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# TWO VOICES: SCIENCE AND LITERATURE

BY MARJORIE HOPE NICOLSON

I HAVE TAKEN my title from the opening phrase of one of Wordsworth's sonnets on liberty:

> Two voices are there; one is of the sea,
> One of the mountains; each a mighty voice.

Yet I confess that I had in mind not only the original sonnet but also the wickedly brilliant parody in which James Stephen heard two voices in Wordsworth, one a mighty voice, the other that

> of an old half-witted sheep
> Which bleats articulate monotony,
> And indicates that two and one are three,
> That grass is green, lakes damp, and mountains steep. . . .

You will see why the parody came into my mind, I think, as I try to awaken for you echoes of two voices that were raised in the early days of our modern era, when the sciences, as we know them today, either emerged or became so changed that they seem just to have been born; when astrology became astronomy, alchemy chemistry; when the microscope transformed botany, zoology, and medicine, and geology gradually emerged from the shadow of Genesis, which delayed its development longer than the other sciences. The voices will sometimes be those of scientists, sometimes those of laymen, particularly poets. One group responded to the "New Philosophy" (they did not yet generally use our word "science" in its modern sense) with enthusiasm, acclaim, even rapture. The other drew back in fear or doubt, or took refuge in satire, parody, laughter, not very different from that of James Stephen.

## *Melancholy, and the End of the World*

The seventeenth century has been called "The Century of Revolutions" and "The Century of Genius," both titles well deserved. There were revolutions in politics, in religion, in society, in economics. But a century that has left a roster of such names as those of Harvey, Kepler, Galileo, Boyle, Newton, as Bruno, Bacon, Hobbes, Spinoza, Leibniz, Locke, was, even more, a century of genius. Yet in England, as the sixteenth century gave way to the next, we are conscious of a cloud of melancholy, reflected in much literature of the changing years. To be sure, some of this is only "white melancholy," a literary fad, rather than the "black melancholy" the word implies. When Shakespeare's Antonio opens *The Merchant of Venice* by saying, "In sooth, I know not why I am so sad," he is using literary patter, since there was nothing in the world to make him sad. Although "Monsieur Melancholy," Jaques in *As You Like It,* "can suck melancholy out of a song as a weasel sucks eggs," we need not fear for his mental health. Milton's "divinest Melancholy" is robed in black, but her spirit is white. Antonio, Jaques, Il Penseroso were in no danger of committing suicide. But Shakespeare also wrote *Hamlet;* and Donne his *Anniversaries,* the most sombre poems in our language, not long after he had written a tract on suicide. In 1621 Robert Burton published the first edition of *The Anatomy of Melancholy,* that extraordinary series of case histories of white, black, and shaded melancholy, in which he was as conscious of the prevalence and danger of melancholy as any modern psychiatrist could have been. There was profoundly serious "black melancholy" in this period which not only might lead to individual suicide but, as Burton and Bacon both realized, was holding back a generation from advancement in its ways of thinking. " 'Tis too late to be ambitious," Sir Thomas Browne wrote in his *Hydriotaphia.* "The great mutations of the world are acted, or time may be too short for our designs.

[Our] generations are ordained in the setting part of time."

It would take far too long to answer the question: why were our ancestors of the seventeenth century so melancholy? Burton understood, better than many modern historians, the complexities in the political, economic, and social scene that were leading to despondency and inanition. Of the preconceptions and presuppositions the age took for granted, I shall stop over only one, in many ways the most basic of all, which lay behind Sir Thomas Browne's feeling that it was too late to be ambitious. Our forefathers believed implicitly in Biblical prophecy. Accepting Genesis reverently, they knew the date of the creation of the world, and they also knew the date of its end. By the kind of analogical thinking prevalent in the period, since the world had been created in six days, it would remain for six millennia. Created approximately 4000 B.C., it must end no later than 2000 A.D. – as still seems tragically possible. The great teachers of the Reformation, particularly Martin Luther, constantly warned that, if evil continued, God would not permit the world to run its course, but might destroy it at any moment.

Over a generation of men "brooded like a master o'er a slave a Presence that would not be put by," the end of the world.The coming of a new century must have seemed the beginning of an ominous period. Even today, many men and women are conscious about the coming of a New Year. What of the coming of a New Century? This event has a peculiar psychological effect. I was only a child when this century dawned, but I remember the latent excitement, which even a child may sense, and recall – like many children – being taken up from bed at midnight to watch a new century come in. I suspect that the experience when men felt themselves not just one year but one century nearer the end of the world had a psychological effect in making the pessimism of the early seventeenth century as acute as it was.

### *Optimism, and the "New Philosophy"*

The century that began under a pall of gloom ended in a great burst of optimism. While there were many reasons for the remarkable change, there is little doubt that the greatest single stimulus to optimism came about through the "New Philosophy," as it continued to be called throughout the century. The temper of the later period was largely determined by the work of one man, Francis Bacon. Historians differ sharply in their estimate of Bacon's importance in the history of either science or philosophy. There can be little disagreement about the part he played in making an age "science conscious," as no age until our own has been. In the *Novum Organum,* published in 1620, a year before the first edition of Burton's *Anatomy,* Bacon, like Burton, though in a different idiom, analyzed many reasons for despondency and found the most serious in the fact that "men despair and *think things impossible.*" Acróss the lethargy he describes, we hear the clarion call of optimism in the great passage beginning, "I am now to speak concerning Hope." And speak he did. In his hands, "the thing became a trumpet."

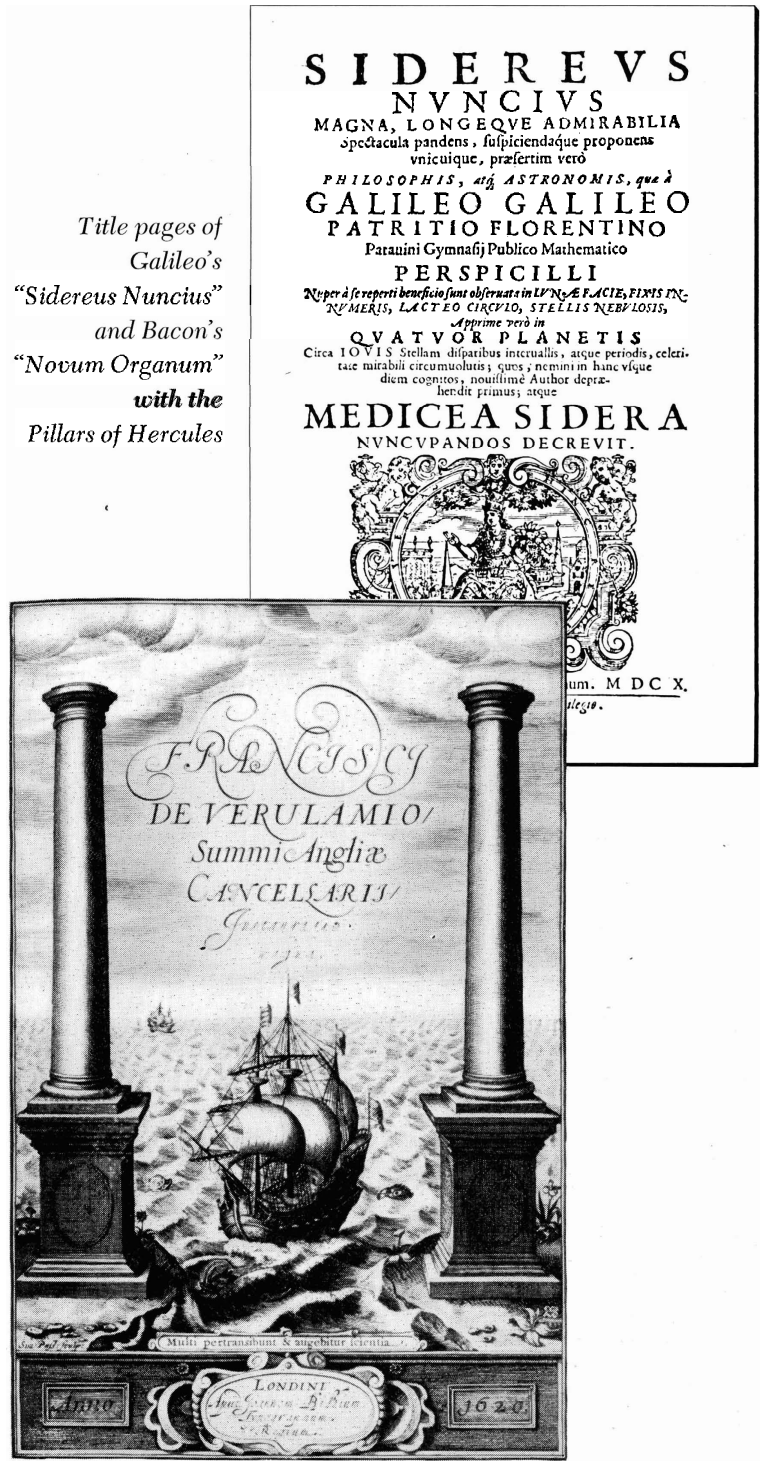
When I am teaching Bacon, I urge my students to read Marlowe's *Doctor Faustus* just before they read Bacon's *New Atlantis* to see the popular interpretation in literature of science and scientists. The Faust story was old when Marlowe used it, long before Goethe and Gounod. Faustus was a scientist in that he was an alchemist. He had a laboratory of sorts, with a certain amount of equipment, "limbecks," and chemicals he mixed in his retorts. Like most alchemists he was seeking the "Quintessence," the Philosopher's Stone to turn base metals to gold, or the Universal Panacea which would cure all ills. For the most part he worked secretly and alone. He had one "laboratory assistant," but we may be sure that Wagner did not know all his master was doing. Faustus had an esoteric language of mystic words, an abracadabra of charms and incantations, and equally mystic symbols, by means of which he could raise demons to assist him. In time he summoned Mephistopheles himself. Insatiable for knowledge, he sold his soul to the devil. At the end of the drama we hear the bell that warns, "This night thy soul shall be required of thee."

