



HOW HURRICANES ARE BORN

BOULDER, COLO.

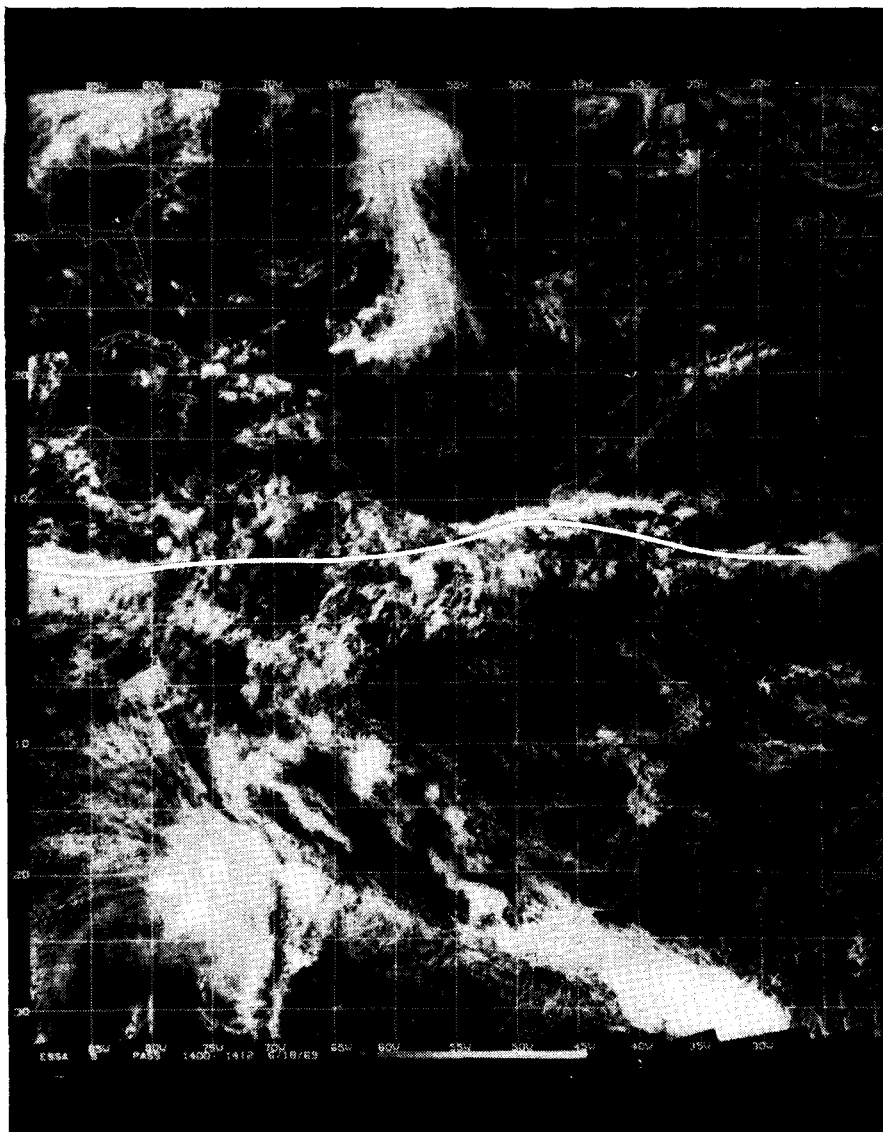
C*amille* began her short and violent life in obscurity. The only recognition of her coming early in August 1969 was the appearance of a long inverted V in a thin cloud line high over Africa. Artificial satellites of Earth noticed her; they watched her drift west over the face of the planet; but they saw no sign that she might be vicious. Not until she had crossed the Atlantic Ocean and most of the Caribbean Sea did the V dissolve into cloud streets, which then tightened into a spiral. South of Cuba, the winds within her churned up to sixty miles per hour and so made her a hurricane. At that point, *Camille* was too close to inhabited land for Environmental Science Services Administration observers to risk trying to slow her by dousing her eye with ice-crystal seeds. She was plainly headed for the Gulf of Mexico. Warnings of her dangerous nature preceded her as she picked up speed and swung north in a looping rage through the Mississippi and Ohio River valleys to the Atlantic coast of Virginia. After that, she collapsed in exhaustion and died above the sea that had awakened her ferocity.

