judge his own cause." Handler says he will continue as a member of the National Science Board but will resign the chairmanship of the board and a directorship he has held in the Squibb-Beechnut Company.

Whether the National Academy of Sciences will prove adequate to the needs of today's divided society is an open question. In preparing this report, I asked the opinions of a selected group of scientists, scientific administrators, and legislators concerned with science as a social force. One influential Senator said: "It may be preferable for Congress to inquire into the nature of the mandate it gave this organization so casually a century ago."

As I noted earlier, the Academy charter has already been employed to cover the creation of a National Academy of Engineering. Before very long, the realization of an Academy of Medicine may be expected under the NAS aegis. Will even those institutions together be enough? Handler has considered the problem and occasionally has dreamed—he won't discuss it except as a dream—of a single American Academy to serve all sectors of the society equally. Such a conglomerate seems far in the future, but it may be the only alternative to disintegration.

An embryo that could grow into an American Academy has been in being since 1944. It is the Conference Board of Research Councils. Once a year, sometimes more often, it brings together representatives of the National Academy of Sciences, the Social Science Research Council, the American Council on Education, and the American Council of Learned Societies to exchange information of common interest. One regular item of business is nomination of candidates for post-doctoral Fulbright Scholarships. One extraordinary mission will be finished this year with publication by Russell Sage Foundation of a report on manpower studies of the Presidential Commission on Human Resources and Advanced Education. This report may focus attention anew on the ludicrously small membership of the National Academy of Sciences—839 men and seven women.

Philip Handler is a hard-driving man. He can exasperate those who disagree with his objectives. His daring is conceded by his severest critics. What they dispute is his ability to harness his boldness for the general good of society when that is in conflict with the selfish interests of science. A mild example of what they fear was the recent White House fracas over Cornell Professor Franklin Long's nomination as director of the National Science Foundation. Handler helped to advertise that affair as a partisan political intrusion into the province of science. Actually, under the usual rules of politics, Long—a Democrat and a declared opponent of some of President Nixon's policies—would not have been eligible for a presidential appointment. Yet, he was nominated by the National Science Board under Handler's chairmanship and his name was cleared in the customary way with the two Senators from his home state, New York. The appointment was withdrawn at the last moment because of protests from the conservative Republicans who had put Nixon into office. The President was not guilty of political direction; he was obligated to exercise it; he simply backed down on a commitment.

Because of his proclaimed concern with bringing the Academy more into tune with society's needs, Handler lacks the freedom enjoyed by his more magisterial predecessor, Dr. Seitz, who frankly considered the Academy a part of the Establishment and left it to the press to expose abuses that might arise from that relationship (a responsibility the press has not understood).

When asked where he is going, Handler says he can't tell until he sees where his current experiment takes him. But we know where he has been (here at Durham, building from scratch one of the top ten biochemical schools in the country; at Woods Hole, Massachusetts, in the summers, with the "invisible Academy" of the biological science; at Washington, shaping biological science into a force almost certain to dominate the close of the twentieth century) and who has intimately shared his travels—principally his wife Lucille and their two sons, school teacher Eric Paul, and news photographer Mark (on the *Chapel Hill Weekly*). We know, too, that although Handler is retaining title to the chair of James B. Duke Professor of Biochemistry, he is abandoning a beautiful Durham hilltop home surrounded by grass, trees, and flowers that he planted himself. He has encouraged the Academy to sell the quarter-million-dollar mansion in Washington that goes with the presidency in order to allow him to live in the posh Watergate West apartments. "We don't think the home of the Academy president should be a museum exactly, but we do expect to furnish the apartment with the best we can find of America," he says. Somewhere among the Americana will be a herd of 300 miniature cows. They are all sizes and breeds, including at least one Brahman (see photo, page 38). Some are of clay, some of ceramic, some of metal, some of wood. He says he doesn't know why he keeps the cows, except that he likes cows. Maybe they are a subconscious recognition of the importance in his life of Bull Durham and Washington Duke's mule. —JOHN LEAR.

WHAT WE CAN'T KNOW

by JACOB BRONOWSKI

Of course, we never know with certainty what the social consequences of any discovery will be. Who would have thought that the unfortunate character who invented photographic film would have been responsible for the California film industry? And thus, indirectly, for contracts that would prevent film stars from having affairs that might give rise to gossip and scandal? That consequently stars would lead their love life in public, by repeated divorce and marriage? That therefore the beautiful pin-ups of films would, in time, become the models of the divorce business? And the climax, that one-third of all marriages contracted this year in California are going to end in divorce—all because somebody invented the process of printing pictures on a celluloid strip?