Marlowe's *Doctor Faustus* was played in London in 1592. Bacon's first philosophical work, *The Advancement of Learning,* was published in 1605, his last work, the *New Atlantis,* was written in 1626, the year of his death. Thirteen years between *Doctor Faustus* and the first, only thirty-four between the drama and Bacon's last work. It happened as quickly as that: a complete transformation of the popular conception of both science and scientist.

Bacon never did a wiser thing than to write that last work, the epitome of all his philosophical and scientific thinking, in fictional form. Here is a story anyone could read and understand. Like most Renaissance utopias, it is a tale of travel to a new land – really an old land, since the new Atlantis proves to be the "lost Atlantis" of Platonic myth. The new Atlantis is a monarchy, but from the beginning we are aware that the real center of the kingdom is not the throne but "Salomon's House," a foundation, somewhat in our sense of the word. Bacon has gone a step farther than Plato with his "philosopher-kings." In Bacon's imaginary world, scientists are kings. When I visualize "Salomon's House," I find myself thinking of the campuses of certain modern American universities: this campus of The Rockefeller Institute, for example, or those of the Massachusetts and the California Institutes of Technology. On such campuses today, Bacon would find his dream come true, his suppressed desires abundantly fulfilled. "Salomon's House" had its campus, buildings in which experimentation was carried on, as well as other kinds of laboratories: deep caves and lakes, real or artificial, in which men were working on problems of refrigeration and preservation; high towers, something like observatories; museums of natural history (unknown in Bacon's time), orchards, gardens, in all of which experimentation went on.

Bacon's scientists are no lonely alchemists, working secretly for their own gain. They are groups of men ranging in a hierarchy down from "top-secret" heads through various ranks to many laboratory assistants. They work according to a scientific method, pooling their knowledge and their findings. They have various instruments for "weighing, measuring, verifying." They have discovered and invented many things we take for granted today: flying machines, for example, submarines, instruments "for hearing at a distance," prophesying our telephones, telegraphs, radios. They make synthetic medicines, even synthetic perfumes. All their labors are devoted to the end Bacon reiterated throughout his works: "the benefit and use of man, the relief of man's estate." Like Faustus, Bacon took all knowledge to be his province, but his road to knowledge was very different.

Lewis Mumford in his *Story of Utopias* dismisses the *New Atlantis* with some contempt in comparison with More's *Utopia,* because Bacon's ideal world was still a monarchy and he did not suggest a political, social, or economic revolution as a clue to the future. Thomas More foresaw a world in which socialism, perhaps communism, would rule. Bacon believed that that nation would be most powerful in which science had made the greatest strides. We who live today on this side of an iron curtain behind which




*Title pages of Galileo's "Sidereus Nuncius" and Bacon's "Novum Organum"* ***with the*** *Pillars of Hercules*

communism prevails, in an Atomic Age made by science, and dominated at the moment by Russian and American competition, may look back to both our far-sighted Renaissance utopian ancestors as prophets of the future. Which of them guessed most truly, time has not as yet finally told.

## *Plus Ultra*

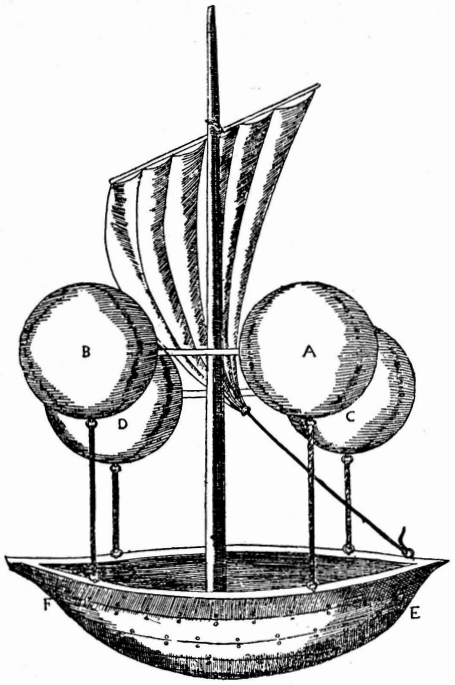
From the *New Atlantis* England caught fire, even more than from Bacon's philosophical works. Under its influence men gathered strength and went on, as Bacon had hoped, to discover new "intellectual worlds" as their grandfathers had discovered new geographical worlds. Under its influence, at least in large part, the Royal Society of London was chartered in 1661, to begin its distinguished career, celebrated in 1961, as the only academy in the world which has had an unbroken history of three hundred years. In the minds of many of its members, Bacon was the real founder of this attempt at a "Salomon's House," peculiarly its father, as we can see in the first history of the Society, published by Thomas Sprat in 1667. Here, forty years after Bacon's death, Sprat set down an account of the inventions and discoveries of its members — and an imposing list it is for the short period of time that had elapsed.

Throughout the Restoration period, the prevailing tone of the "Bacon-faced generation" was one of optimism. The motto of his followers was *Plus Ultra* (there is "more beyond"), which had an interesting history. Before Columbus set sail across the Atlantic, the coat of arms of the royal family of Spain had been an *impressa*, depicting the Pillars of Hercules, the Straits of Gibraltar, with the motto, *Ne Plus Ultra*. There was "no more beyond." It was the glory of Spain that it was the outpost of the world. When Columbus made his discovery, Spanish royalty thriftily did the only thing necessary: erased the negative, leaving the Pillars of Hercules now bearing the motto, *Plus Ultra*. There was more beyond, and Spain proudly marked the gateway to a new world. In the *Novum Organum* Bacon used as frontispiece the Pillars of Hercules, though on this occasion he took his motto from the Book of Daniel: "Many shall run to and fro and knowledge shall be increased." Among his followers, *Plus Ultra* became the rallying cry. The Baconians exulted in what they had done, in what they would do. Modern man, as one of them said, was greater than Adam. He had gone on to such strength that none could set a *non-ultra* to his accomplishments.

By the end of the century pessimism had almost entirely disappeared. Man was looking forward, not back. The idea of progress was well on its way. It was not too late to be ambitious. Prefaces and conclusions of works of "popular science" in the late seventeenth and early eighteenth century are paeans of praise to a new world and a brave new universe, so diverse as to enchant imagination. Indeed, the world was so full of all manner of things that men had every right to be happy as kings. Man gloried in his strength and his accomplishments. So proud had man become that his theme song seemed that Swinburne satirized in his "Hymn to Man": "Glory to Man in the Highest, for Man is the Master of Things."

## *The Voice of Doubt*

For a number of years after I first began exploring the relationships between literature and science, I thought that the voice of Scientia in this period was universally optimistic, that all scientists, within or without the Royal Society, believed, as did Bacon, that the effects of science would be entirely benign, only "for the benefit and use of man." Then I heard another note, even in science. Bacon's "Fathers of Salomon's House" had invented flying machines, among other things. In 1670 many men throughout Europe believed that the principle of flight had been discovered by an Italian scientist, Francesco Lana, who, whether his own invention was successful or not, may well be considered the real father of aerostatics, in that his little model laid the basis for the balloon, the first flying machine in which animals, then men, rose perilously from the ground and ascended into the air. In his *Prodromo,* Lana insisted that the basic problems of weight and gravity were readily soluble and that in a short time sizable flying machines could be developed in which men might fly, even to the moon. But then he wrote — and remember, this is a scientist speaking — "Other difficulties I do not foresee that could prevail against this invention, *save one only, which seems to me the greatest of all, and that is, that God would surely never allow such a machine to be successful.*" Consider, he said, what might follow: airships could be steered over public squares, over navies lying at




THE BETTMANN ARCHIVE

*Vacuum airship designed by Lana, 1670*

anchor in a harbor. Iron weights could be dropped, fireballs and bombs thrown down. So the first important inventor in aviation prophesied in 1670 what we have lived to see: the destruction of ships and cities from the air. "God would surely never allow such a machine to be successful."

### *The Vast and the Minute*

Two voices were there, even among scientists. What of literary voices in this first great age of invention and discovery? The first science to make an immediate appeal to laymen was astronomy. Throughout Europe excitement was aroused by Galileo's spectacular discoveries through his fifth telescope, announced in 1610 in the *Sidereus Nuncius,* a starry messenger and message to man. Almost overnight Galileo had discovered not only a new world but a new universe. His observations had proved the truth of the Copernican hypothesis, establishing the sun rather than the earth as the center of our system. He had discovered many other things as well: stars innumerable, never before seen; the phases of Venus; the true nature of the Milky Way; the fact that the moon was a world, topographically much like our own; and – for a time, he thought – four new planets, which later proved to be the satellites of Mars. Astrology was doomed that night, and astronomy was born. All these discoveries passed quickly into literature. There are few poets of the seventeenth century who do not make use of one or another. Milton, for example, had no hesitation in introducing them into a religious epic. In *Paradise Lost* he referred more than once to Galileo's "optic tube." In the most reverent scenes, those describing the Creation, Milton – no more disturbed than Shakespeare by anachronism – did not hesitate to introduce Galilean discoveries of the phases of Venus and the nature of the moon into the Miracle of the Fourth Day when Christ created the sun and moon. One of the most beautiful scenes in the poem is that in which Milton described Christ and the angels, returning from the Creation, making their triumphant way over Galileo's Milky Way.

