

10 March 1978 • Vol. 199 • No. 4333

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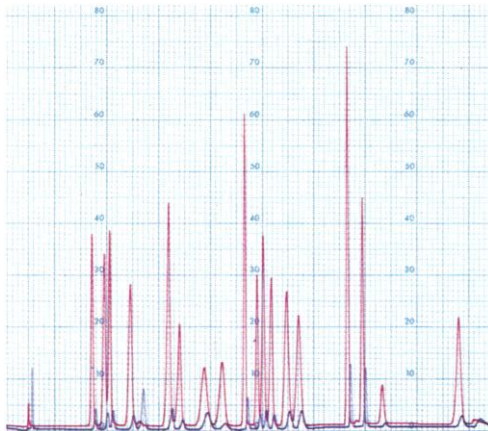


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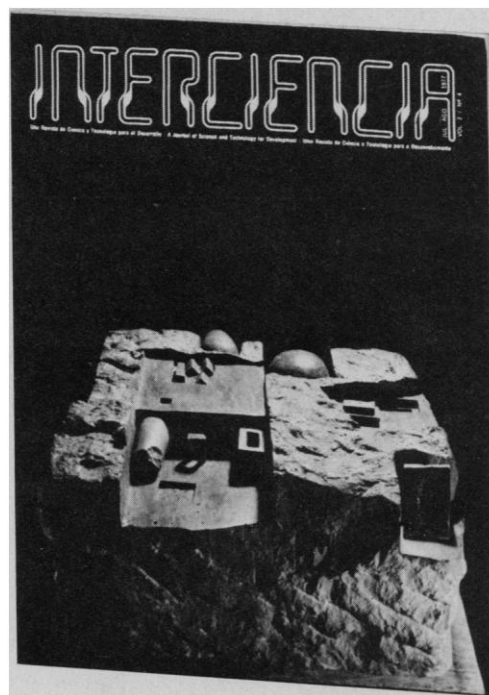
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COVER

Mediterranean member (*Chameleo vulgaris*) of the Old World family of lizards, Chameleontidae, leans across the table from the right foreground. Scientists have commented on chameleons' independent eye movements since Aristotelian times. See page 1087. [Drawing by Heinrich Kley, 1863-1945]

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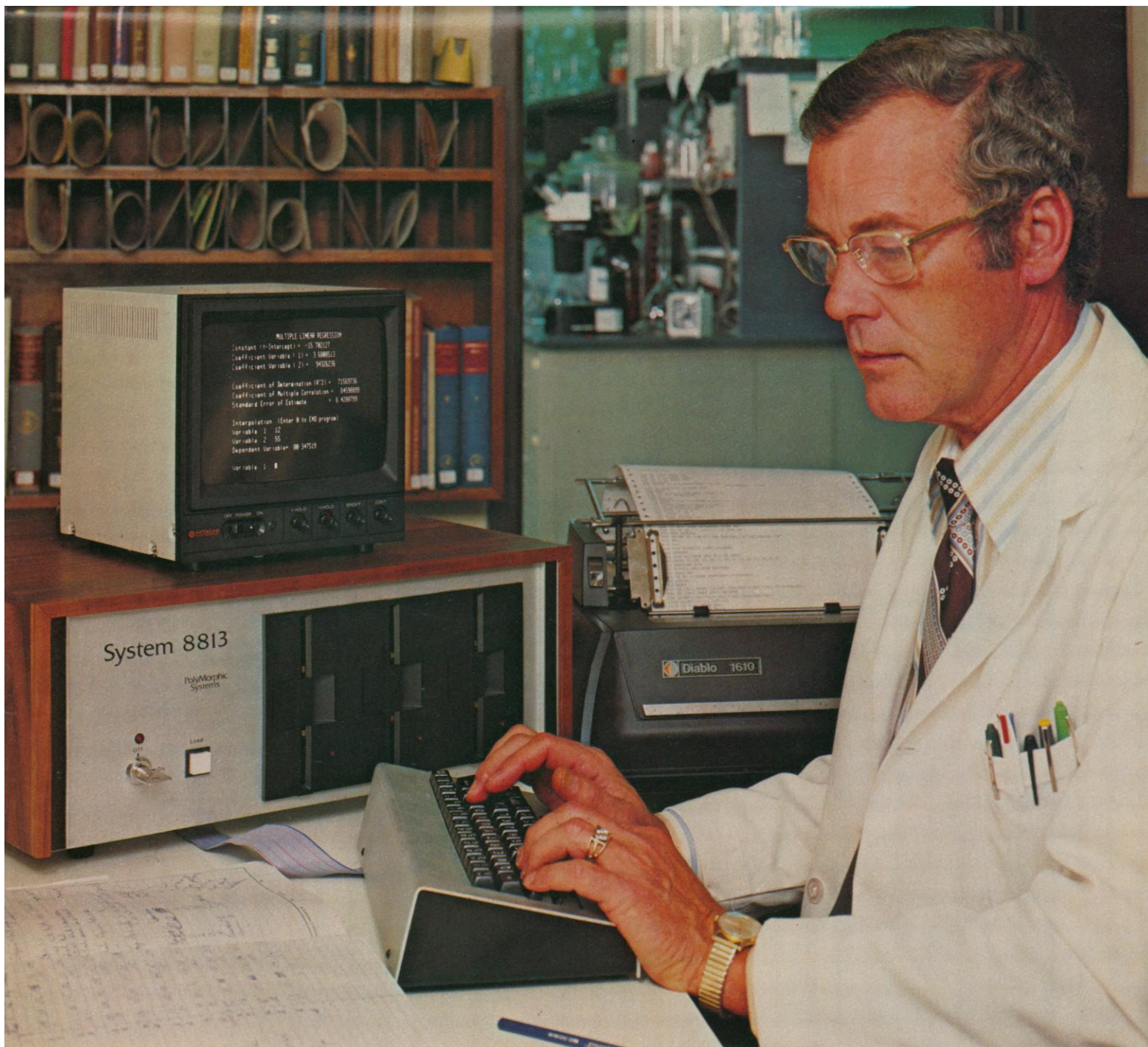
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LETTERS

