SCIENCE

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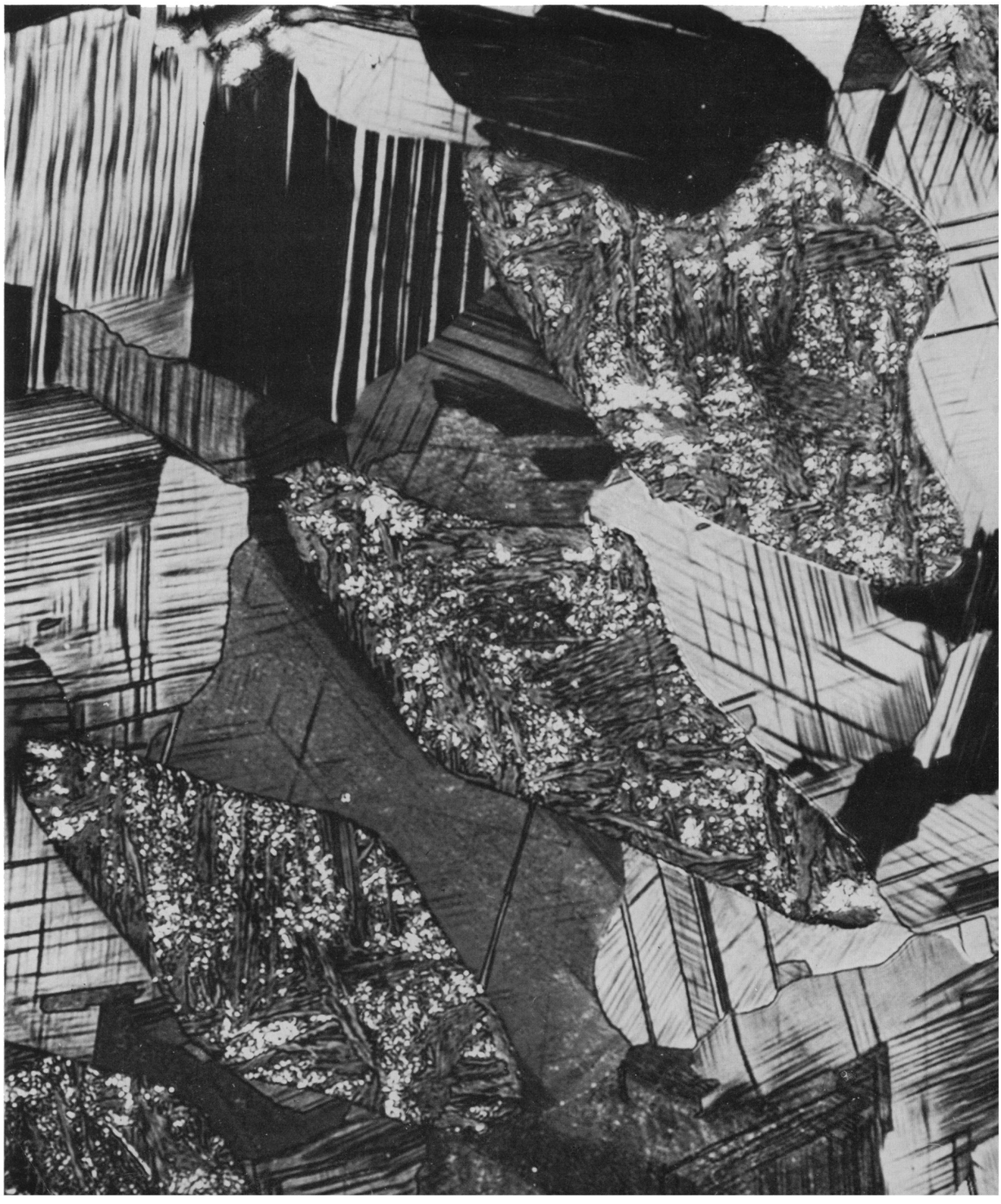