But Milton was writing almost fifty years after Galileo's discoveries. He had been only an infant in 1610 and never experienced the shock of older men who had accepted all their lives the belief that their world was the proud center of the universe. Many of you are familiar with the passage in which John Donne, only a year after Galileo's announcement, felt that "New Philosophy calls all in doubt," that both the sun and the earth are lost, that " 'tis all in pieces, all coherence gone." Here, for the first time in English literature, we hear the other voice, of human doubt and even terror, as man faces discoveries of science.

The conception of a new universe, which developed as the century proceeded, both captivated and horrified human imagination. Telescopic observations of Galileo, Kepler, and others merged with another "new philosophy," stemming in part from Giordano Bruno, a poet-philosopher, obsessed by Space and Infinity. This was the generation which discovered the Space modern man thinks was discovered only yesterday. They were as fascinated by it as we have been, glued to our televisions while Gemini casually greeted each other as they orbited through Space. Astronomy and philosophy together developed the idea of a plurality, possibly of an infinity of worlds. Not only was our world not the center of a universe, but even our universe was not unique, only one of many universes stretching indefinitely, perhaps to infinity. Space enthralls, but it also appals. Today, as in that early period, there are those among us who echo Pascal's great sentence: «Le silence éternel de ces espaces infinis m'effraye.»

The development of the microscope, following inevitably upon the invention of the telescope,

opened to human imagination another new universe – that of the small, stretching perhaps to infinity, as did the new universe of the vast. Antony van Leeuwenhoek and other microbiologists discovered a new world of life in stagnant water, in saliva, in blood and urine, life infinitesimal, but still life. Was there any point, asked an amazed and astounded generation, at which life ceased? Here, too, Pascal spoke for many in the magnificent rhetoric of the *Pensées* when his imagination turned from the infinitely vast of the "New Philosophy" to the infinitely small of microbiology:

> Car enfin qu'est-ce que l'homme dans la nature? Un néant à l'égard de l'infini, un tout à l'égard du néant: un milieu entre rien et tout. Infiniment éloigné de comprendre les extrêmes, la fin des choses et leur principe sont pour lui invinciblement cachés dans un secret impénétrable; également incapable de voir le néant d'où il est tiré, et l'infini où il est englouti.

Alexander Pope's Man,

> Placed on this isthmus of a middle state,
> A Being darkly wise and rudely great,

felt himself hanging between two extremes, neither of which he was capable of comprehending:

> Great lord of all things, yet a prey to all;
> Sole judge of Truth, in endless error hurled,
> The glory, jest, and riddle of the world.

But the voice of Pascal's and Pope's Man was far from being the only voice in which men of letters responded to the new universes of the vast and the minute. Poets like Henry More and Thomas Traherne exulted in the new vastness, indeed, were almost drunk with it.

> Then all the works of God, with close embrace
> I dearly hug in my enlargéd arms,

Henry More wrote. One can almost see those arms growing, as imagination was growing, in poetic desire to grasp the Infinite. These were the first Romanticists, with their aspiration to grow with a new world, to accept their universe in a sense quite different from Margaret Fuller's. They felt no disillusion or despair because they could not grasp the whole of things, but fresh stimulus and enthusiasm. Always there was "more beyond" on which their insatiability might feed, "more beyond," with which imagination might continue to grow. In poetry as in science, the dominant voice of the early period of modern science was optimism and enthusiasm.

### *The Voice of Scorn*

But there was still another literary voice, of a different sort. Anyone who has read Restoration literature will realize that the "Restoration Wits" were not likely to share the exuberance and lack of restraint of these early Romanticists. We begin to hear the voice of satire most clearly shortly after the invention of the microscope. Until the development of the compound microscope, the enthusiasm of scientists and laymen alike was as simple and childlike as that of youngsters when they first discover magnification. Samuel Pepys, always avid for novelty, bought himself a microscope, and he and Mistress Pepys spent an evening with it, sharing the experience of many students in "Freshman Biology." At first they could see nothing, and when they saw something they did not know what they were seeing until Pepys wisely bought a book that told him. Scientists, gentlemen and ladies alike – ladies proved as important a new "buying public" for glass grinders as they have proved for cigarette manufacturers in our own time – were fascinated by seeing through their lenses simple, ordinary, homely things they had always known but never really seen. Bacon had warned his followers not to avoid "mean and even filthy things." He would have been delighted to watch his descendants – scientists and laymen alike – engrossed with the magnified flea and louse. There grew up what I like to call a "literature of vermin," expatiating on fleas, lice, maggots, ants, tadpoles, worms, and even rats' testicles. Inevitably the Restoration satirists had their fun with such childlike enthusiasm. Part of the great popularity of *Hudibras* was the result of Butler's many satiric passages on science and scientists. He turned his light artillery upon Virtuosi who spent hours upon such problems as

> How many different specieses
> Of maggots breed in rotten cheeses,

and pilloried a distinguished member of the Royal Society

> whose task was to determine
> And solve the appearances of vermin,
> Who had made profound discoveries
> In frogs, and toads, and rats, and lice.

The most familiar lines on the flea have been quoted and misquoted ever since they were written by Jonathan Swift:

So naturalists observe, a flea
Has smaller fleas that on him prey,
And these have smaller still to bite 'em,
And so proceed *ad infinitum*.

Only a few weeks ago I was delighted to discover in the Huntington Library two works which I was sure must have been written but which I had never seen: two mock epics, one called *The Louseiad*, the other *The Fleaiad*.

Yet light satire may be a more deadly weapon than more serious literature. So it proved in the Restoration period. Today many people are concerned with the effect modern science may have upon literature, particularly poetry. In this early period the tables were turned. There was a time when literature almost put an end to an important chapter in the advancement of science. If one reads Sprat's *History of the Royal Society* carefully, it becomes clear that Sprat was commissioned to write it by members of the Society, greatly concerned with the public attitude toward their scientific work. They were clearly less worried about the attitude of men of religion than they were about the "Restoration Wits." In his lengthy digression on this subject, Sprat said, "I acknowledge that we ought to have a great dread of their power. . . . I believe the New Philosophy need not (as Caesar) fear the pale or the melancholy, as much as the humorous and the merry." Pepys' *Diary* gives a clue to the concern of the Fellows of the Royal Society. On the surface, Charles II, who had chartered the Society, remained its patron, but behind the scenes his attitude was different. Pepys tells of an evening when the King attended an aristocratic party and spent an hour and a half laughing at the Virtuosi. Why? Because, said His Majesty, those silly men had spent their time, ever since their foundation, in "weighing the air," and doing nothing else. Weighing the air, indeed. It sounds as absurd to the layman today as it must have to the aristocrats that evening. As it happens, the experiments at which the King was laughing were largely those of Robert Boyle, who was laying down some of the premisses upon which modern physics still rests. But the King's jibe passed from mouth to mouth, as some of Butler's satiric verses seem to have passed from hand to hand before they were published. On the stage too were sly digs at the absurdities of the new science, culminating a few years later in the comedy of Shadwell's *Virtuoso*, the most extensive, drastic, and amusing stage criticism of the Royal Society in which the name character, Sir Nicholas Gimcrack, epitomizes all that seemed absurd in science. He not only weighed the air, but bottled it up and kept it in his wine cellar, like fine champagne, to open in his chamber when he desired a change of climate. Each of Gimcrack's discoveries and experiments had its source in a real experiment or discovery by a member of the Royal Society, as the audience well knew. As Shadwell satirized them, they sound as silly as Boyle's weighing the air did to the King and his courtiers. If I repeat for you one scene, you will readily see why the aristocrats laughed at the theatre, as they had behind the scenes, at the foolishness of science.

Two young men who have come to visit the great Virtuoso are kept waiting by his wife, who tells them that Sir Nicholas is engaged in learning to swim. "Why," says one of them, "is there any water hereabouts?" "He does not learn to swim in the water, Sir," replies the wife. The scene opens to discover Sir Nicholas lying upon his laboratory table, watching a frog in a bowl. As the frog strikes out, so does Sir Nicholas, while his swimming master and a toady stand admiringly by, exclaiming in chorus, "Oh, well swum, Sir, very well swum indeed!" Listen to the conversation that follows:

LONGVILLE: Have you tried to swim in the water, Sir?
GIMCRACK: No, but I swim most exquisitely on land.
BRUCE: Do you intend to swim in the water, Sir?
GIMCRACK: No, Sir, I hate the water.
LONGVILLE: Then there will be no use in swimming.
GIMCRACK: I content myself with the speculative part of swimming. I care not for the practical. I seldom bring any thing to use. 'Tis not my way. To study for use is base and mercenary, below the temper of a philosopher. Knowledge is my ultimate aim.