On the same lines (which I leave you to trace), who would have supposed that Henry Ford's devising of the sequential method of assembling a motorcar would finally result in upsetting the whole moral code of the American middle classes? For it is evident now that the car provided young people with more privacy than the home, and that as a result it became usual to begin sexual experience on the backseat of a motorcar.

Although my examples may seem extravagant, they are not. The fact is that, in a strange way, the side effects of technical innovation are more influential than the direct effects, and they spread out in a civilization to transform its behavior, its outlook, and its moral ethic. For morality is an organization of life that grows spontaneously from activities, and not a

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Jacob Bronowski, one of the foremost living philosophers of science, is a senior fellow and trustee of the Salk Institute for Biological Studies. The remarks here constitute a preview of a forthcoming Columbia University Press Book, *The Environment of Change* edited by Aaron W. Warner, Dean Morse, and Thomas E. Cooney.

formula taken ready-made from somebody else.

Of course, we can foresee that certain modern technical developments will have profound social consequences. But we do not know what these are going to be. Let us take a simple example. I have no doubt that before my children finish the childbearing age, say roughly during the next twenty or thirty years, it will become a trivial matter for them to go to the doctor and say, "We've had two girls. We want a boy." The doctor will then be able to guarantee, with 95 per cent assurance, a male child.

We have no idea what the social consequences of this will be. They might be manifold. It might suddenly become modish to have girls. The cover of *Vogue* or *Life* might carry a picture of an alluring-looking woman, and all parents would suddenly decide to have girls. After all, many parents named their daughters "Shirley" not so many years ago.

On the other hand, what might happen is what was tried in Italy and in Germany. There the Fascists tried to encourage people to have boys. It is not out of the question that if the Chinese knew the secret of producing boys and were not producing enough, they would suddenly switch to this practice. (And, you know, what we think about Chinese militarism, the Chinese think about American.)

The birth control pill already has had many social consequences; it will have more profound ones, and some that are unforeseeable. It is already evident that the particular female hormones which produce a good birth control pill also keep the female reproductive cycle going long beyond its present span. As a result, women of fifty and sixty years go on ovulating and, unexpectedly, have the look of younger women—fresher skin, hair, and eyes. Consequently, the whole relation between the old and the young may change. Our society is geared to relations in which women think a man in his fifties still attractive, but men think a woman in her fifties unattractive. Now we may be within a generation of seeing that reversed.

We also now have the unusual situation that men in their thirties and early forties are unexpectedly attractive to many teen-age girls. This is because the American government has chosen astronauts from that age group, and they have ousted the young Italian film star and the young Frenchman as objects of adoration. Who would have thought that the invention of space rocketry would lead to an age shift in the image of the ideal man among many teen-age girls?

I want now to draw your attention to some foreseeable social consequences of modern technology. Whenever people talk about genetic control in biology, they immediately ask such questions as, "Are we all going to be monsters? Or supermen? And what's going to happen to kids like mine?" But, of course, that is *not* where genetics will be important in the near future. Genetics will begin to have its first influence in smaller ways.

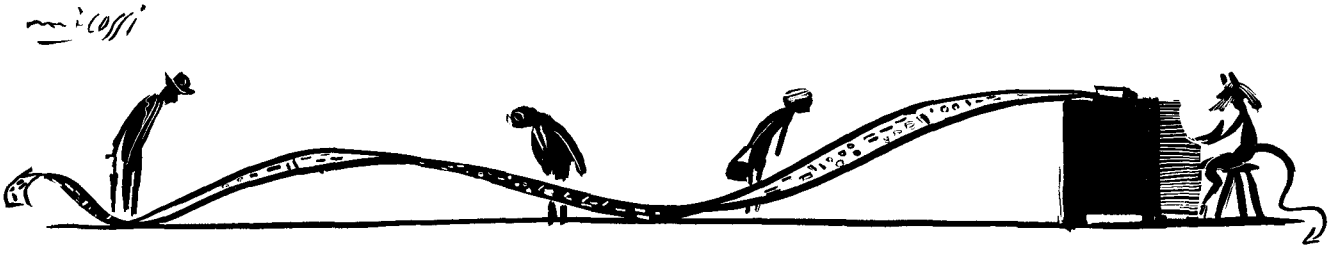
For example, the kinds of plants and domestic animals that we breed will be much more nearly tailor-made than they are today. I would like to give two examples. To prepare you for these, let me ask first what is going to be the single greatest technological change in the physical sciences over the next twenty or thirty years. My guess is that desalting of sea water is going to be the most important advance for overall world development. Without this the whole complex problem of bringing underdeveloped countries to an acceptable level of economics, education, and political maturity is insoluble.