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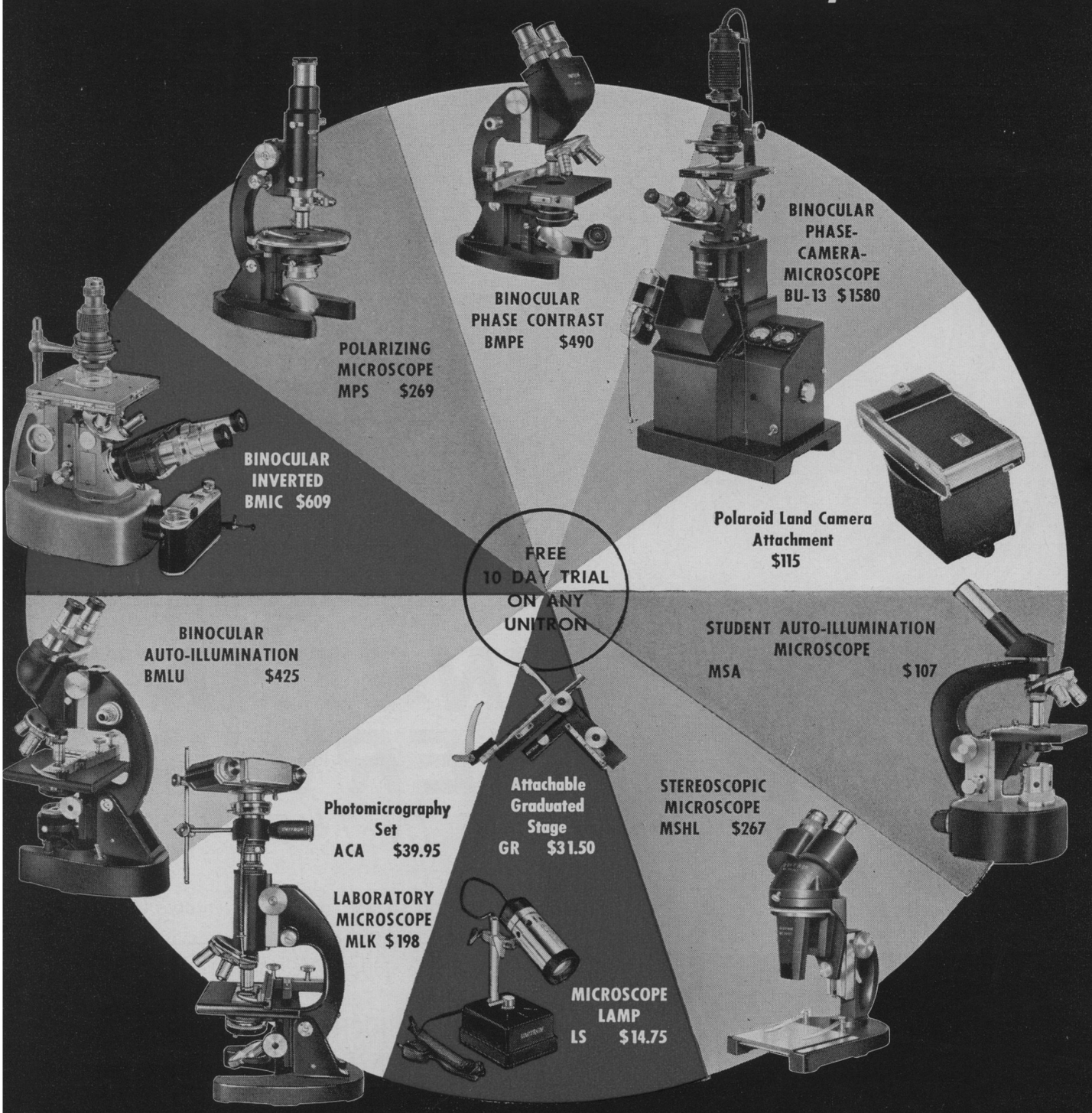

