee
> And show'd thee all the qualities o' the isle,
> The fresh springs, brine-pits, barren place and fertile.
> Cursed be I that did so! . . .
> For I am all the subjects that you have,
> Which first was first mine own king.

I was happy, I was master unto myself, I was contented. Prospero responds:

> I pitied thee
> Took pains to make thee speak, taught thee each hour
> One thing or other: when thou didst not, savage,
> know thine own meaning, but wouldst gabble like
> A thing most brutish, I endowed thy purposes
> With words that made them known.

Charles Wedemeyer

The whole role of learning, of human development, of education—the whole thrust of man to comprehend his life, to make it meaningful, to label, to isolate separate factors and understand their relationships—civilization, culture, progress, advancement—are all caught here. But Caliban has the last word:

> You taught me language: and my profit on't
> Is, I know how to curse. The red plague rid you
> For me learning your language!

It is just this predicament that we have recognized time and time again. As Gretchen Schoff has stated, no matter what myth we have used to explain this to ourselves, we have eaten from the tree of knowledge and have lost our innocence, that kind of state of private individual security where we didn't have any interaction with our environment. We did not build fires, we did not use tools, we did not use clothes, or anything to soften the privation of our own human existence, and we probably were kingdoms unto ourselves. Somehow we have moved out. We have discovered the uses of language, discovery, invention and that does not always make us very happy. We have learned how to curse. Still, as Van Potter has stated, we have to keep moving even though the way is not clear and surely not easy.

But there is a lesson as well as an illustration in *The Tempest*. Prospero, the complete scholar of his day, the complete scientist-humanist, has mastered all learning, but he is not wise because, in isolating himself from humanity, he has lost touch with his own humanity. He has not accepted the foolish nature of his own common human being. By the end of the play, Prospero does learn to recognize his tie to humanity and he fittingly adopts Caliban as a kind of son: "This thing of darkness, I acknowledge mine." Prospero, who has been so superior, so isolated, sees that he is not whole unless he recognizes the totality of his own human nature, and this action of recognition, this act of humility, shows a gain of wisdom through a total expression of a reverence for life. He resumes his mantle as the one-time Duke of Milan and prepares to return having learned this human value. In returning to Milan as duke, our hope is that his new "humility" will lead to an exercise in "responsibility."

In his book, *The Coming of Post-Industrial Society*, Professor Daniel Bell of Harvard University suggests that we are entering a new state of societal development which may be characterized by: (1) change from a goods-producing to a service economy, (2) the preeminence of the professional and technical classes, (3) the centrality of theoretical knowledge as the source of innovation and policy formation for society, (4) new control of technology and technological assessment, and (5) the creation of a new "intellectual technology."

The society which Bell postulates seems to be implied in this series on "Science, Technology and Human Values." In reviewing the range of problems posited by my scientific colleagues, I note the following characteristics:

- The problems cited go beyond concern for the free, untrammeled search for knowledge and reflect concern for the very survival of society;
- The problems express the conflict of solution with respect to time-frames; that is, a good solution in the short-range might be a bad solution in the long-range and vice versa, or, even more important, the time-frame chosen for the solution inexorably chooses the solution;
- The problems express the conflict of the concerns of and for the individual versus the need for societal goods and survival—this being related to the time-frame problem simply because the individual lives in the short-range period while the evolvement and survival of society are long-range matters;
- The problems suggest that conflicts of choice which extend into moral and ethical realms tend to introduce the delusion that there is a rightness in following standard practices for any new procedure—although these same standard practices may well be part of the problem and offer no real security from malpractice.

In addition to these characteristics, the problems also seem to raise the question of whether our knowledge ethic (the pursuit of knowledge wherever it may lead) might now require modification, modification which would direct our efforts specifically toward an improvement in the quality of life and the survival of the species. Such an alteration of the knowledge ethic might reflect the changed nature of the world, the interdependence of knowledge and life systems and the unprecedented power of knowledge through technology.

Gretchen Schoff

The problems also raised questions regarding the intervention by the new knowledge-technology "priesthoods" in areas where moral and ethical constraints are yet to be developed. Throughout the presentations there is a consistent recognition of the need for constraints on science and technology. There seems to be a yearning for what might be called a "qualitative knowledge" to supplement our objective and presumably value-neutral "quantitative knowledge."

What is called for, I believe, is the modification of our knowledge-generating systems in a manner which would allow us to single out inquiries leading in the direction of serious problems related to social survival, and to do so before they go beyond the point at which rational and moral decisions can be made.

But let us ask ourselves the question: Is every problem of survival new or is there an ancient and over-arching concern for human survival that links all ages together? Perhaps we can derive guidelines from our social and cultural precedents, that heritage of human experience which speaks to the choices we must make today and in the future.

And what of the question of who is to make the decisions? When there is possible conflict of interest, should we consider relieving individuals and specialized groups of the responsibility of making the final choice? We could do this by invoking other decision-making patterns—by establishing juries, by determining criteria for professional behavior in areas of uncertainty, and by including the social and humanistic communities, as well as the scientific, in the decision-making process.

I endorse Professor Van Potter's call for "humility with responsibility" and his concept of the "basic bioethic." The new social era is already upon us, and enormous power is in the hands of those who possess and apply knowledge by means of the technology which that same knowledge produces.

Still, I am heartened by the candor, the openness and the apparent sensitivity of the scientists and technologists with whom I have been associated and those whose ideas have been expressed in this series of papers. It is my distinct impression that we are of one voice in saying that society's first line of defense against the potentially destructive value-neutrality of science and technology is the human character and concern of each of us.