The Origins of the Laser

On 28 October 1977 (p. 379), *Science* published a News and Comment article "Forgotten inventor emerges from epic patent battle with claim to laser" by Nicholas Wade that raises questions about the invention of the laser. The following is a review of the origins and invention of the laser that should shed additional light on these matters and correct some major errors that appeared in this article.

As is so often the case with scientific advances, the laser had its roots in early theoretical and experimental effort that was not applied to practical uses at the time.

Earlier, theoretical workers in quantum mechanics had appreciated that an incident electromagnetic beam of an appropriate resonant frequency passing through a medium might stimulate molecules in an upper quantum energy state to return to a lower quantum energy state and reinforce the primary beam by negative absorption (1). In 1940, Fabrikant (2) of the Soviet Union proposed experiments to establish the proof of negative absorption, including use of a medium made more conducive to negative absorption by a discharge to effect "collisions of the second kind." A "collision of the second kind" is one in which some of the kinetic energy of motion of the colliding particles is converted to internal energy or a change in energy state of at least one of the colliding particles. In 1950, Lamb and Retherford (3) at Columbia University pointed out that, if an upper quantum energy state could be made more highly populated than a lower quantum energy state, there would be a net induced emission to an incident beam and suggested that such a population inversion could be effected between the 2p and 2s levels in hydrogen. In 1951, Purcell and Pound (4) at Harvard University used magnetic techniques to invert the population of a pair of nuclear spin states in lithium fluoride and made the first direct observation of negative absorption of an applied pulse. They described a medium in this condition as at a negative temperature.

Townes at Columbia University was the first to recognize that stimulated emission could provide a new class of useful devices. He capitalized on previous work in molecular beam spectroscopy in Germany (5), which involved a quadrupolar focusing technique for separating a beam of molecules into two portions (of which one is predominantly of

molecules in the upper of two energy states). Townes proposed dividing an ammonia beam into two portions in this fashion and then passing the high-energy portion through a cavity resonant at the frequency corresponding to the energy separation of the two states. This proposal was first reported in the 31 December 1951 issue of "Columbia Radiation Laboratory Quarterly Reports," and subsequent reports detailed the progress of the experimental work that followed. The original plan, to construct a sub-millimeter wave generator, was soon modified in favor of a microwave oscillator. The 30 April 1954 issue of the same reports described successful operation of the oscillator, which had by then been named the maser.

In 1959, Townes was awarded U.S. Patent No. 2,879,439, assigned to the Research Corporation. The patent described apparatus using stimulated emission for the amplification and/or generation of oscillatory electromagnetic energy. That patent has been widely licensed to laser manufacturers.