Sprat and the Fellows of the Royal Society were more than justified in their belief that the "New Philosophy" need not fear the pale and melancholy so much as the humorous and the merry. Then, as now, laymen responded to what Bacon called "Experiments of Fruit"—science applied to human life—but "Experiments of Light"—pure science that must

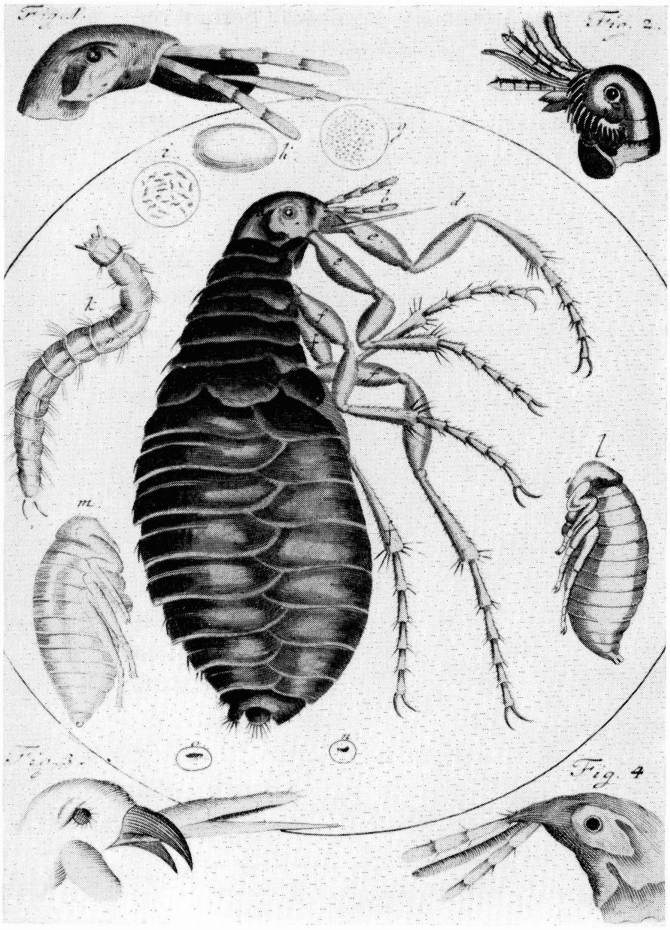


*Illustration of a flea, from "Amusement Microscopique" by Martin Frobene Ledermuller, published in Nuremberg, 1764*

precede the application – often, now as then, seem as useless and meaningless as Boyle's weighing the air seemed to Charles II. Those were parlous years for the struggling little academy, when the laughter of the "Restoration Wits" almost put an end to a valiant scientific group.

The Royal Society survived this period, to continue its distinguished history. Fortunately, it was on somewhat firmer ground before the greatest satirist of the Society began to write, or it might not have weathered Swift's *Battle of the Books, A Tale of a Tub,* and the third book of *Gulliver's Travels,* all of which are filled with irony about the new science. In *The Battle of the Books* we begin to hear two voices persistent today, most resonant and, indeed, often vociferous on college and university campuses. In France the Quarrel of Ancients and Moderns was primarily a literary controversy, but in England it became the first important skirmish in a protracted warfare between Science and the Humanities. Its direction had been determined before Swift was drawn into it by his patron, Sir William Temple, a professed Ancient, who had run afoul of William Wotton, to him an upstart Modern. Temple called upon Swift for aid, which he gave abundantly. Well aware that satire was a most trenchant weapon, he wrote *The Battle of the Books* as a mock epic in prose. His scene is the Royal Library of St. James', his characters the books on the library shelves that divide themselves into passionate camps of warriors, fighting to claim the higher peak of Helicon, long assigned to the Ancients, now attempted by the Moderns.

We see them drawn up in battle array, the army of the Moderns reminiscent of the rabble rout Falstaff once led on a battlefield, mercenaries, rogues, ragamuffins. The army of the Ancients, much fewer in number, appears in all its venerable dignity: "Homer led the horse, and Pindar the light-horse; Euclid was the chief engineer; Plato and Aristotle commanded the bowmen; Herodotus and Livy the foot; Hippocrates the dragoons." Those of us who have grown up in the seventeenth century needed no C. P. Snow to warn us of "The Two Cultures" nor F. R. Leavis to answer him. We were there in person that Friday in St. James', to watch the single-combat between Virgil and Dryden, between Homer and Gondibert. We saw Aristotle draw his bow and watched the arrow almost hit Bacon, then penetrate Descartes' armor. Swift avoided telling how the battle came out. His mock epic ends with lines of asterisks, unconsciously prophetic, since, although a battle had been fought, the war between Science and the Humanities was only beginning. Wherever you find two or three gathered together on modern campuses, you hear it fought today, most vocally by the Humanists, who feel that they have lost their proud place in the sun, been summarily deposed from that high peak of Helicon. The war is not yet over. Swift's asterisks still confront us, though the budgets of both universities and governments would seem, like the golden scales of the gods, to have prejudged the issue. So, too, a fact I always notice on my many travels to university campuses: the Sciences are housed in the newest, most modern (and most expensive) buildings. The Humanities have moved into the abandoned

huts, presumably humbly grateful if they have a place to stand or sit, even if often no shelves for those antiquated tools of their trade, still the Books of the Ancients.

### *Antiphonal Music*

During the many years I have spent in trying to recapture these various voices of the past, as they echoed in science and literature, I have heard them as a sort of antiphonal music, one voice replying to the other, one strain now dominant, then another. A few weeks ago I was surprised and delighted to learn that my "Voices" have actually been set to music by Ross Lee Finney, Composer in Residence at the University of Michigan, once my colleague at Smith College. He sent me the score of a choral composition, *Still Are New Worlds,** which is to be performed for the first time at the May Festival in Ann Arbor. When I asked if I might describe it to you, he replied with characteristic generosity, "I wrote the music; you wrote the words." The words are mine only to the extent that they have largely been taken from passages I have collected and quoted in books and articles dealing with the impact of science upon literary imagination. Mr. Finney has added another dimension to my studies: to science and literature, he has added music. Then, too, at the end of the composition, he uses electronic tape, suggesting a way in which modern science is affecting music, and affording still another medium of communication in the arts. I cannot let you hear the music, but perhaps through the text I can give you some idea why *Still Are New Worlds* is to me a climax of the voices I have heard so long. If I change the order of some passages in the first movement, it is in part because I have been trying to let you hear the voices chronologically, and in part because I cannot do with words what Mr. Finney can with music – let you hear two themes at the same time.**

I begin with a passage written just before the dawn of the New Science. The first words you hear are those of Marlowe – not Faustus this time, but Tamburlaine – but the voice is the perennial voice of Man, whose imagination has always sought to understand the world in which he lives:

> Our souls . . . can comprehend
> The wondrous Architecture of the world,
> Our souls can comprehend the world,
> And measure every planet in its course,
> Still climbing after knowledge infinite,
> And always moving as the restless spheres.

To inquiring man, God seems to reply that the world is there for him to study. Far from interdicting knowledge, as many men believed, God has expressed Himself in the Book of God's Works as in the Book of God's Words – phrases loved by both Bacon and Sir Thomas Browne. The next words you hear are those which the Angel Raphael spoke to Adam in the dialogue on astronomy in *Paradise Lost,* but the message is that of God to man:

> To ask or seek I blame thee not,
> For Heaven is as a book of God before thee set,
> Wherein to read his wondrous works, and learn
> His seasons, hours, or days, or months, or years.

Then Galileo's telescope discovered a new universe and proved the truth of the Copernican hypothesis that the sun, not the earth, is the center of our system. The voice you hear exulting in the New Astronomy is that of Kepler, scientist, poet, and mystic:

> The Sun, of all the orbs most excellent, whose whole essence is purest light, than which there is no greater star, the warmer of all things; the Sun singly and alone the producer, conserver, most fair, limpid and pure. The Sun, king of the planets for his motion, heart of the world. The Sun, its eye, for his beauty and alone we judge worthy of the Most High God.

Man is coming to worship the Sun, but he still worships God, who – in that most reverent of all Renaissance puns – is both the Sun and the Son.

To the exultation of Kepler is added the voice of William Harvey, discoverer of the circulation of the blood, in a passage in which he carries over to the geocosm and the macrocosm the principle he had found in the microcosm, the little world of man:

> The moist earth, warmed by the Sun, evaporates, drawn upwards. The moist earth by the Sun is condensed, de-

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*Commissioned by the University Musical Society of the University of Michigan, Ann Arbor, for the Fiftieth Anniversary of the construction of Hill Auditorium, for first performance at the Seventieth Annual May Festival by the University Choral Union and the Philadelphia Orchestra, Thor Johnson conducting. The score is published by the C. F. Peters Corporation (Peters Edition No. 6553), Copyright by Henmar Press, Inc., New York, New York.

**In Mr. Finney's score, the order of the voices in Part I is, Kepler, Harvey, Marlowe, Donne, Milton, Fontenelle, More.

scends in the form of rain again. Generations of living things are produced, and tempests and meteors engendered by the circular motion of the Sun.

But the acclaim for the Galilean discoveries was not universal. Across the exultation cuts another note in the voice of John Donne, to whom a "New Philosophy" called all in doubt:

> Man hath weaved out a net, and this net thrown
> Upon the heavens, and now they are his own.
> Loth to go up the hill, or labor thus
> To go to Heaven, we make Heaven come to us.
> We spur, we rein the stars, and in their race
> They're diversely content to obey our pace.

Galileo's telescope has drawn down the heavens. Man need no longer climb that long and arduous way. Man has conquered the heavens, and made them his. Where, then, is Heaven? And where is God?

From the time of Galileo, Kepler, and Bruno, man found himself not only in a new universe, but surrounded by illimitable universes stretching indefinitely, perhaps infinitely. The excited bewilderment of man is expressed in the eager questions Fontenelle's Marchioness asked a Philosopher in *Conversations upon a Plurality of Worlds*, the finest work of popular science ever written, I think. The Lady and the Philosopher are strolling in the evening in moonlight. Looking up to clear moonlit sky, he teaches her the implications of the New Philosophy. It is she who asks,

> Is every star a Center or a Vortex as big as ours? Is that vast space which comprehends our Sun and Planets but a part of the Universe? Are there as many spaces, as there are fixed stars?