Camille never grew very big as hurricanes grow. She killed fewer people (between 300 and 400) than *Audrey* did in 1959, wrought but a third of the \$1.5-billion property damage *Betsy* wreaked in 1965; she nevertheless drove the mercury columns in barometers down almost to the vanishing point, pushed wind speeds up to at least 190 mph and probably above 200 mph, drowned the lowlands under a twenty-five-foot-high tidal wave, and set more than a hundred tornadoes whirling from her skirts. The intensity of her punch was the fiercest of any storm that ever hit the North American continent. Only once before—in India—had any place on Earth suffered worse devastation.

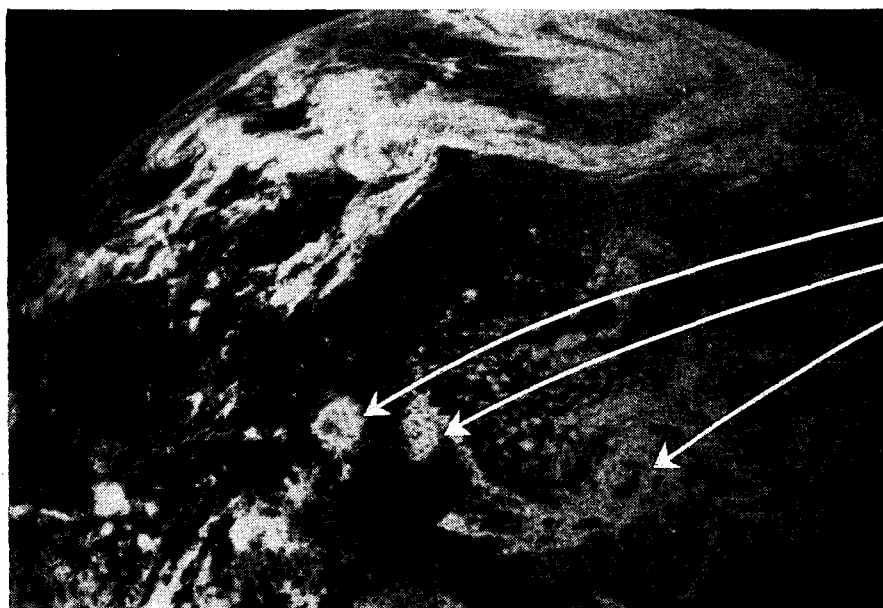
Could *Camille* have been intercept-



What hurricane "Camille" did to Biloxi, Mississippi.



Constant turning of the Earth generates the trade winds, which meet north of the equator and create a shear in the atmosphere, driving warm air up to form clouds (marked by undulating tinted line in photo above) which sometimes break up into stormy pinwheels (indicated by arrows in the photo below).



ed? Could she have been tamed en route to her rendezvous with disaster?

Given the present state of scientific knowledge of atmospheric behavior, the answer must be negative. Although theoretical work with mathematical models indicates a reasonable possibility of altering individual clouds by forming rain-nucleating ice crystals at particular points in those clouds, the science of hurricane modification is still too primitive to allow experiments with any developing storm that has as much as a 10 per cent chance of making itself felt on densely populated land within the following twenty-four hours. *Camille* never fell into that cautious category from the time she earned the name of hurricane off Cuba. Yet, her grisly biography is not altogether discouraging. There is positive potential in the fact that *Camille* could be traced in weather satellite pictures as far back as the African continent. Only her identity—not her presence—had escaped detection. What remains for the study of her successors is to discover how all hurricanes are born.

So deep and long sustained a mystery is not likely to give up its secrets in a night or even in a season. Science has taken a long while to discover the little that is now known about disturbances of the tropical atmosphere. That little can be put into a few brief sentences. The sun radiates energy at 6,000 degrees Centigrade, mostly in those wave lengths of the electromagnetic spectrum that can be seen by the human eye. More of this energy reaches Earth in the neighborhood of the equator than elsewhere on the planet. Since most of Earth at its equator is covered by sea water, the preponderant fraction of solar energy is captured in the upper reaches of the sea. The temperature of the surface waters therefore rises to an average range of 28 to 30 degrees C., the waters evaporate at a relatively steady rate and, at the same time, strike a balance with the cooler atmosphere by radiating back into the sky the electromagnetic wave lengths that arise from the temperature level of the ocean. This turns out to be in the invisible spectrum of the infrared.