If we propose to desalt sea water so as to make it fit for drinking, we are setting a task which is really foolish, because we already have all the drinking water that we need. If we were to keep drinking water now only for drinking, and use the rest of the water for watering plants and other purposes, there would be no shortage of drinking water. So the obvious thing is to have desalinization processes which leave water as brackish as plants can stand it. A great deal of research in desert countries such as Israel is directed to this end.

I guess that the single most important biological contribution to world peace will be to produce plants which grow effectively in quite salty water. This follows from what we know about diminishing return. If we are going to knock out all the salt in sea water, it is going to cost many times more than if we need only knock down 80 per cent of the salt. So if somebody can come along and breed plants which can grow in 20 per cent of the total salt content of sea water, we shall have the means to take a long economic stride. This is the kind of advance that biology in general and genetics in particular will make.

The other example I have in mind concerns the breeding of animals. The potentially most useful animal that we lack at the moment is a sea animal that really harvests the sea efficiently. The countryside is full of animals which do a fairly good job of turning indigestible protein such as grass into digestible protein such as milk, eggs, and meat. But in the sea, although there are such animals, they do it extremely inefficiently. If you take the smallest vegetable algae in the sea and think of the number of steps necessary before they are turned into a sizable fish you can eat—say, a sardine—the answer is discouraging. At present, it takes three tons of algae to feed the small plankton that feed the larger plankton and so on until they make one sardine. This is a ridiculous ratio: three tons of algae to make one sardine. Nobody would breed cows or pigs if that was the required ratio from vegetable to animal. So we are badly in need of sea animals—particularly a scavenging pig of the sea—which have a higher efficiency than this. I have no doubt that we will breed them in the long run. There is no biological reason why we should not.

Familiarity with these modern ideas is the best way of guessing the social consequences. I may know more about biology than many of you, but about social consequences we all start equal. If you know the facts, if you immerse yourself in the facts, you will be more farsighted than the next man. You may come up with a practical or social gimmick before anybody else. But for this purpose it is necessary to be immersed in the new science, not to run out behind the field and start building computers when everybody else has already gone into biology.



LETTERS TO THE SCIENCE EDITOR

The Moon Landing

I WAS very impressed with John Lear's perceptive and timely descriptions of lunar mascons and their significantly strong gravitational pull on Apollo spacecraft in "The Hidden Perils of a Lunar Landing" [*SR*, June 7]. The problems which beset NASA in predicting Apollo lunar orbits and landing trajectories become evident from reading Lear's quotation of an interview conducted two months ago between newsmen and NASA mission planner Emil Schiesser. Schiesser stated that the theoretical gravitational shape of the moon used for predicting the *Apollo 8* orbit was "the equivalent of a flattened basketball stretched along the Earth-moon line," but admitted that this model worked poorly in practice for *Apollo 8*. He went on to say that the large errors decreased to smaller ones when three belts were superimposed onto the oblate basketball. Finally, he pictured the mascons as smaller local effects as opposed to the belts which indicate "a gross shape that no way comes near reflecting the presence of a mascon."

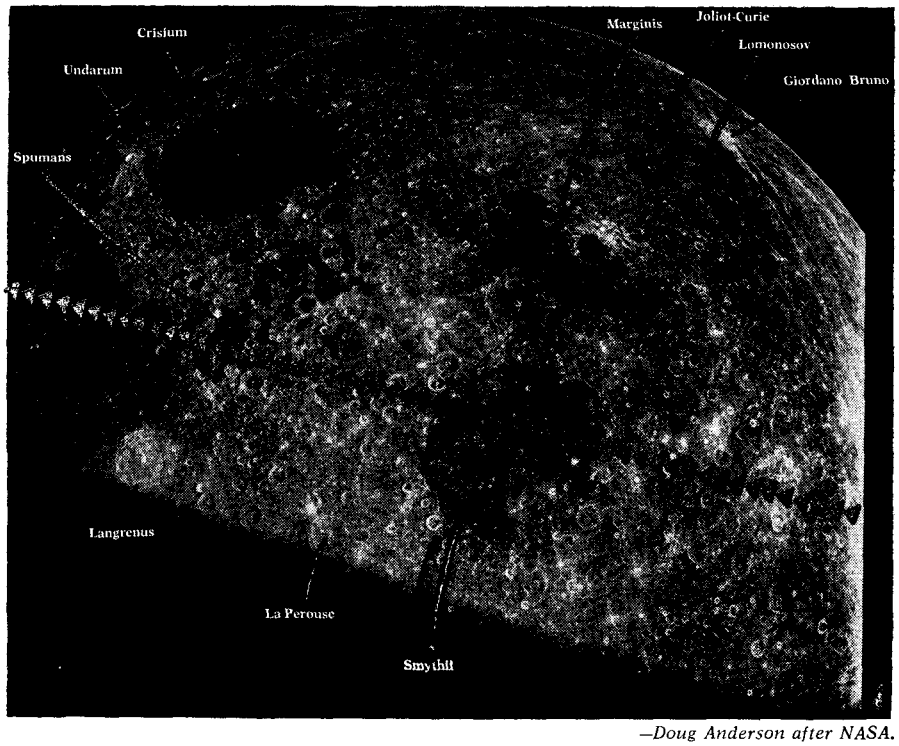
I believe that the deviation of the moon from a gravitationally perfect sphere is due principally to the mascons themselves, and that this might be where the mission planners in Houston are having their troubles. I presented reasonably straightforward evidence for this in the journal *Nature* (December 28, 1968) by taking the mass and location of each mascon (fairly well known for those on the nearside hemisphere) and summing their influences. This simple calculation shows that mascons in the six large circular seas on the nearside hemisphere can account for nearly half of the so-called flattening and stretching of the moon, with the rest of the deviation probably contributed by mascons on the farside hemisphere. In other words, the largest mascons tend to be located near the lunar equator and close to the Earth-moon line, where they collectively could account for Schiesser's bulges and belts.