Human imagination – of men, even of women – is expanding with the Space that terrified Pascal and liberated the imagination of other poets. The voice we hear is that of Henry More, the Cambridge Platonist, who, as philosopher, was the first to posit the idea of infinite Space. Poet-philosopher as he was, he expressed the idea in verse well before he developed it into a philosophical system. From his poem Mr. Finney has taken the title of his composition, *Still Are New Worlds:*

> Farre aboven,
> Further than furthest thought of men can traverse,
> Still are new worlds, aboven and aboven,
> In the endless hollow Heaven, farre aboven,
> Still are new worlds, and each world hath his Sun.

More's voice is the voice of rapture many men felt as the walls of the world, which too long had cribbed, cabined, and confined human imagination, fell with a crash far greater than that of the walls of Troy. Human imagination rises with the new conceptions, exulting and rejoicing in a universe so vast that imagination, still climbing after knowledge infinite, grows and expands, discovering in itself potentialities it had never known. Science and imagination have found infinite worlds in infinite Space. This is the climax of the first movement of *Still Are New Worlds.*

From the second part, I must omit earlier lines and center attention upon a voice that speaks for the poet living in our own time, in the Atomic Age. The voice we hear is that of a poet in *The Myth of Sisyphus* by the French poet-dramatist, Albert Camus.* First we seem to hear a poet walking alone outdoors in the evening:

> Here are trees, and I know their gnarled surface,
> Here is water, and I feel its taste.
> These scents of grass and stars at night, evenings when the heart relaxes,
> How shall I negate this world, whose power and strength I feel?
> Yet all the knowledge on earth will give me nothing to assure me that the world is mine.

The poet is feeling and speaking as poets have always felt and spoken, experiencing Nature intuitively, through the senses. The poet turns now to address the modern scientist, who has discovered a new Nature:

> You teach me that this wondrous and multicolored universe can be reduced to the atom, and that the atom itself can be reduced to the electron. You tell me of an invisible planetary system in which electrons gravitate around a nucleus. You explain the world to me with an image. I realize then that you have been reduced to poetry. You have changed theories. Science, that was to teach me everything, ends in hypothesis, lucidity founders in metaphor, uncertainty is resolved in a work of art.

Has the scientist, indeed, become poet? Even he cannot put into words this new Nature he has discovered. The explanation he offers does not explain his world to the poet:

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**The Myth of Sisyphus* by Albert Camus, translated from the French by Justin O'Brien. Used by permission of the publisher, Alfred A. Knopf, Inc. Copyright 1955.

> The soft lines of these hills and the hand of
> evening on my troubled heart teach me much
> more. I have returned to my beginning.
> I realize that if, through science, I can seize
> phenomena and enumerate them, I cannot, for
> all that, apprehend the world.

Here for the first time electronic tape is used, but, as Mr. Finney comments, "The use of tape here is only for quiet sounds, the chirping of crickets and of night insects," as the poet listens to Nature at night. As you will surmise, the use of electronic music increases in greater and greater intensity as we approach the passage that marks the climax of *Still Are New Worlds*. It is significant, I think, that Mr. Finney sought a long time in modern science and modern poetry for the language he needed to express emotions many of us share in this Atomic Age. Only in *Paradise Lost* could he find the language he was seeking. He has deliberately wrenched the words out of Milton's context, and, to my mind, has made the great rhetoric even more profound than it was originally. The first lines from Milton were used by the poet to describe "the Almighty Power," God, casting out the rebel Satan from Heaven. In Mr. Finney's score, "the Almighty Power" has become, not God, but nuclear physics:

> He with ambitious aim
> . . . . . the Almighty Power
> Hurled headlong flaming from the ethereal sky
> With hideous ruin and combustion down
> To bottomless perdition . . .
> Who durst defy the Omnipotent.

As the full power of the music echoes that fearful sound some human beings heard in reality, but all of us have heard in nightmare imagination, it seems that, in the Book of Revelation, there should be silence in Heaven for the space of half an hour. Only Milton, long before it happened, described the desolation of a devastated city caused by the atomic bomb:

> The dismal . . . waste
> On all sides round . . .
> As one great furnace flamed . . .
> No light, but rather darkness visible,
> Regions of sorrow . . . where peace
> Can never dwell, hope never comes.

As the words are used, they are no longer what they were – a description of the Hell God made for Satan – but a description of the Hell man made for man.

Lines from Milton serve, too, for the conclusion of *Still Are New Worlds*. The words from the Prologue to *Paradise Lost* have again been deliberately removed from their original context. Milton wrote of God,

> Thou from the first
> Wast present, and with mighty wings outspread,
> Dove-like satst brooding on the vast abyss
> And madst it pregnant.

It is no longer God who, brooding upon an abyss, brought order out of chaos to create a world. The source of power in the great abyss is something man has discovered which may destroy a world.

*Still Are New Worlds* concludes with the familiar words that conclude the General Prologue to *Paradise Lost*. As Milton wrote them, they said,

> That so I may assert Eternal Providence
> And justify the ways of God to men.

I do not pretend to know how Mr. Finney interprets them, but read against the history which I have been tracing, the familiar words echo in my ears with a melancholy far more profound than that against which science dawned. To me they say something which I can express only by changing both order and meaning. Milton ended with an affirmation. He believed that man could assert Eternal Providence. We end with a question: May we assert Eternal Providence? Milton could and did justify the ways of God to men. I read the line today as a profoundly ironic query: Can we justify *the ways of men to God?* Two voices are there. Which will triumph in our time?

THE AUTHOR was for twelve years Professor of English and Dean at Smith College, and for twenty-one years Professor of English in the Graduate School of Columbia University. Last year she was Luther J. Lee, Jr., Visiting Professor of Renaissance Studies, Claremont Graduate School. She is presently William Peterfield Trent Professor Emeritus of English, Columbia University. "The incomparable Miss Marjorie" holds honorary degrees from fifteen colleges and universities. She is notable as an English scholar who has appreciated and interpreted the influence of science on literature. *Two Voices* was the first Ellery Sedgwick Memorial Lecture in Literature; it was delivered at The Rockefeller Institute in April, 1963. The Ellery Sedgwick Lectures are named in memory of a distinguished editor of the *Atlantic Monthly* who was an admired friend of the donors of the Lectureship.

# HERBERT SPENCER GASSER

## 1881-1963

BY DETLEV W. BRONK

*A personal appreciation of a great physiologist who was Director of The Rockefeller Institute from 1935 to 1953.*

*Dr. Gasser at the time of his appointment to the Institute*

HERBERT GASSER'S whole-souled devotion to science made clear and simple the pattern of his career.

Gasser had a long heritage of dominating regard for intellectual values and deep respect for the rights and welfare of individuals. Such ideals were further fostered by a physician father in the tranquil environment of a Midwestern village.

Immediately after graduating from the University of his native Wisconsin, he there began research. That interest was further nurtured during four years at The Johns Hopkins School of Medicine. In those early years of his academic life, Gasser had exceptional opportunities for cultivating his gift of warm and loyal friendliness. Arthur Lowenhart and Walter Meek, William H. Howell and Joseph Erlanger were but a few of his early teachers and lifelong friends from whom he derived inspiration, and whom he enriched by his kindly thoughtfulness and versatility of interests. Those qualities were later prized by countless other friends.

After taking his degree of Doctor of Medicine at the Hopkins, Gasser began fifteen happy, fruitful years of teaching and research in pharmacology at Washington University. His was no slow ascent of the academic ladder. At the age of thirty-two he was appointed full professor and thereby hangs a tale told to me by Abraham Flexner. When that powerful catalyst of medical progress was considering financial support of full-time teaching and research at Washington University, Dean Nathaniel Allison gave a dinner for Flexner to whom he displayed the stars of his faculty. Seeing the youthful Gasser, straightforward Flexner queried the Dean, "Are you making freshmen full professors?" Acute judge of promise in youthful scholars that he was, Flexner then asked Gasser, "How would you like to go to Europe for two years and learn some languages?" knowing full well that Gasser's restless mind would acquire more than knowledge of foreign languages and cultures. During those two fruitful, happy years his scientific horizons widened and he made many

friends who often lured him back to Europe.

Breadth of scientific knowledge, developed by continuing rigorous self-education, enabled Gasser to broaden the scope of pharmacology and to foster the unity of medical education. He was thus fitted for the transition to Professor of Physiology in the Cornell University Medical College, where he developed the new physiological laboratories of that college in 1931.

Four years later, his widening range of competence and interests were given even greater scope by appointment as Director of The Rockefeller Institute. It was no easy task to be successor to Simon Flexner, who had been the Institute's first Director for thirty-two years. But Gasser was qualified for the challenging duties of successor to a distinguished predecessor by more than wide knowledge and a keen mind. He had rare qualities of courage, vision, and sensitive understanding of the spiritual needs of a scientist.

A personal quality of which I would write was his ceaseless effort to extend the scope and depth of his knowledge. In a time when narrow specialization threatened the wholesome development of science and the achievement of broad, humane objectives, Gasser remained a scholar; he did not recognize a distinction between humanist and scientist. Few fields of learning lay outside the bounds of his curiosity.

In the early days of electronics, Gasser mastered all related fields of physics and was thus able to open a new era of neurological research. With characteristic vision of the potentialities of new methods, he saw in electronic amplifiers and recorders the means for observing the minute and fleeting electric signs of nerve message which are now known to constitute nerve action.