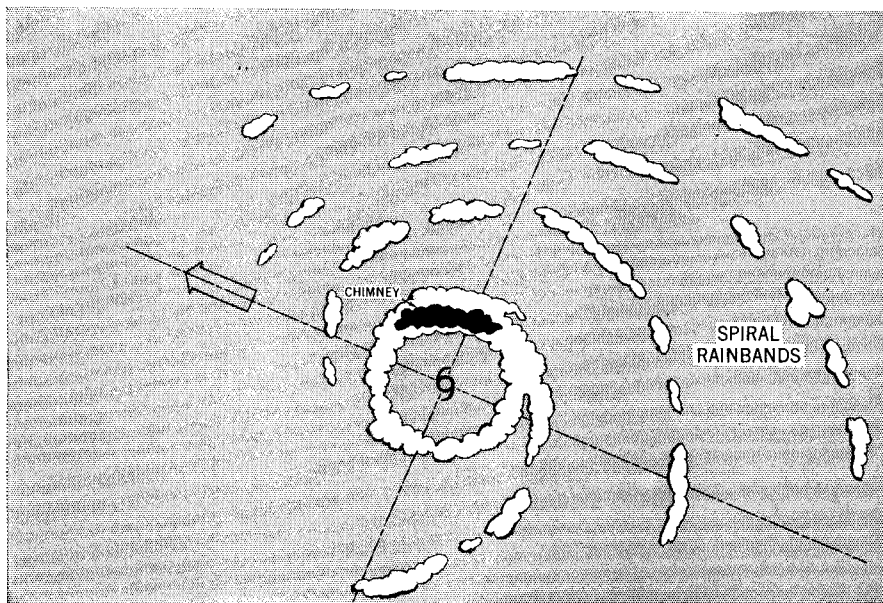
During these happenings, the planet is constantly turning eastward. The circular motion swirls both the sea water and the air above it to the left (of observers facing the sunrise) in the Northern Hemisphere, and to the right in the Southern Hemisphere. Theoretically, the dividing line between the opposing manifestations of this (the Coriolis) force is the equator. But the Earth wobbles on its axis and the geographic equator often does not mark a true center line of planetary

effects. Over the Atlantic Ocean, for example, the northeast and southeast trade winds (consequences of the Coriolis force in the lowermost mile of the atmosphere) meet in what is called the Intertropical Convergence (ITC) between 5 and 10 degrees north of the equator. Flowing in opposite directions, the trade winds create an undulating shear line that drives air laden with sea vapor upward to somehow find its way to the poles.

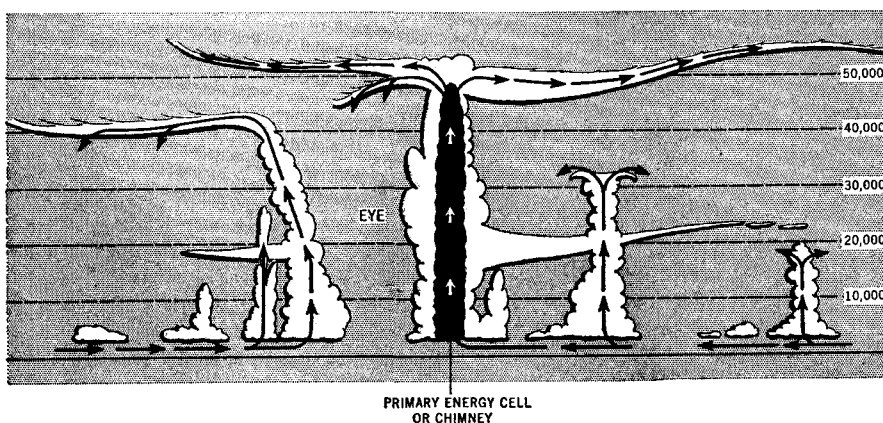
The clouds that ride the ITC flow westward from the African coast (sometimes they originate beyond the coast over the African continent), encounter other natural forces en route, dissipate, free their imprisoned energy for generation of new clouds, and so perpetuate the cloud life cycle in the midst of which they now and then throw off cloud pinwheels to carry on lives of their own (see photographs, opposite page). Hurricanes are such pinwheels; they spiral ever more tightly as the energy within them drives the clouds up to and beyond the 50,000-foot level (sketch, right). There, temperatures fall 50 to 60 degrees below zero and fuse vapor droplets into ice crystals, packing the spiral with energy that ultimately must be used up in some way; for one of the primary laws of nature says that although energy can be transferred freely, back and forth from light to heat to motion to heat to light, it can never be lost.