Apparently, others had also been stimulated by the successful Harvard experiments in 1951. In 1953, Weber (6) discussed the possibility of a microwave amplifier that involved creation of a population inversion in a suitable medium, with a signal of appropriate frequency supplied. Weber concluded that the amount of amplification produced would be very small under ordinary circumstances and would not be able to compete with other methods, but he felt the approach might have certain special applications. In the Soviet Union, Basov and Prokhorov appear, in the period of 1952-1954, to have independently proposed (7) a system rather similar to that of Townes.

Townes's success with the ammonia maser stimulated considerable research aimed at extending the device's applicability and remedying various shortcomings, such as relative complexity and low power. For amplification the research focused on development of a solid-state version that would be simpler and capable of higher power output. This initially involved use of a paramagnetic crystal in which a population inversion was periodically created by application of magnetic fields—which were reversed in a relatively short time as compared to the relaxation times of the energy transitions in the medium (8). This however permitted only pulsed operation.

Another approach, followed by Soviet researchers (9), aimed at continuous operation and involved applying, to an appropriate gaseous medium, pumping

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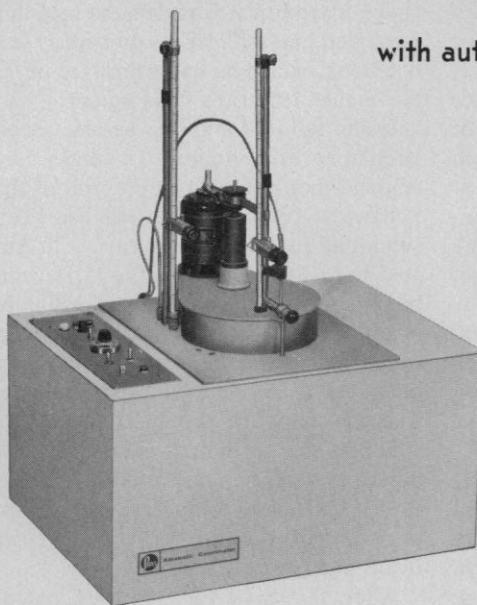