One less aware than he of the swift evolution of science, one less able to increase in knowledge with the evolution of science, would soon have found that the means of investigation he first cultivated had developed beyond his comprehension. Not Gasser. Tireless study kept him alert to new developments in every field of science that could aid research on the structure and functions of nerves. At an age when many men retire, the youthful vigor of his mind led him to new studies of the structural basis of nerve action by the most sensitive methods of electron microscopy. Gasser was an example worthy of thoughtful notice by young scientists; he deplored careers that are quickly built on small intellectual foundations which cannot support long-continued growth of competence to deal with unanticipated problems of the future.

I am reminded of another pre-eminent attribute of Gasser, the scientist, when I recall this by Lord Kelvin: "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it. But when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and inadequate kind. It may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science."

One of Gasser's major contributions to the furtherance of science was such an emphasis on the value of precise measurement of biological structures and of physiological events. By the former he was enabled to define groups of nerve fibers and relate them to specific sensory and motor functions. By measuring with great precision the magnitude and temporal course of the action potential of nerve, he was enabled to classify the functions of the groups of fibers comprising nerves and to follow the progression of basic cellular processes.

As the methods of research become more complex and the body of scientific knowledge rapidly increases, specialization is necessarily fostered. Many now find themselves unable to perform their own experiments. Physical research is replete with instances of this, and biological science tends that way. Teams of workers are indeed necessary for many scientific investigations as are the groups organized for geographical exploration or for ascent of the highest mountains. But scientific research is based upon the curiosity and the inquiry of individuals who seek to understand. Accordingly, a characteristic of Herbert Gasser that I admired was his vigorous defense of freedom for the individual investigator to work as he chose to work – in association with others on cooperative projects or in lonely quest of new knowledge and understanding. He, himself, a lonely worker, showed that the day of the investigator who performs his own experiments has not passed. He had qualities of Newton characterized thus by Einstein: "Fortunate Newton, happy childhood of science . . . In one person he combined the experi-

menter, the theorist, the mechanic, and, not least, the artist in exposition."

The excellence of Gasser's scientific work was recognized by degrees from the oldest universities in the United States and Britain and from many others too, and by membership in the National Academy of Sciences and The Royal Society of London. He was awarded the Nobel Prize in Physiology and the Kober Medal of the Association of American Physicians.

THE AUTHOR of this memoir was a close friend of Dr. Gasser. Gasser and the Bronk family shared a summer cottage for twenty years, and together celebrated Christmas each year at Hill House Farm, that was so named by the Bronks for the physiologist A. V. Hill, with whom Gasser worked as a young man. The author had the unusual privilege of conferring the honorary degree of Doctor of Science on Gasser *three* times: at the University of Pennsylvania in 1932; at The Johns Hopkins University in 1951; and at The Rockefeller Institute in 1959.

# WORLD POPULATION PROBLEMS

*In 1952 the National Academy of Sciences convened a conference on scientific aspects of population problems. The scientists who met for three days in Williamsburg, Virginia, urged the creation of a non-governmental foundation that would foster research and education in demography and in the biology of reproduction and its control. Following the recommendation of that Academy conference which was supported by John D. Rockefeller, III, The Population Council was founded. It has fostered research and studies in this field by grants to universities, by the award of fellowships, and by its own program of research.*

*Ten years later in May, 1962, the National Academy of Sciences again asked a panel of eminent scientists to consider the population problem. That which follows is a significant chapter in their report, and is here reproduced by courtesy of the Academy. It is appropriate that it should be published in* The Rockefeller Institute Review *because the Division of Biology and Medicine of The Population Council and its laboratories are located in the Institute; for many years the faculty of the Institute has contributed much to related biological problems.*

## *The Growth of World Population*

THE POPULATION of the world, now somewhat in excess of three billion persons, is growing at about two per cent a year, or faster than at any other period in man's history. While there has been a steady increase of population growth during the past two or three centuries, it has been especially rapid during the past 20 years. To appreciate the pace of population growth we should recall that world population doubled in about 1,700 years from the time of Christ until the middle of the 17th century; it doubled again in about 200 years, doubled again in less than 100, and, if the current *rate* of population increase were to remain constant, would double every 35 years. Moreover, this rate is still increasing.

To be sure, the rate of increase cannot continue to grow much further. Even if the death rate were to fall to zero, at the present level of human reproduction the growth rate would not be much in excess of three and one-half per cent per year, and the time required for world population to double would not fall much below 20 years.

Although the current two per cent a year does not sound like an extraordinary rate of increase, a few simple calculations demonstrate that such a rate of increase in human population could not possibly continue for more than a few hundred years. Had this rate existed from the time of Christ to now, the world population would have increased in this period by a factor of about $7 \times 10^{16}$; in other words, there would be about 20 million individuals in place of each person now alive, or 100 people to each square foot. If the present world population should continue to increase at its present rate of two per cent per year, then, within two centuries, there will be more than 150 billion people. Calculations of this sort demonstrate without question not only that the current continued increase in the rate of population growth must

cease but also that this rate must decline again. There can be no doubt concerning this long-term prognosis: *Either the birth rate of the world must come down or the death rate must go back up.*

### *Population Growth in Different Parts of the World*

The rates of population growth are not the same, of course, in all parts of the world. Among the industrialized countries, Japan and most of the countries of Europe are now growing relatively slowly – doubling their populations in 50 to 100 years. Another group of industrialized countries – the United States, the Soviet Union, Australia, New Zealand, Canada, and Argentina – are doubling their populations in 30 to 40 years, approximately the world average. The pre-industrial, low-income, and less-developed areas of the world, with two thirds of the world's population – including Asia (except Japan and the Asiatic part of the Soviet Union), the southwestern Pacific islands (principally the Philippines and Indonesia), Africa (with the exception of European minorities), the Caribbean Islands, and Latin America (with the exception of Argentina and Uruguay) – are growing at rates ranging from moderate to very fast. Annual growth rates in all these areas range from one and one-half to three and one-half per cent, doubling in 20 to 40 years.

The rates of population growth of the various countries of the world are, with few exceptions, simply the differences between their birth rates and death rates. International migration is a negligible factor in rates of growth today. Thus, one can understand the varying rates of population growth of different parts of the world by understanding what underlies their respective birth and death rates.

### *Reduction of Fertility and Mortality*

A brief, over-simplified history of the course of birth and death rates in western Europe since about 1800 not only provides a frame of reference for understanding the current birth and death rates in Europe, but also casts some light on the present situation and prospects in other parts of the world. A simplified picture of the population history of a typical western European country is shown in Figure 1. The jagged interval in the early death rate and the recent birth rate is intended to indicate that all the rates are subject to substantial annual variation. The birth rate in 1800 was about 35 per 1,000 population and the average number of children ever born to women reaching age 45 was about five. The death rate in 1800 averaged 25 to 30 per 1,000 population although, as indicated, it was subject to variation because of episodic plagues, epidemics, and crop failures. The average expectation of life at birth was 35 years or less. The current birth rate in western European countries is 14 to 20 per 1,000 population with an average of two to three children born to a woman by the end of childbearing. The death rate is 7 to 11 per 1,000 population per year, and the expectation of life at birth is about 70 years. The death rate declined, starting in the late 18th or early 19th century, partly because of better transport and communication, wider markets, and greater productivity, but more directly because of the development of sanitation and, later, modern medicine. These developments, part of the changes in the whole complex of modern civilization, involved scientific and technological advances in many areas, specifically in public health, medicine, agriculture, and industry. The im-

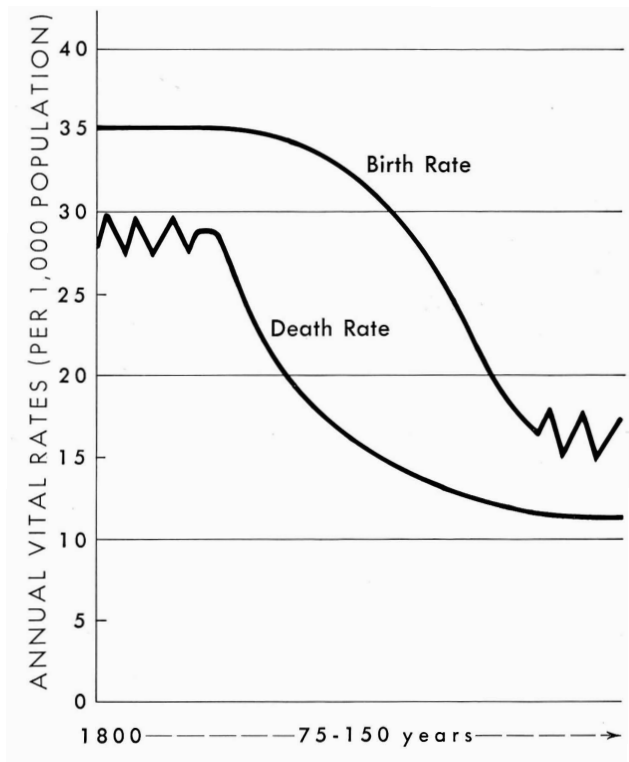


FIGURE 1. *Schematic presentation of birth and death rates in western Europe after 1800. (The time span varies roughly from 75 to 150 years.)*

mediate cause of the decline in the birth rate was the increased deliberate control of fertility within marriage. The only important exception to this statement relates to Ireland, where the decline in the birth rate was brought about by an increase of several years in the age at marriage combined with an increase of 10 to 15 per cent in the proportion of people remaining single. The average age at marriage rose to 28 and more than a fourth of Irish women remained unmarried at age 45. In other countries, however, such social changes have had either insignificant or favorable effects on the birth rate. In these countries – England, Wales, Scotland, Scandinavia, the Low Countries, Germany, Switzerland, Austria, and France – the birth rate went down because of the practice of contraception among married couples. It is certain that there was no decline in the reproductive capacity; in fact, with improved health, the contrary is likely.