Not all the pinwheels that spin off the ITC cloud belt develop into hurricanes. Nor, apparently, do all hurricanes originate as ITC pinwheels. *Camille*, as has already been noted, crossed the Atlantic in the relatively passive form of an inverted V in the ITC cloud strand; she was not recognized as a hurricane until she was south of Cuba. In the grand sense, however, this is mere detail. The ITC is the source both of the pinwheels and the V-shaped cloud patterns; hence the ITC is the governing influence in weather-making over the Atlantic. Any doubt there may have been about that last spring was disposed of during the summer just ended by the most elaborate weather experiment man has ever undertaken.

I came to the foot of the Rocky Mountains here at Boulder, Colorado, to learn about this experiment from the scientist who directed it: former German rocketeer Dr. Joachim P. Kuettner, who began his career in this country in the Wernher von Braun group of the National Aeronautics and Space Administration. Dr. Kuettner is now employing his meteorological skill in ESSA's basic research laboratory here—more than 3,000 miles northwest of the site of the experiment I have referred to: Barbados, eastern-



HURRICANE MODEL



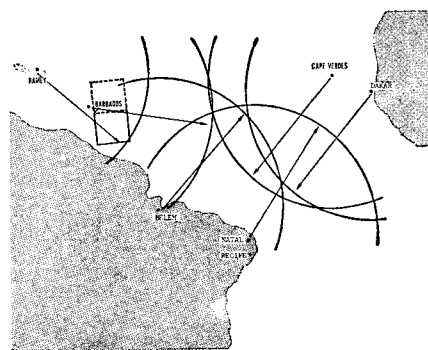
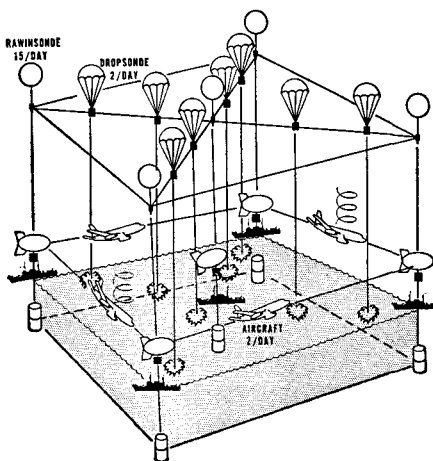
The hurricane pinwheel, from above (top) and head-on (below).

most of the islands that set off the Caribbean from the Atlantic.

Because of the site, the historic experiment was nicknamed BOMEX, short for Barbados Oceanographic and Meteorological Experiment. Many months in preparation and three months plus a week (May 1 to August 5) in execution, BOMEX had as its purpose the observation and chronolo-

gy of every natural transaction that could in any way contribute to the energy budget of a column of space 300 miles square. The column rested on the ocean floor and extended upward through three miles of sea water and twenty miles of atmosphere.

The boundary points of the two million cubic miles of water and air contained within the column were marked