These presentations have described for us fresh settings for ancient formulations of man and nature; a new kind of life that has been persistently and doggedly split into its components by the methods of natural science. We have learned how science renders that new life statistical and increasingly capable of manipulation. In the process we have concomitantly discovered that science and technology are no longer separated in the old-fashioned ways.

The first of the several themes I recognize in these presentations is that as the range and context of man's knowledge are steadily widening, the options open to ethical decisions brought about by science are staggering.

The second theme has come in a variety of keys, both major and minor. It has described sets of operations with the material world which offer, on the one hand, exciting forms of health, brotherhood and wholeness, and on the other, mindless—perhaps arrogant and potentially suicidal—manipulations of the created order. To this we must ask the question: What kind of vision is demanded when freedoms of such magnitude are a part of our work-a-day scientific bag of tools?

The third theme arises out of the second. Surgeons are asking for a sharing of responsibility; medical researchers are looking for workable structures within professional organizations; biologists are tracing histories of self-imposed moratoria. Is there in all of this a red thread that leaps out of the fabric? I think there is. It is the unspoken realization that, at present, we have no ethic or vision sufficiently expanded to the enormity of the questions. When scientists and humanists ask for the mechanisms of sharing responsibilities; when pleas are made for medical conferences on ethics, moratoria, citizens' committees; when there are suggestions of ethical arms of government to supplement our current arms of government—the message is unmistakable. These calls for consortium and consensus are an admission of shaky knees, a groping for company in the dock. They contain a fundamental predisposition that "group think" and pluralism have built into them agents of support and restraint. They are comforting mechanisms by which the guilt for things gone wrong is diluted and the glory for things gone right is shared.

A fourth theme is the recognition that all categories leak, that all orders are frayed at the edges, that all truths have their limitations. The physician has been wary of philosophical speculation thrust on him. The researcher depends on his academic institution and his grant, the grant upon the politician and the politician upon the voter. Powerful individual insights have been rendered helpless in the larger grasp of economic and political powers. In this regard, we really lie like Nash's distracted centipedes in a ditch, regarding our hundred legs, wondering how to run, and taking whatever small consolation we can from the other centipedes in the same condition.

A theme which I have not noticed—probably out of our participants' natural modesty—is an explanation of what makes them tick. I have been curious about it; I have tried to ferret it out from them in private discussions. What fuel is it that sparks the motors of these people? There is so much here of joy, of creativity, of feelings for their fellow men. Why do they ask questions about justice and fair play? And quality of life? Some principle of natural law seems to establish in all of us the assumption that continuation and enhancement of life is desirable.

The sum of these themes suggests to me a greatly expanded conceptualizing of natural law, a reformulated idea of how we judge and measure our human freedoms, some ground rule—acceptable to men of all persuasions—that is capable of subsuming our little orders. This seems to me to be a necessary precondition for even considering ethics. A committee without that charge is only a collection of centipedes considering its legs.

What would be involved in such a formulation? If I'm pulling a procrustean trick, cutting off the legs of the giant in order to make him fit the bed, then I hope the scientists will correct me. We know that the closed cosmos imposes, by definition, a law of a fragile biosphere already despoiled by technological misuse. We are learning that science must help us back to a certain kind of "rightness," where our waters, if not fit for trout, are at least drinkable. Can science add to humanistic insights about similar fragilities in our human natures—whether they be physical, emotional or spiritual—which we despoil at our peril?

Many scientists have hastened to leave behind the dry husks of religious and philosophic language. Ghosts of old creeds lie in the dust of the last two centuries along with anthropomorphic gods and obsolete institutions. What can science tell us about new meanings for ancient dicta? Perhaps there are minds that will shut like steel traps at the mere mention of these ancient phrases, but for me they have been suffused with new meaning: "God created man in His image," "We see through a glass darkly." A phrase like "Fallen Man" tells me why I distrust everyone slightly—because I distrust myself as well. A phrase like the "Holy Ghost" is no longer some sort of vapid hot gas that hovers over me but may suggest the twin voices of creation and destruction, the connections between life and death, between the organic and inorganic.

A final question: Is not the interplay between factual reality and right action more subtle than "knowing the facts will produce right action"? Could it not be that thought produces action but action also produces thought? If this were the case, then scientific advance would have to be construed not as linear but as oscillatory. Progress would always have to be understood to be ambiguous. Thinking would help us to do, doing to think and right action would result when we realize that if we take a wrong step, true progress is not in going forward but in turning back.

I think we all share the conviction that scientific conservatism will not do. We are too far into the Faustian bargain to resort to the club and the stone-ax again. Science and technology are some of the principal reservoirs of our creative powers, but we take up the tools with fear and trembling; they hang like Macbeth's intangible sword in front of us, drawing us on and inviting us.

It hath been taught us from the primal state
That he which is, was wished, until he were.

Loren Eiseley calls this cryptic, paradoxical line "a deadly message," implying the problem of free will. It tells us, "Whatever we wish, will come."

What is it that we wish?

The Wisconsin Academy wishes to thank Robert Najem, director of the Midwestern Center of the National Humanities Series, and Douglas Freshner, coordinator of special projects for the Center, as well as the participants in this series, for their cooperation in the preparation of these manuscripts for publication.

CORRECTION

I want to correct an error in my review of the book *Ice Age Lost* which appeared in the last issue of the *Review*. I attributed to the book the statement that "glaciers in Wisconsin were probably 12,000 feet deep."

In the book the author, Gwen Schultz, writes that the North American ice sheet may possibly have been about two miles thick in its thickest parts (using Antarctica's ice sheet as a comparison). According to her, the ice sheet's thickness over Wisconsin is unknown. She believes that in this state, which was near the ice sheet's margin, the ice's maximum thickness probably was considerably less than the above figure.

Tom Murray

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