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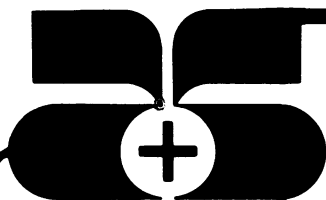
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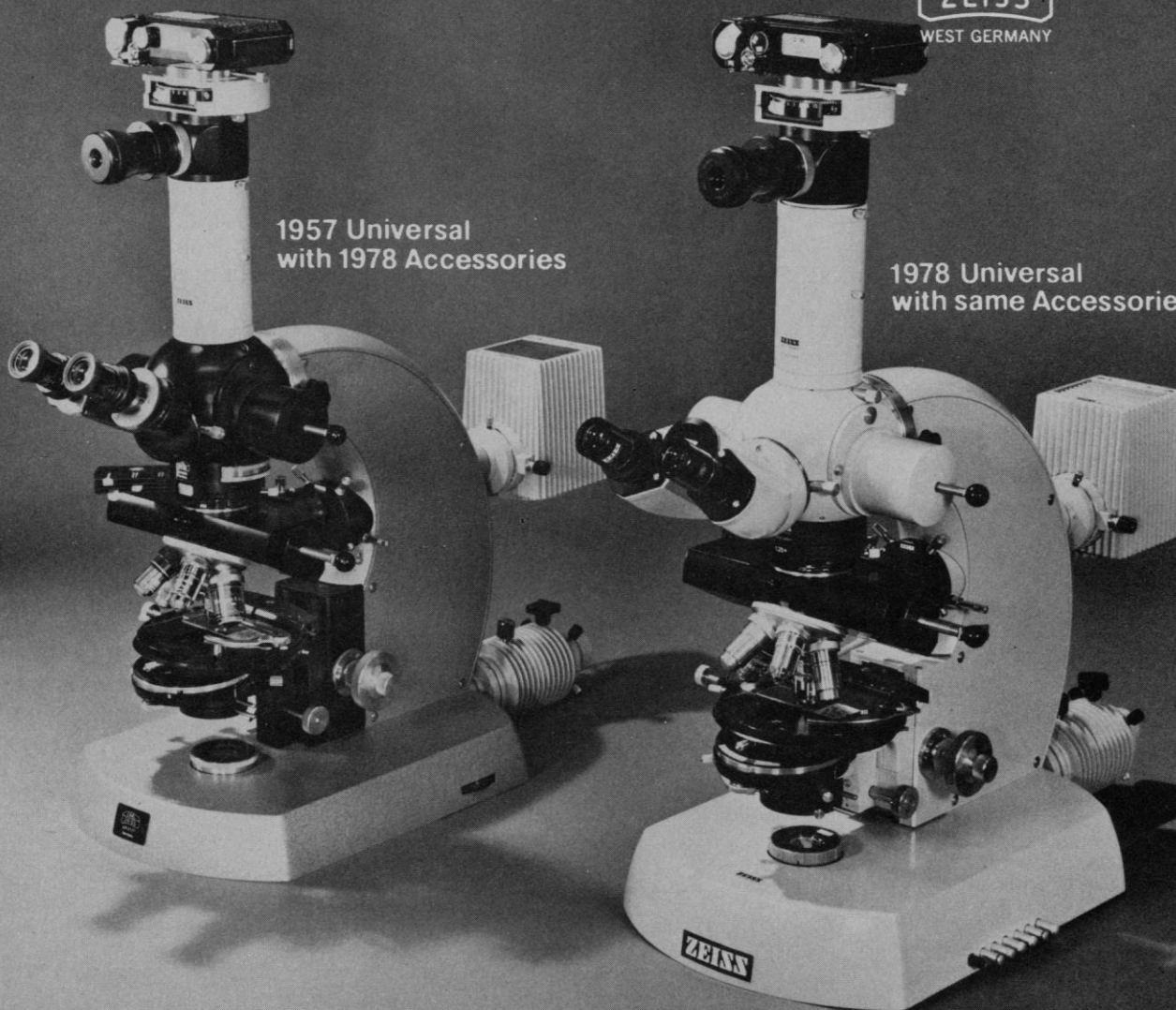
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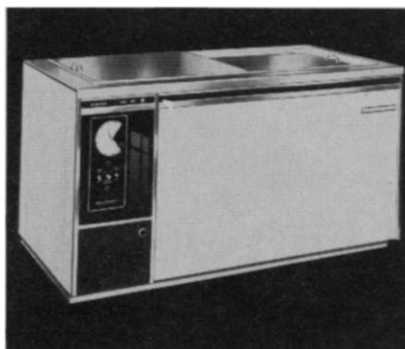
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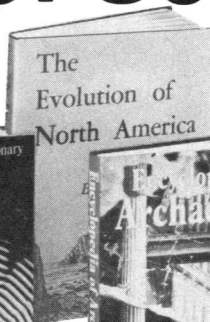
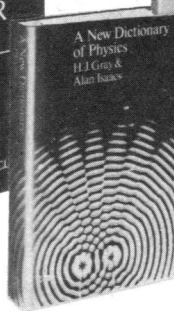
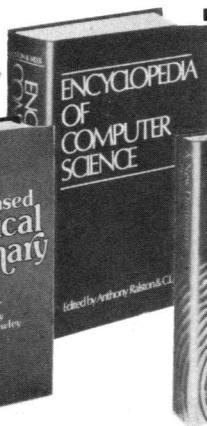
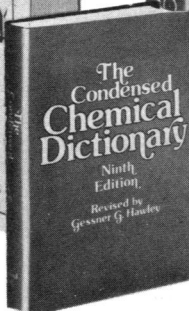
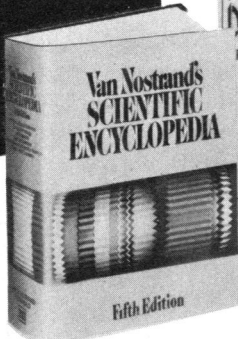
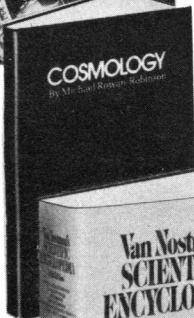
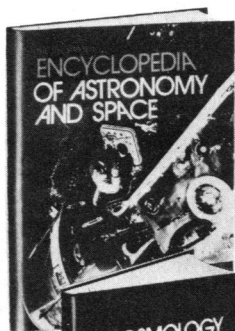
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Policy for Energy

The recent (13–17 February) Annual Meeting of the American Association for the Advancement of Science in Washington, D.C., included 139 symposia with some 180 half-day sessions. Many of these were policy-oriented and especially appropriate for the locale. One major theme was energy, which was addressed in 12 sessions. Conservation and renewable energy sources were strongly represented. Of particular interest was a session on "New Batteries in Energy Use of the Future." Substantial progress is being made in the development of batteries which have higher energy storage per unit weight than those employing lead and which utilize cheap, abundant materials. But the path from laboratory to large-scale use will require a decade or more. It is also clear that major practical effects from conservation and from renewable energy sources will only come slowly.