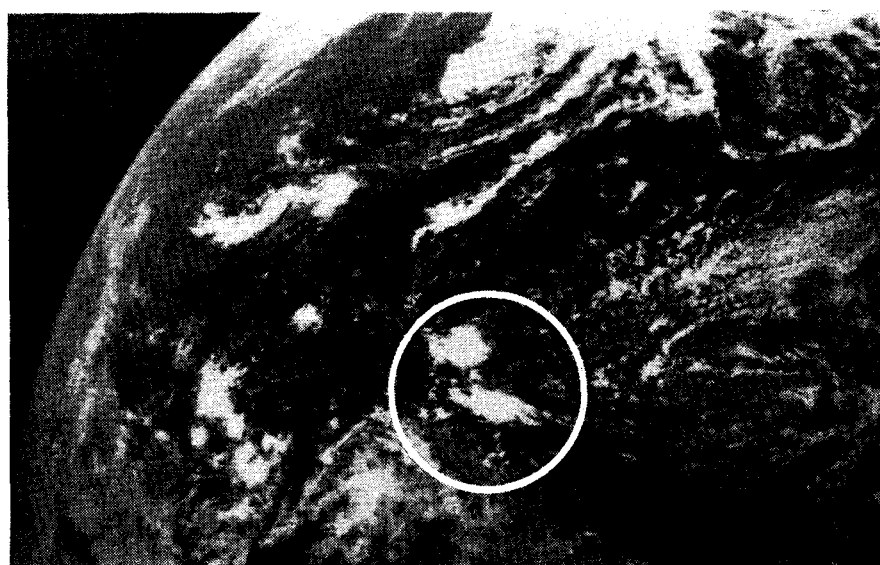
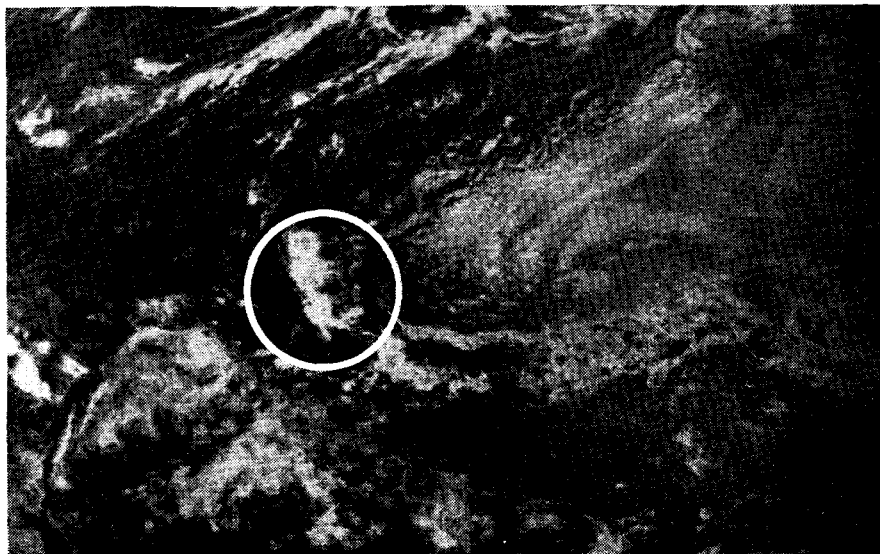


BOMEX experimental column is sketched at left. Above: observing planes' flight ranges.

off on the water by surface-going ships and in the air by observation blimps (see sketch, page 69). The boundary lines were regularly patrolled by airplanes stacked in 1,000-, 4,000-, 7,000-, 10,000-, 13,000-, and 16,000-foot arrays. Other planes traversed the column by other routes from 500- to 60,000-foot altitudes. Sounding balloons were sent up to the 100,000-foot level fifteen times a day, and packages of instruments were parachuted from the column's top twice a day. Instrumented buoys watched events that occurred where the air met the water, and measurements were taken as far as 100 feet beneath the water's surface by a unique ship named *FLIP* that is capable of turning on end and hanging upright in the sea with most of its length submerged.

Water and air currents were clocked, movements of sunlight and water vapor were registered, temperature and pressure variations were recorded, and energy transfers were noted along with appearances and disappearances of clouds. The data collection was guided by 1,500 scientists and technicians from a dozen American government agencies, twenty-two university faculties, and six industrial laboratory staffs, who funneled numerical data into a computer bank that will continue integrating the information for at least one and probably two years.

The numerical picture of the situation will be verified by a multitude of photographs. Throughout the three months of BOMEX, *Nimbus III*, a weather satellite orbiting over the poles at an altitude of 700 miles, snapped the scene each day at local noon and scanned the experiment site with infrared sensors at each local midnight. Three other heavenly observers were also involved. *ESSA 8* and *ESSA 9* were close to 900 miles out, the former recording the scene at 9 a.m. and the latter at 3 p.m. Far beyond them—22,000 miles from Earth—at the distance where a satellite's speed matches the speed of Earth's turning and so holds the satellite constantly over one spot on the planet's surface, *Applications Technology Satellite III* hung over the equator just southeast of Barbados. *ATS III* had been ordered to go there from a point farther west, where it earlier watched tornadoes forming in the Mississippi River Valley. Not only did *ATS III* take a new cloud picture of a third of the Earth's face every twenty minutes; the photos were radioed to Barbados for virtually instant reproduction. Two thousand four hundred lines of light and shade went into each picture. Clear transmission was assured by the stationing of a thirty-foot-wide radio signal receiving dish on Barbados. Designed, built, and