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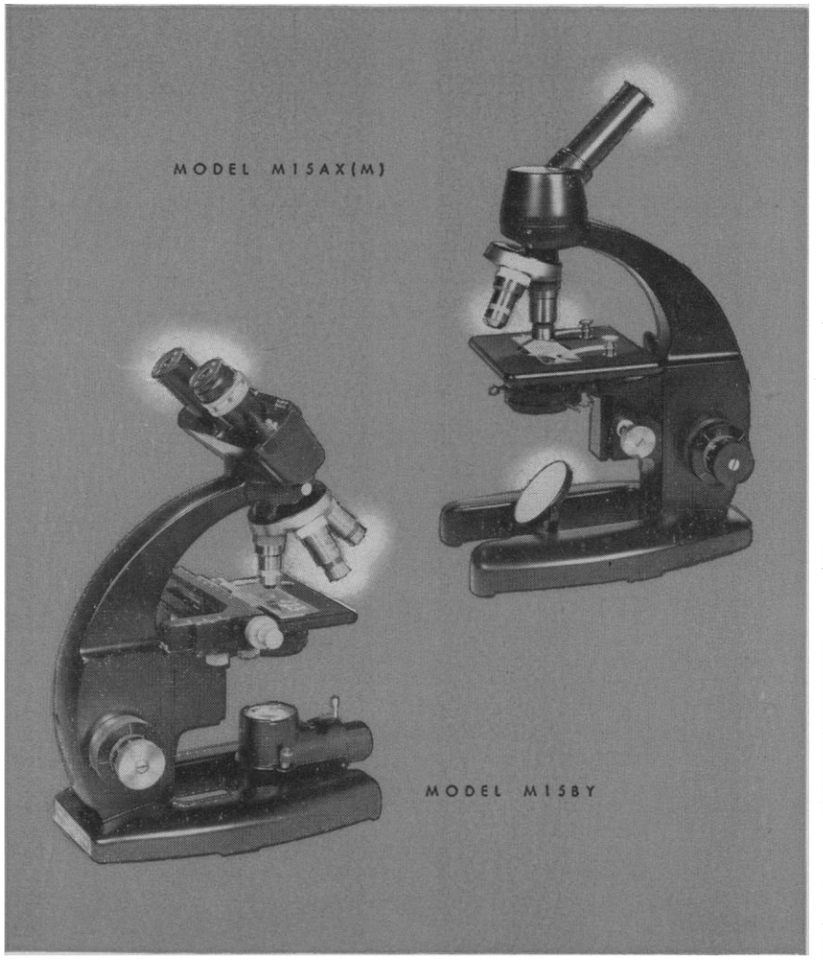

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Thermoelectricity, Electrical Resistance and Electron Scattering in Metal Alloys

How does the scattering of electrons affect the thermoelectric behavior and the conduction of electricity in metals? Physicists at Honeywell have been able to successfully predict certain features of this behavior on the basis of a simple mathematical model.

Everyone is familiar with the fact that metals are good conductors of electricity and also good conductors of heat. All of the electrical current and most of the heat is carried ordinarily by the electrons in a metal. The flow of electricity is intimately associated with the flow of heat or energy, and we can say that the heat flow "interacts" with the electrical current flow. Whatever gives rise to one of these flows will also give rise to the other. Thus if we connect a wire across a battery we get a flow of energy (heat) as well as a flow of electricity; conversely, if we place one end of a copper wire in a flame, heat will pass down the wire and at the same time an electrical current will flow momentarily so as to "readapt" the electrons to the new situation in the wire—one end of the wire is now hotter than the other. The electrical current flow is only momentary because there is no "return path" by which the electrons can flow around in a closed circuit.

If we connect an iron wire to the copper wire at the hot end, and connect the two free ends to a sensitive voltmeter, there will be a flow of heat (energy) in both wires, of course, and there will also be a flow of electrons in both wires. But now, since the electrons are free to traverse a closed loop (through the voltmeter), the electrical current flow is sustained as long as we keep the hot junction in the flame.