Only a minor fraction of the decline in western European fertility can be ascribed to the invention of modern techniques of contraception. In the first place, very substantial declines in some European countries antedated the invention and mass manufacture of contraceptive devices. Second, we know from surveys that as recently as just before World War II more than half of the couples in Great Britain practicing birth control were practicing withdrawal, or *coitus interruptus*. There is similar direct evidence for other European countries.

In this instance, the decline in fertility was not the result of technical innovations in contraception, but of the decision of married couples to resort to folk methods known for centuries. Thus we must explain the decline in the western European birth rates in terms of why people were willing to modify their sexual behavior in order to have fewer children. Such changes in attitude were doubtless a part of a whole set of profound social and economic changes that accompanied the industrialization and modernization of western Europe. Among the factors underlying this particular change in attitude was a change in the economic consequences of childbearing. In a preindustrial, agrarian society children start helping with chores at an early age; they do not remain in a dependent status during a long period of education. They provide the principal form of support for the parents in their old age, and, with high mortality, many children must be born to ensure that some will survive to take care of their parents. On the other hand, in an urban, industrialized society, children are less of an economic asset and more of an economic burden.

Among the social factors that might account for the change in attitude is the decline in the importance of the family as an economic unit that has accompanied the industrialization and modernization of Europe. In an industrialized economy, the family is no longer the unit of production and individuals come to be judged by what they do rather than who they are. Children leave home to seek jobs and parents no longer count on support by their children in their old age. As this kind of modernization continues, public education, which is essential to the production of a literate labor force, is extended to women, and thus the traditional subordinate role of women is modified. Since the burden of child care falls primarily on women, their rise in status is probably an important element in the development of an attitude favoring the deliberate limitation of family size. Finally, the social and economic changes characteristic of industrialization and modernization of a country are accompanied by and reinforce a rise of secularism, pragmatism, and rationalism in place of custom and tradition. Since modernization of a nation involves extension of deliberate human control over an increasing range of the environment, it is not surprising that people living in an economy undergoing industrialization should extend the notion of deliberate and rational control to the question of whether or not birth should result from their sexual activities.

As the simplified representation in Figure 1 indicates, the birth rate in western Europe usually began its descent after the death rate had already fallen substantially. (France is a partial exception. The decline in French births began late in the 18th century and the downward courses of the birth and death rates during the 19th century were more or less parallel.) In general, the death rate appears to be affected more immediately and automatically by industrialization. One may surmise that the birth rate responds more slowly because its reduction requires changes in more deeply seated customs. There is in most societies a consensus in favor of improving health and reducing the incidence of premature

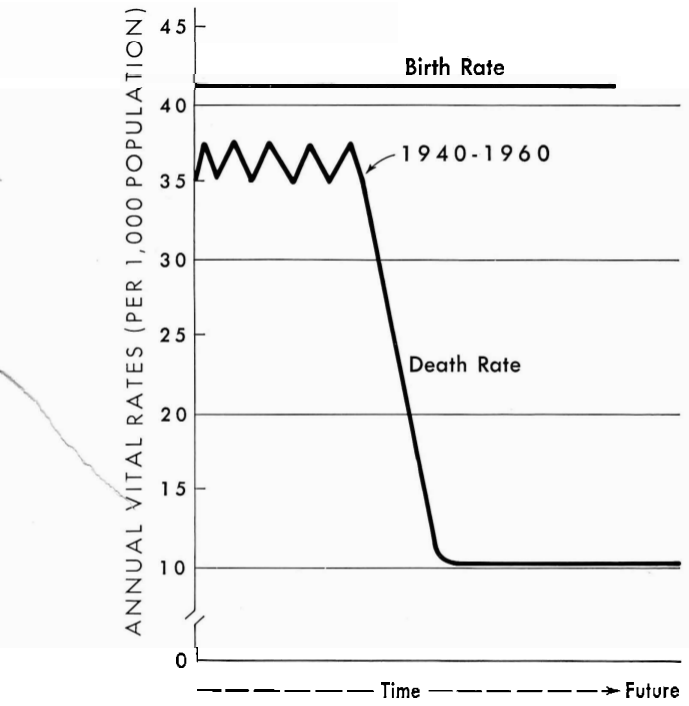


FIGURE 2. *Schematic presentation of birth and death rates in less-developed countries, mid-20th century. (The steep drop in the death rate from approximately 35 per thousand began at times varying roughly between 1940 and 1960 from country to country.)*

death. There is no such consensus for changes in attitudes and behavior needed to reduce the birth rate.

### *Declining Fertility and Mortality in other Industrialized Areas*

The pattern of declining mortality and fertility that we have described for western Europe fits not only the western European countries upon which it is based but also, with suitable adjustment in the initial birth and death rates and in the time scale, eastern and southern Europe (with the exception of Albania), the Soviet Union, Japan, the United States, Australia, Canada, Argentina, and New Zealand. In short, every country that has changed from a predominantly rural agrarian society to a predominantly industrial urban society and has extended public education to near universality, at least at the primary school level, has had a major reduction in birth and death rates of the sort depicted in Figure 1.

The jagged line describing the variable current birth rate represents in some instances — notably the United States — a major recovery in the birth rate from its low point. It must be remembered, however, that this recovery has not been caused by a reversion to uncontrolled family size. In the United States, for example, one can scarcely imagine that married couples have forgotten how to employ the contraceptive techniques that reduced the birth rates to a level of mere replacement just before World War II. We know, in fact, that more couples are skilled in the use of contraception today than ever before. (Nevertheless, effective methods of controlling family size are still unknown and unused by many couples even in the United States.) The recent increase in the birth rate has been the result largely of earlier and more nearly universal marriage, the virtual disappearance of childless and one-child families, and a voluntary choice of two, three, or four children by a vast majority of American couples. There has been no general return to the very large family of pre-industrial times, although some segments of our society still produce many unwanted children.

### *Population Trends in Less-Developed Countries*

We turn now to a comparison of the present situation in the less-developed areas with the demographic circumstances in western Europe prior to the industrial revolution. Figure 2 presents the trends of birth and death rates in the less-developed areas in a rough schematic way similar to that employed in Figure 1. There are several important differences between the circumstances in today's less-developed areas and those in pre-industrial Europe. Note first that the birth rate in the less-developed areas is higher than it was in pre-industrial western Europe. This difference results from the fact that in many less-developed countries almost all women at age 35 have married, and at an average age substantially less than in 18th-century Europe. Second, many of the less-developed areas of the world today are much more densely populated than was western Europe at the beginning of the industrial revolution. Moreover, there are few remaining areas comparable to North and South America into which a growing population could move and which could provide rapidly expanding markets. Finally, and most significantly, the death rate in the less-developed areas is dropping very rapidly — a decline that looks almost vertical compared to the gradual decline in western Europe

– and without regard to economic change.

The precipitous decline in the death rate that is occurring in the low-income countries of the world is a consequence of the development and application of low-cost public health techniques. Unlike the countries of western Europe, the less-developed areas have not had to wait for the slow gradual development of medical science, nor have they had to await the possibly more rapid but still difficult process of constructing major sanitary engineering works and the build-up of a large inventory of expensive hospitals, public health services, and highly trained doctors. Instead, the less-developed areas have been able to import low-cost measures of controlling disease, measures developed for the most part in the highly industrialized countries. The use of residual insecticides to provide effective protection against malaria at a cost of no more than 25 cents per capita per annum is an outstanding example. Other innovations include antibiotics and chemotherapy, and low-cost ways of providing safe water supplies and adequate environmental sanitation in villages that in most other ways remain relatively untouched by modernization. The death rate in Ceylon was cut in half in less than a decade, and declines approaching this in rapidity are almost commonplace.

The result of a precipitous decline in mortality while the birth rate remains essentially unchanged is, of course, a very rapid acceleration in population growth, reaching rates of three to three and one-half per cent. Mexico's population, for example, has grown in recent years at a rate of approximately three and one-half per cent a year. This extreme rate is undoubtedly due to temporary factors and would stabilize at not more than three per cent. But even at three per cent per year, two centuries would see the population of Mexico grow to about 13.5 billion people. Two centuries is a long time, however. Might we not expect that long before 200 years had passed the population of Mexico would have responded to modernization, as did the populations of western Europe, by reducing the birth rate? A positive answer might suggest that organized educational efforts to reduce the birth rate are not necessary. But there is a more immediate problem demanding solution in much less than two centuries. Is the current demographic situation in the less-developed countries impeding the process of modernization itself? If so, a course of action that would directly accelerate the decline in fertility becomes an important part of the whole development effort which is directed toward improving the quality of each individual's life.

### *Population Trends and the Economic Development of Pre-Industrial Countries*

The combination of high birth rates and low or rapidly declining death rates now found in the less-developed countries implies two different characteristics of the population that have important implications for the pace of their economic development. One important characteristic is rapid growth, which is the immediate consequence of the large and often growing difference between birth and death rates; the other is the heavy burden of child dependency which results from a high birth rate whether death rates are high or low. A reduced death rate has only a slight effect on the proportion of children in the population, and this effect is in a rather surprising direction. The kinds of mortality reduction that have actually occurred in the world have the effect, if fertility remains unchanged, of reducing rather than increasing the average age of the population.