While it is essential that great efforts be made to achieve distant goals, the nation must also meet the day-to-day demands of the next 10 years. A number of speakers emphasized that for the next decade the major sources of energy will be oil, natural gas, coal, and nuclear reactors. Of these, oil will continue to be the most important.

Considerable apprehension was expressed as to whether sufficient supplies of petroleum will be available during the coming years. It was noted that about 75 percent of the oil that is exported by producers comes from the Middle East. An Arab-Israeli conflict is only one of many potential developments that might lead to interruption of supplies.

The present weakness of the dollar was also mentioned, though perhaps without as much emphasis as the matter warrants. During the past 6 months the dollar has declined about 17 percent with respect to strong currencies, while the price of gold has increased nearly 25 percent. Most of these changes have occurred in the past 3 months. This weakness attests to a loss of confidence in the dollar occasioned by a huge trade deficit arising out of soaring oil imports. As foreigners continue to convert their holdings into stronger currencies, they place further pressure on the dollar. The ingredients for a damaging panic are present. Even should this not occur, weakness of the dollar is likely to persist while the value of oil reserves is likely to increase. The Arabs may decide to conserve their nonrenewable wealth.

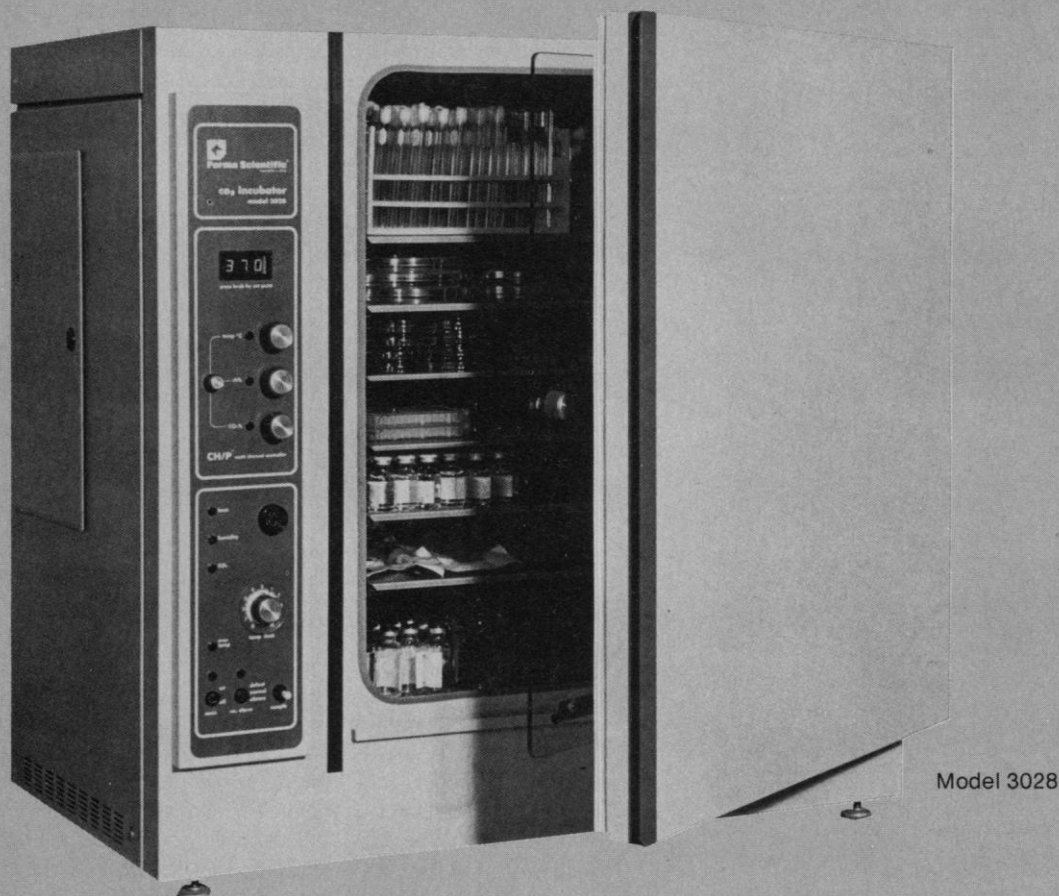
It is possible that adverse political and financial developments will not occur. However, another cloud has appeared in the form of questions concerning the volume of supplies that might be obtained from Saudi Arabia, which has the largest reserves. Optimists had assumed that the Saudis would be willing to more than double their current production. Several sources now take the view, on technical grounds, that such an increase is unlikely. But if current trends continue the United States will be seeking substantially increased imports. The Carter Energy Plan projected imports of as little as 6 million barrels per day in 1985, but experts now predict imports of 11 to 12 million barrels per day at that time.