The experimental facts that heat flow in a pair of wires (called a *thermocouple*) can cause electricity to flow has been known for over a century and is called the Seebeck Effect; the reverse phenomenon, that electrical current flow through a junction of dissimilar metals will cause heat to flow toward or away from the junction, depending upon the *direction* of the current, has been known for nearly a century and is called the Peltier Effect. The Seebeck Effect is used in thermocouples to measure temperature, to detect radiation (which simply heats the junction), to generate electricity from heat, and for many other related applications which involve the conversion of heat into electrical current flow. The Peltier Effect has only recently come into prominence in thermoelectric refrigerators, and in these applications as well as in thermoelectric generators it has been found that semiconductors are often more suitable than metals.

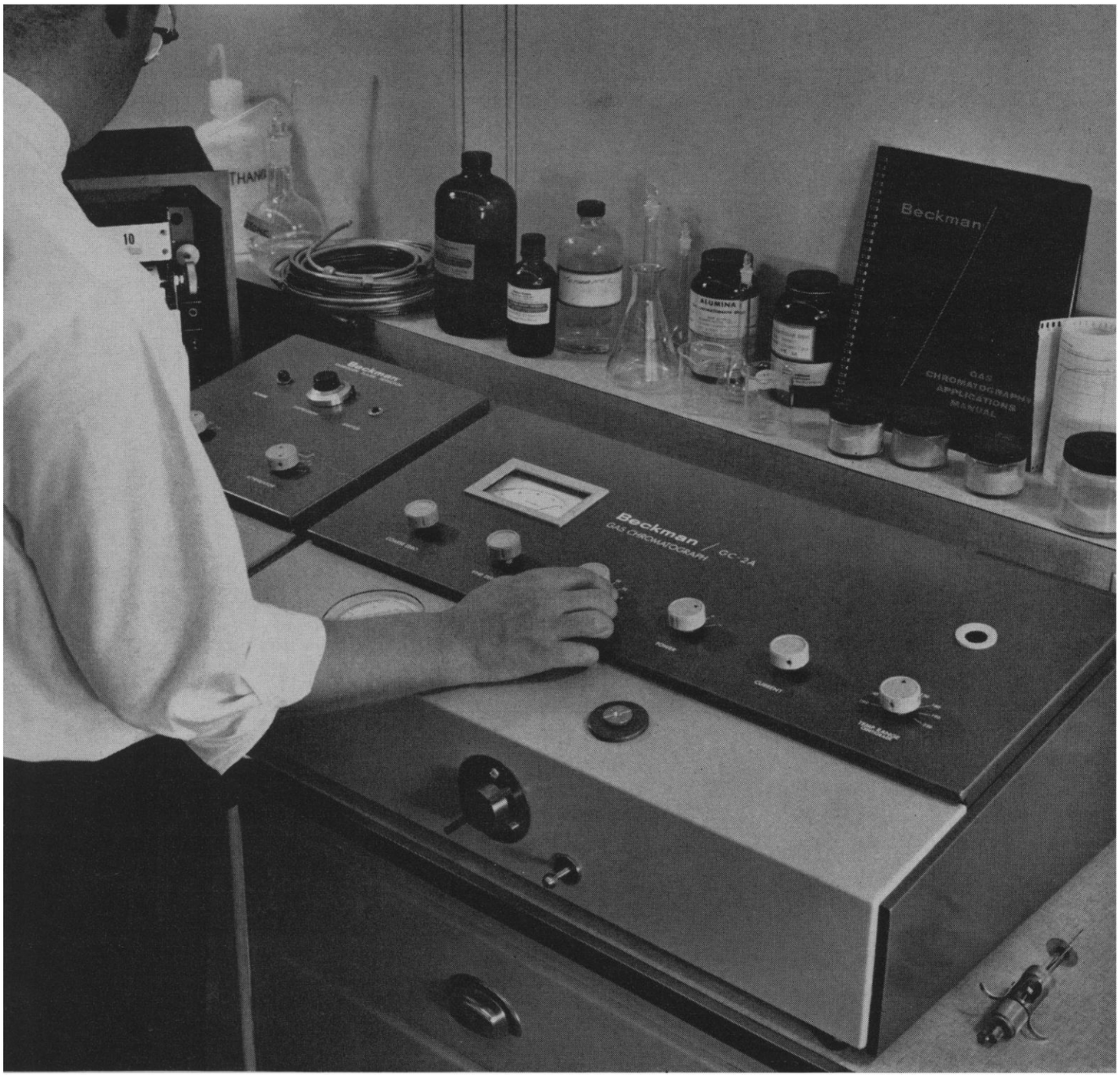
Although the general connection between heat flow and electrical current flow is now well known, the detailed *mechanisms* of electrical and heat conduction in metals is only poorly understood. The extent to which a particular metal conducts electricity or heat is determined in part by the number of electrons which can contribute to the conduction process, and in part by the opposition or "resistance" which these electrons meet as they move along the wire. This resistance results from the presence of various kinds of "obstacles" or "irregularities" in the wire and can be treated as a *scattering* of the electrons from their normal forward motion along the wire. For example, a "perfect" crystal lattice consisting of only copper atoms at *fixed* positions would present no resistance to the flow of electrons; but at any temperature above absolute zero the copper atoms vibrate about their normal positions and behave as "obstacles" to the conduction electrons.