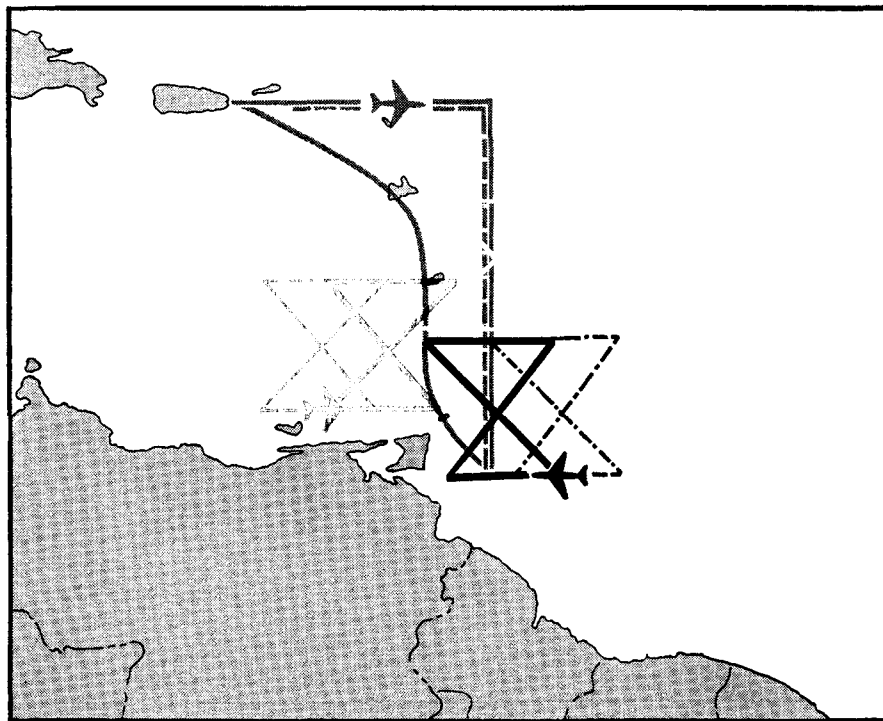
owned by the Hughes Aircraft Company, this half-million dollar instrument had been flown from California in thirty pie-slice wedges; it was put together in six days with a seventy-foot crane from Barbados Deepwater Harbor. Its performance edged weather experiments into a new era.

As Dr. Kuettner has explained it to me, the major problem in sampling clouds lay in the planning of flights that would place the observation planes where the clouds would be at significant moments of cloud life. Since many of the flights were flown by the military (see sketch, page 69), lasted four to fourteen hours, and covered 400 to 3,000 nautical miles, they had to be scheduled in relation to other responsibilities of the military bases concerned. Consequently, flight paths for one day would be laid out at 2 o'clock on the afternoon of the pre-

vious day. Photos received from *ATS III* up to that hour would be consulted and compared with photos taken on preceding days; positions of target clouds would then be estimated for the target hour of the target day, and planes would be assigned accordingly.

But in the tropics a great many atmospheric disturbances last only twelve to twenty-four hours. Clouds pictured at 2 p.m. of any day—or even at tropical sunset four hours later—were very likely to disappear, change radically, or move to quite different places in the sky before the next sunrise provided light for *ATS III* to begin another day's work. The midnight infrared readings of *Nimbus* gave a fair idea of what had been happening halfway through the darkness, but those observations were difficult to fit to the visible light picture grid; therefore, the dawn photos of *ATS III*

On Orders From Above



During BOMEX, the grandest weather experiment man has ever tried, Applications Technology Satellite III, stationed 22,000 miles out from the equator south of the experiment site, took pictures of clouds over that third of the globe every twenty minutes from dawn to nightfall and radioed them to Barbados for immediate reproduction and use in directing aircraft assigned to observe cloud life patterns. When cloud mass circled in top photo on opposite page split in two overnight, three planes already aloft were shifted to watch the newborn twins. Dotted lines in sketch above mark original flight paths, solid lines the revised paths. One plane in color, one in black, one in gray.

would be used as a source of new instructions to the plane crews, who would often be ordered to alter flight paths in the midst of missions.