Mortality reduction produces this effect because the largest increases occur in the survival of infants, and, although the reduction in mortality increases the number of old persons, it increases the number of children even more. The result is that the high fertility found in low-income countries produces a proportion of children under fifteen of 40 to 45 per cent of the total population, compared to 25 per cent or less in most of the industrialized countries.

What do these characteristics of rapid growth and very large proportions of children imply about the capacity to achieve rapid industrialization? It must be noted that it is probably technically possible in every less-developed area to increase national output at rates even more rapid than the very rapid rates of population increase we have discussed, at least for a few years. The reason at least slight increases in per capita income appear feasible is that the low-income countries can import industrial and agricultural technology as well as medical technology. Briefly, the realistic question in the short run does not seem to be whether some increases in per capita income are possible while the population grows rapidly, but rather whether rapid population growth is a major

deterrent to a *rapid* and *continuing* increase in per capita income.

A specific example will clarify this point. If the birth rate in India is not reduced, its population will probably double in the next 25 or 30 years, increasing from about 450 to about 900 million. Agricultural experts consider it feasible within achievable limits of capital investment to accomplish a doubling of Indian agricultural output within the next 20 to 25 years. In the same period the output of the non-agricultural part of the Indian economy probably would be slightly more than doubled if the birth rate remained unchanged. For a generation at least, then, India's economic output probably can stay ahead of its maximum rate of population increase. This bare excess over the increase in population, however, is scarcely a satisfactory outcome of India's struggle to achieve economic betterment. The real question is, could India and the other less-developed areas of the world do substantially better if their birth rates and thus their population growth rates were reduced? Economic analysis clearly indicates that the answer is yes. Any growth of population adds to the rate of increase of national output that must be achieved in order to increase per capita output by any given amount.

To double per capita output in 30 years requires an annual increase in per capita output of 2.3 per cent; if population growth is three per cent a year, then the annual increase in national output must be raised to 5.3 per cent to achieve the desired level of economic growth. In either instance an economy, to grow, must divert effort and resources from producing for current consumption to the enhancement of future productivity. In other words, to grow faster an economy must raise its level of net investment. Net investment is investment in factories, roads, irrigation networks, and fertilizer plants, and also in education and training. The low-income countries find it difficult to mobilize resources for these purposes for three reasons. The pressure to use all available resources for current consumption is great; rapid population growth adds very substantially to the investment targets that must be met to achieve any given rate of increase in material well-being; and the very high proportions of children that result from high fertility demand that a larger portion of national output must be used to support a very large number of non-earning dependents. These dependents create pressure to produce for immediate consumption only. In individual terms, the family with a large number of children finds it more difficult to save, and a government that tries to finance development expenditures out of taxes can expect less support from a population with many children. Moreover, rapid population growth and a heavy burden of child dependency divert investment funds to less productives uses – that is, less productive in the long run. To achieve a given level of literacy in a population much more must be spent on schools. In an expanding population of large families, construction effort must go into housing rather than into factories or power plants.

Thus the combination of continued high fertility and greatly reduced mortality in the less-developed countries raises the levels of investment required while impairing the capacity of the economy to achieve high levels of investment. Economists have estimated that a gradual reduction in the rate of childbearing, totaling 50 per cent in 30 years, would add about 40 per cent to the income per consumer that could be achieved by the end of that time.

To recapitulate, a short-term increase in per capita income may be possible in most less-developed areas, even if the fertility rate is not reduced. Nevertheless, even in the short run, progress will be much faster and more certain if the birth rate falls. In the longer run, economic progress will eventually be stopped and reversed unless the birth rate declines or the death rate increases. Economic progress will be slower and more doubtful if less-developed areas wait for the supposedly inevitable impact of modernization on the birth rate. They run the risk that rapid population growth and adverse age distribution would themselves prevent the achievement of the very modernization they count on to bring the birth rate down.

THE MEMBERS of the National Academy of Sciences Panel on Population Problems were, William D. McElroy, Chairman, The Johns Hopkins University; Willard Allen, The Washington University; Bernard Berelson, The Population Council; Ansley Coale, Princeton University; Harold Dorn, National Institutes of Health; Clement L. Markert, The Johns Hopkins University; Warren Nelson, The Population Council; Albert Tyler, California Institute of Technology. George B. Kistiakowsky is Chairman of the Academy Committee on Science and Public Policy, which sponsored the Panel.

# INSTITUTE RECORD

## ACADEMICIAN

Professor Maclyn McCarty was elected a member of the National Academy of Sciences at the Academy's Annual Meeting. Among Dr. McCarty's many scientific achievements which were recognized by his election was his collaboration with Avery and MacLeod in the isolation of the substance responsible for transformation of pneumococcal types and in its identification as deoxyribonucleic acid. This demonstrated for the first time the biological activity and genetic significance of DNA.

McCarty's studies on group A streptococci and their relationship to rheumatic fever have dealt with both the intracellular products and cellular composition of these organisms. He demonstrated the occurrence of deoxyribonuclease as a prominent member of the family of substances released into the environment by streptococci and studied the enzymatic and immunological properties of this bacterial enzyme. In the course of his studies on cellular composition, work on the bacterial cell wall revealed that the group-specific carbohydrate is the major constituent of this structure. Elucidation of the chemical structure of the cell-wall carbohydrate of group A streptococci and that of certain of their mutants led to a correlation between monosaccharide composition and serological specificity and identification of the chemical groupings responsible for such specificity.

There are now thirty-three members of the Academy on the faculty of the Institute, not including Visiting Professors.

## HONORARY DEGREES

Professor Richard E. Shope received the honorary degree of Doctor of Science from his Alma Mater, the University of Iowa, at its May Commencement.

President Bronk received an honorary doctorate at the Annual Commencement of the University of Illinois.

## GUESTS

The Institute is host to an ever-increasing number of academic and scientific organizations. The Johns Hopkins University Alumni Association of Connecticut, New York, and New Jersey, and the University of Pennsylvania medical alumni in the New York area held their annual dinner meetings in Welch Hall and Caspary Auditorium. The Panel on International Science of the President's Science Advisory Committee met for two days in Abby Aldrich Rockefeller Hall. The Health Research Council of the City of New York held its annual meeting in the Abby followed by a dinner at which Mayor Robert Wagner was a guest. The Hospital for Special Surgery held part of their three-day Centennial Celebration in Caspary Auditorium.

## CONVOCATION

Sixteen graduate students received the degree of Doctor of Philosophy at the Fifth Annual Convocation for Conferring Degrees:

ALAN R. ADOLPH, B.E.E. Rensselaer Polytechnic Institute, S.M. Massachusetts Institute of Technology

BARRY R. BLOOM, B.A. Amherst College

ROBERT D. CAMPO, B.S., M.S. St. John's University

STEPHEN COOPER, B.A. Union College

BRIAN A. CURTIS, A.B. The University of Rochester

ERIC H. DAVIDSON, B.A. University of Pennsylvania

FREDERICK A. DODGE, JR., B.A. University of Pennsylvania

ALAN FINKELSTEIN, A.B. Washington and Jefferson College

PETER J. GOMATOS, S.B. Massachusetts Institute of Technology, M.D. The Johns Hopkins University School of Medicine

GUIDO GUIDOTTI, M.D. Washington University School of Medicine

JOHN W. B. HERSHEY, B.A. Haverford College

JOAN L. KENT, B.A. Barnard College

W. CAREY PARKER, B.S.E. Princeton University, B.A. University of Oxford

CAROLYN W. SLAYMAN, B.A. Swarthmore College

CLIFFORD L. SLAYMAN, JR., B.A. Kenyon College

CECIL C. YIP, B.Sc. McMaster University

Honorary degrees of Doctor of Laws were conferred on Henry Allen Moe, President of the John Simon Guggenheim Memorial Foundation and of the American Philosophical Society, and Alan Tower Waterman, Director of the National Science Foundation and President of the American Association for the Advancement of Science.

## LECTURERS

The R. A. F. Penrose, Jr., Memorial Lecture of the American Philosophical Society was delivered by Professor René Dubos, the G. H. A. Clowes Memorial Lecture of the American Association for Cancer Research by Dr. Peyton Rous, the Centennial Lecture of the Kansas State University by President Bronk.

## PROFESSOR EMERITUS

Norman R. Stoll has been appointed Professor Emeritus. His distinguished career in parasitology began four decades ago after graduating from Syracuse University. In 1927 he became associated with The Rockefeller Institute's Department of Animal Pathology in Princeton, moving to New York in 1951 when the Department at Princeton was discontinued. Dr. Stoll will continue his significant contributions to science in the laboratories he has been occupying in Theobald Smith Hall.

## PROMOTIONS

To Professor:
Vincent G. Allfrey

To Associate Professor:
Gerald M. Edelman
Te Piao King
Alexander Mauro
Robert L. Schoenfeld
Walther Stoeckenius

To Assistant Professor:
Aharon Gibor
Edward Reich
Alexander Tomasz

## RETIREMENT

Miss Florence M. Stewart has retired as Supervisor of the Journals Department after forty-seven years of devoted and excellent service. A reception in her honor was attended by her many friends at the Institute. She is succeeded by Miss Margaret Broadbent, her assistant, who has been with the Department since 1940.

THE COVER *shows the tree-shaded walk on east side of Abby Aldrich Rockefeller Hall, photograph by Stephan Pischinger.*