A very effective kind of obstacle or scatterer is an atom of a kind different from that of which the crystal itself is made. Thus if we place a gold atom in a copper lattice, the electrons are confronted with an "oddity" in the otherwise "pure" copper lattice and are thereby scattered: the more gold atoms, the larger the total scattering and the larger the electrical resistivity. Also, some atoms are more effective scatterers than others; thus iron atoms in copper are nearly twenty times more effective than gold atoms. Finally, the scattering ability of a given atom usually depends upon the temperature of the crystal.

Our understanding of the facts just described is at best only qualitative, and the specific *interactions* between heat flow and electrical flow which give rise to the Seebeck and Peltier thermoelectric effects are even more of a mystery! Nevertheless, we have been successful in predicting the thermoelectric behavior of *ternary* alloys on the basis of empirical information on *binary* alloys. We have thus contributed some small amount of order into a technological field (metal thermocouples) which for a century has been within the exclusive domain of alchemy.

But our motivation in this work has not been *primarily* the development of "bigger and better" resistance and thermocouple materials—rather it has been a desire to understand specifically how electrons intereact with various kinds of imperfections in a crystal. Together with physicists, chemists and metallurgists in other laboratories throughout the world, we look forward to a more thorough understanding of this very small facet in the fascinating study of matter.

If you wish to have more details of our work in the field of thermoelectricity in metal alloys, we will be happy to provide them. Simply write to Honeywell Research, Minneapolis 8, Minnesota.



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SCIENCE

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Diversity in Research Support

Philanthropy, though not an exclusively American phenomenon, has had its most exuberant manifestations in this country. The larger endowed foundations—those with assets of $50,000 or more—include such giants as the Ford, the Rockefeller, and the Carnegie Foundations and number more than 5200. Their total assets exceed $11 billion. Among the 7000 philanthropic organizations not included in these totals are those that have little or no endowment and that depend for funds upon annual public appeals. In this category are the voluntary health agencies, such as the National Foundation, the American Cancer Society, and the American Heart Association.

The voluntary health agencies typically concentrate on one or, at most, several diseases and put on annual public fund-raising campaigns. Some devote the major share of their efforts to public education and to care and rehabilitation of patients; others, in addition to these functions, support research and research training in their areas of interest; still others focus exclusively on public education and research.