Dr. Kuettner gave me two photographs to illustrate the kind of problem that BOMEX solved in this way. These are reproduced on page 70. On the evening of July 14, the upper photograph showed a suspicious cloud mass. On the morning of July 15, this mass had split in two. The sketch above shows how the observation planes were shifted to catch the results of the split.

Final results of the BOMEX experiment will not be available for at least two years. However, Dr. Kuettner will state some rough preliminary conclusions at an international scientific conference in Buenos Aires early this month. Here are some of the discoveries scheduled for disclosure:

► The ITC is the dominant governing force in the tropical atmosphere and is closely related to development of all tropical storms. It is the principal mechanism that lifts the warm, moist air of the tropics from the trade wind belt into the higher atmosphere.

► The ITC interacts considerably more vigorously with local forces in the tropical atmosphere than had been assumed before BOMEX.

► The very large cloud clusters so often seen in weather satellite photographs are not the major vehicles of upward air transport that they were thought to be.

► The atmosphere captures perhaps twice as much of the incoming radiation of the sun before the radiation reaches the sea than had been sup-

posed. This means that less energy is available to heat the oceans, and a deep-sea mechanism of some kind is now being postulated to help explain the ocean's role in heat storage and transfer.

► Whereas the assumed effects of the sea on the atmosphere have been confirmed, the air has less effect on the water than scientists had calculated.

► The behavior of the air just above the surface of the water is not as simple as had been postulated. For example, the humidity and the temperature had been thought to rise and fall in unison. Actually, packets of air three to four miles long have been observed in which temperature and vapor content jumped suddenly; but when the temperature fell, its drop occurred more sharply than the subsidence in humidity.

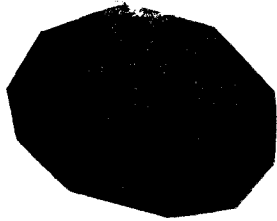
► There are eastbound currents in the sea off Barbados where navigation charts indicate all motion of the water is westward.

► The Amazon River pours a torrent of fresh water 120 feet deep and 200-500 miles wide north and northwest of its mouth in summer. This great stream remains unmixed with the salt water of the Atlantic for 1,000 miles. The salt content of the ocean in this vicinity is markedly diminished, the temperature of the overlying air is lowered, evaporation of the sea water is slowed, and cloud convection is accordingly reduced. Something happens—apparently a major shift in the wind—to remove this Amazonian phenomenon in winter.

For all its scientific implications, BOMEX had far greater political ones. It was an obvious first step in GARP, the Global Atmospheric Research Project on which world-wide weather forecasting three weeks in advance depends. What can be done by nations that really want to work together is demonstrated by successful transmission of *ATS III* pictures to Europe and their successful reproduction there.

Perhaps if the peoples concerned could be more adequately informed, it would be possible within the next five years to extend BOMEX northward in the Atlantic, in the direction most promising for further discoveries about the circulation of atmospheric energy from the ITC to the poles. In the absence of popular understanding, the next step toward GARP probably will have to be shifted, out of logical phase, to some uninhabited stretch of the Pacific Ocean.

—JOHN LEAR.



The Maturing Science

1. Background

by HARRY BENJAMIN, M.D.

The phenomenon of gender-role disorientation, that is, of anatomic males feeling themselves to be women and wanting to be women and of anatomic females feeling themselves to be men and wanting to "change sex," has existed in rare individuals since time immemorial. In modern days, it occasionally has been described by psychologists as "total sex-inversion" or with similar designations. Its clinical picture, however, only recently has been seen as a definite, recognizable medical entity, rare in the general population and impressive in its often tragic consequences for the individual.

The first book relating in popular scientific form a probable case of transsexualism may be Niels Hoyer's *Man into Woman* (1933). The noted British sexologist Norman Haire wrote the introduction that made Hoyer's book a semi-medical contribution. It is the story of a Danish painter who in the 1920s became "Lili Elbe" after operations that altered his genital organs. He had been married as a man, but before he could enter into a second marriage as a woman, he died.