Because of increased world demand without commensurate increase in supplies, a number of speakers at the AAAS predicted that there will be another "oil crisis." Accordingly, it was repeatedly recommended that ways be found to construct and operate a few full-scale plants designed to produce oil from shale, liquids from coal, and methane from lignite or coal.

Neither the Congress nor events have been kind to the Carter Energy Plan. The Administration has recently stated that it will be coming up with a comprehensive plan for production of synthetic fuels. The probable time scale for action though is slow. After a years' study, recommendations will be made to Congress where time-consuming maneuvers will follow. In contrast, were the Administration to move urgently to expedite off-shore drilling and to clear up environmental uncertainties for shale oil, it could cut several years from the time needed to obtain substantial new supplies.

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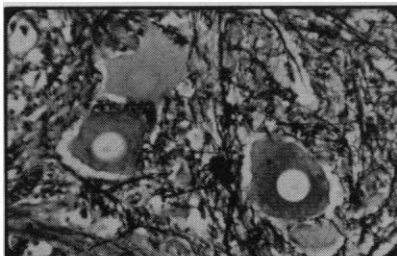
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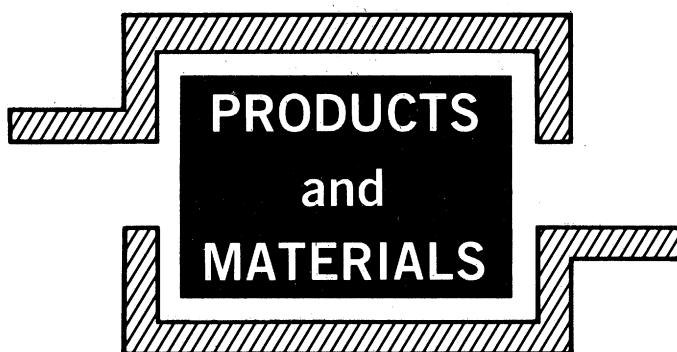
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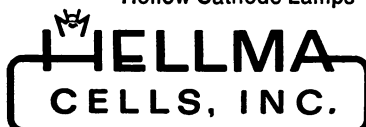
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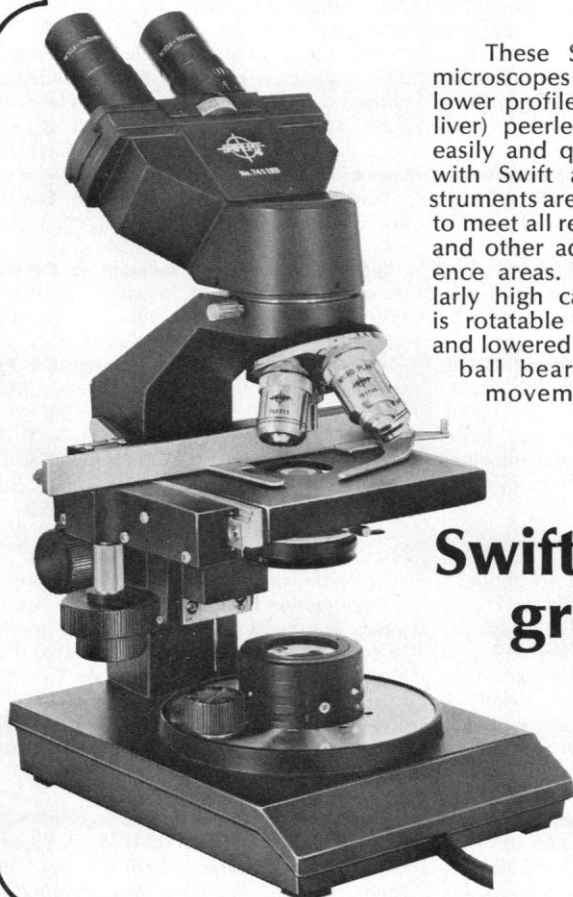
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