These agencies have made important contributions. Although criticized by some for overdramatizing the battle against particular diseases, they can show that this has been the only effective way to marshal support from the general public. They have pioneered in educating the public in the prevention and treatment of disease; in creating greater public understanding of the importance and promise of research; in ameliorating or conquering disease; and in developing effective methods for allocating research grants and fellowships. The American Cancer Society initiated an institutional grants program—one widely adopted by other agencies and authorized (but not funded) for the National Institutes of Health by Congress. The American Heart Association pioneered in making career awards—essentially lifetime professorships—for investigators of exceptional ability, and the American Cancer Society adopted a similar program. The NIH has followed suit, except that its career professorships are limited to a 5-year term, and that it has a moral but not a legal commitment to renew appointments.

Not the least of the accomplishments of the voluntary agencies is the part they have played in persuading Congress to establish the NIH within the U.S. Public Health Service. Starting with a small appropriation in 1945, the NIH—with strong support by representatives of these agencies—has enjoyed a remarkably rapid growth in appropriations: from $52 million in 1950 to more than $400 million in 1960.

But it is this very growth of the federal effort in research that poses a threat to the voluntary health agencies. Of the $150 million spent on cancer research in 1960, $91 million came from the National Cancer Institute, $10.5 million from the American Cancer Society, and the rest from other governmental agencies and private foundations. The same holds in other categories: the government is footing well over half the research bill.

Overlapping support is not the problem, since there is complete exchange of information between all major granting agencies. The problem is that the general public, aware of the increasing federal contribution, no longer sees what part the voluntary agencies may have to play. To show the public that diversity of support is essential to flexibility and creativity in research, and that we would all be the losers if this diversity were lost, is no easy task. But it is a task that ought to be undertaken, and one that is worthy of our best efforts.—G.DuS.

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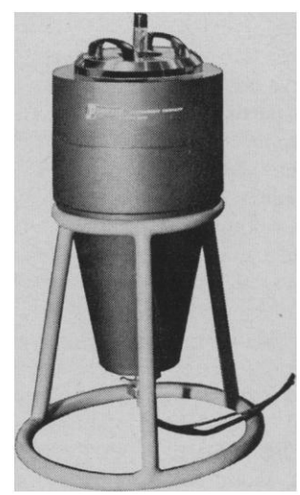

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Letters

Expediency for Latin America

You ought to be congratulated for publishing the survey "U.S. assistance to Latin America" [*Science* **132**, 1936 (1960)]. I cannot help but offer some comments on what appear to me an array of contradictions.

Contradiction number 1. "The Act of Bogotá talks of very much the same . . . things: schools, literacy campaigns, low-cost housing, roads in the country districts. . . . None of these things, any more than any of Castro's original reforms, contributes much to real economic development." If the illiteracy in Latin America is to continue at the level of 50 to 90 percent, if the people are to continue to live in mud huts, sick and undernourished, and if whatever produce is extracted from worn-out soils cannot be taken to the market, how, I ask, can one reach the absurd conclusion that none of the things talked of in the Act of Bogotá contribute to real economic development?

Contradiction number 2. "A real program of development necessarily requires, for one thing, a drastic rise in tax rates, which in every Latin-American country are now far below those in any of the more developed countries." Taxation works wonders in countries with strong middle classes. Latin America, with the exception of Uruguay and Costa Rica and possibly Argentina, is characterized by the "have nots," with incomes of $100 to $500 per year, and the "have everythings," with incomes which approach the national budgets. I do not believe that the oligarchs will ever vote to tax themselves even at the existing rates, and even if they were to pay 1000 percent of what they pay now, the revenues would not be enough to solve any of the basic problems. What is needed first of all is a drastic rise in productivity and incentive to consume. To attain these basic goals, there must be technical know-how and literate, healthy workers. It is an irony to talk about democracy when the elementary ingredients of a decent living are denied the great majority of people.