My own first contact with the phenomenon, although I was far from recognizing it as such, occurred in the early 1920s. The largest part of my medical practice at that time was concerned with the growing fields of endocrinology and geriatrics, but sexological cases were by no means rare. Among the latter was that of an elderly

transvestite who owned a press-clipping bureau. He was a well-educated man, married, and a father. Being separated from his wife, he had his home together with his business establishment and lived there completely as a woman. His family and employees fully accepted his "eccentricity." Outside the house, he dressed as a man.

He had read about the newly discovered female hormone, progynon. This product, then of rather low potency, was the result of long and intensive experiments by Eugen Steinach, professor of physiology at the University of Vienna, and by Professor Schoeller of the Schering Corporation (then of Berlin), the company that manufactures this estrogenic hormone.

My patient wanted to know whether progynon could enlarge his breasts, a prospect that would give him a great emotional satisfaction. With some hesitation I agreed to investigate, and, after a few months of parenteral therapy, a mild gynecomastia was produced to the infinite delight of the patient.

Years later I met my first more immediately recognizable male transsexual through Dr. Alfred C. Kinsey and his associates, Dr. Wardell B. Pomeroy and Dr. Clyde E. Martin. These scientists were then engaged in taking routine sex histories for their work on sexual behavior in the human male and female. The next and perhaps the most important milestone in the history of transsexualism was the "sex conversion" of Christine Jorgensen and the world-wide publicity it created. More patients of this nature were soon referred to me by Christine's doctors, as well as by Christine. By 1953, I had probably examined more cases of gender-identity disturbance than any other clinician in the United States. By 1965, there seemed to be enough clinical material on transsexualism to warrant my writing a book called *The Transsexual Phenomenon*.

But nothing has been quite as encouraging and gratifying as the decision by Johns Hopkins Hospital, where I personally had or have no official connection whatever, to accept transsexual patients for study by its Gender Identity Committee and, if approved by the committee, for treatment and sex-reassignment surgery. Dr. John Money, psychologist at Johns Hopkins, widely known and respected for his extensive studies on hermaphroditism

and related endocrinopathies and sexual disorders, was probably more responsible than any other individual for the decision that such an august institution as Johns Hopkins Hospital would take up this controversial subject and actually endorse sex-altering surgery in suitable subjects. The formation of the committee under the chairmanship of the plastic surgeon Dr. John E. Hoopes, largely for investigational purposes but also for the actual care of patients, was officially announced through *New York Times* reporter Thomas Buckley on November 21, 1966. Two days later, a senior newsman of the *Baltimore Sun*, Weldon Wallace, interviewed thirteen clergymen representing a variety of faiths, as to the moral aspects of the physical change of sex. There were no moral objections to the procedure by anyone. Only one, an official of the Catholic Archdiocese, declined comment. Most members of the medical profession everywhere must have been startled by the Johns Hopkins announcement. Many individual doctors, I like to hope, began to re-examine their own opinion on the subject.

To oppose such surgery in every case as a matter of principle is as wrong from a scientific and human standpoint as it would be to grant a "conversion operation" merely on request. Extended observation and careful screening seem to me indispensable. The technique of the operation itself requires further perfection, in order to avoid the present, not too rare, postoperative complications.

While thanks are due to all the patients who have, with more or less objectivity and altruism, described their deviation, science now eagerly awaits the first truly objective reports from investigational sources, especially about therapeutic results and how genetic men or women have been able to adjust to life and society in the gender roles demanded by their psyche but opposite to their anatomy.

The future may likewise see efforts to solve the riddle of the etiology of gender disturbances. How much can be psychological? How much may be genetic, how much neuroendocrine? What would be the nature of a predisposition to transsexuality, and how much of a role does it play in the final clinical picture? Can the imprinting phenomenon, as observed in animals, find a parallel in humans?

Transsexualism and Sex Reassignment, a new Johns Hopkins Press book edited by Richard Green, M.D., and John Money, Ph.D., is scheduled for publication in November. It is previewed here by special permission of the publisher. Dr. Harry Benjamin is identified on the book's dedicatory page as "the pioneer of transsexual research." Dr. Ira B. Pauly is associate professor of psychiatry at the University of Oregon Medical School, Portland. Dr. Ruth Rae Doorbar, who provided the sketches (drawn by transsexual persons) to illustrate her chapter on psychological testing of transsexuals, is a Park Avenue psychologist. The text here reproduced was published originally with the support of the Erickson Educational Foundation and is copyright © 1969 by the Johns Hopkins Press.