I hope along with John Lear that the mission planners in Houston understand the total effect of mascons on an Apollo spacecraft before next month's trip to the surface of the moon. Perhaps the flaws in NASA's model of the lunar gravity field will be either corrected or considered within mission constraint from *Apollo 10* experience.

In any case, some of us at Cornell think that trouble may lurk from large mascons on the backside of the moon. Such mascons are difficult to put into the models because space vehicles passing over them are hidden from view and cannot be tracked from Earth.

BRIAN O'LEARY,
Ithaca, N.Y.

EDITOR'S NOTE: *Although NASA's Emil Schiesser, before the voyage of Apollo 10, had expressed confidence that Apollo 10 would stay within a half-mile's distance of the lunar points Apollo 11 was scheduled to pass over, Apollo 10's Commander Thomas Stafford reported afterward that the spaceship actually passed four miles south of the landing site chosen for Apollo 11. "We would have had to burn an awful lot of fuel to get back on target," he told reporters in Houston. "It would have been a rough job." Eugene Cernan, pilot of the lunar landing boat on the Apollo 10 mission, pointed out that a last-minute course correction would have had to take place within sight of "a rough crater chain at the bottom of the landing site with some mean-looking peaks inside the craters." Stafford said the mascon in Crater Smythii (see photomap below, reproduced from SR, June 7) had hauled Apollo 10 off course (marked by arrows on the photomap). Smythii pulled Apollo 10 sharply toward the moon, thus accelerating the spacecraft's speed by 14 miles an hour and altering its direction by one-hundredth of a degree for each hour. But NASA, declining to take further time to iron out the risks, scheduled the landing for July.*



—Doug Anderson after NASA.

I'D LIKE TO mention another hidden peril of a lunar landing. If there are microscopic spores or other life forms on the moon, the announced precautions to protect Earth from back-contamination are grossly inadequate. NASA is planning a three-week quarantine for the returning astronauts and moon samples, but a three-week quarantine would not even be long enough to protect against many serious infectious diseases on Earth. Examples are tuberculosis, leprosy, rabies, sporotrichosis, kuru, and sheep scrapie. The "biological accident" type of disease, exemplified by ergotism (St. Anthony's fire), and alimentary toxic aleukia, also, could not be eliminated by the three-week quarantine. In addition, a crash on return to Earth would nullify all quarantine plans.

The chances that life exists on the moon may be small, but since one of the announced reasons for the trip is a search for life, those chances cannot be dismissed as negligible. Unless NASA makes some major changes in its plans, there is a possibility of an astrodemic affecting terrestrial life.

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Heyerdahl's Voyage

"THOR HEYERDAHL'S NEXT VOYAGE" [*SR*, May 3] was fascinating. After twenty-three years in Chile, sixteen of them among the Araucanian Indians, I, also, have formulated some theories about ethnic origins. I know the coast of South America and the Humboldt Current from the Strait of Magellan to Panama, and from there across the Pacific to New Zealand, always by boat. I have been in Callao and Tahiti, so I also know both ends of the *Kon-Tiki* trip, a fabulous voyage that has doubtless helped to authenticate the probability of western journeys across the Pacific.

According to my theory, it was a two-way street. After living in the same house with an Araucanian Indian family for two years in Chile in order to learn the Araucanian language and culture, I encountered the Maoris in New Zealand. I suspect that the Araucanians are distant cousins of the Maoris.

Fifty years ago, we detected three distinct dialects among the Araucanians: coastal, central, and Andean. The Maoris I met later sounded more like the coastal Araucanians than like the Araucanians from the Andes. Furthermore, the Maoris were physically very similiar to the coastal