I could go on analyzing the contradictions which appear to originate from ignorance of the real social and economic problems of Latin America. How can a government be progressive and popular and be able to institute sound economic programs if it does not (i) provide elementary education for the large masses of children who remain illiterate for the lack of schools, work for chronically unemployed people, a little sanitation and modest housing for the

have-nots, and roads to open new areas to productivity; (ii) find democratic formulas to institute land reform in countries where 100 families own 95 percent of the productive land; and (iii) obtain technical aid from the advanced countries and long-range, low-interest loans for broad economic development?

To formulate realistic policies of assistance, it is essential that the experts stop reading government reports, which are invariably colored by national pride, and go, instead, to see for themselves, not Buenos Aires, Caracas, or Quito, but the "people" in the "real countries." Policies based on expediency will bring only disaster.

L. A. ROMO

DuPont Company,
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Racial Differences

The recent letter of Leon S. Minckler [*Science* **133**, 202 (20 Jan. 1961)] on racial differences points out the need for distinguishing between the scientific problem and the applications to daily life.

With regard to the scientific problem, Minckler admits that H. E. Garrett's opposition to the "equalitarian dogma" is probably justified, although the examples he gives have not been adequately studied. Concerning the problem of intelligence, with which Garrett is primarily concerned, nothing is said. Yet this is the crucial problem of the equalitarian dogma. For the results of mental tests almost invariably indicate significant differences in favor of whites, yet are disregarded by upholders of the dogma, who believe the differences to be due to differences in environment. What makes the problem especially difficult is (i) that we do not know how unfavorable an environment must be to stunt mental growth, and (ii) that, as Shuey has shown, the differences are greater at the upper socioeconomic levels, where the stunting effects should be the least.

As for the problem of application, I do not believe that Garrett or any other responsible psychologist would use racial differences as an "excuse for intolerance or discrimination." While Minckler does not give any example of his contention, it is probable that he refers to the question of school segregation, as that is central to the question of racial mental differences. But this problem is not as simple as it appears to be at first sight. For it is assumed that segregation is discrimination in favor of the whites, whereas the possibility that segregation could also help the Negro is entirely overlooked. Where

differences do exist, to force Negroes to meet white standards is to do them no favor. Up north, both as student and teacher, I have been impressed by the Negro's difficulty in meeting white standards. I do not believe that the lower standards down south are the result of poorer teaching by Negroes. Teaching ranks relatively high as a profession among southern Negroes, and the teachers I have met appear to be eager to raise the position of the Negro by way of education.

RALPH W. ERICKSON
Department of Psychology, Mississippi State College for Women, Columbus

Literature Citation Counting

If one relies upon the enumeration of literature citations to identify significant research [J. H. Westbrook, *Science* **132**, 1229 (1960)], one should be reminded that this technique could be considered a special case of the more general opinion polls which so frequently are called into service to analyze economic and political aspects of our society. The pollster classifies and enumerates subjective opinions. Objectivity is introduced into the poll to the extent that opinion sampling is randomized. The more random the sampling is, the more objective will be the conclusion, and the more uncritical, by whatever criterion, will be the selection of opinions upon which the conclusion is to be based.

Thus it would appear that the enumeration of literature citations of a particular research article would represent the current value judgment of the pedestrian researcher in this particular area of research. Past experience has shown that favorable "average judgment" may lag decades behind the publication of brilliant but radical ideas.

Let us suppose that a scientist knew that he was to be rated according to the frequency with which his publications were cited. He might be extremely reluctant to enter any except the most popular areas of research. Such a system might be more vicious than that of rating him on the basis of the number of his publications.

Judging the merit of a scientific publication ultimately requires a subjective evaluation. Why place greater reliance on the "average judgment" than upon the judgment of those whose wisdom is most respected? To do so is to emphasize past accomplishment rather than potentialities for the future.

JAMES R. KUPPERS
Chemistry Department, Pfeiffer College, Misenheimer, North Carolina