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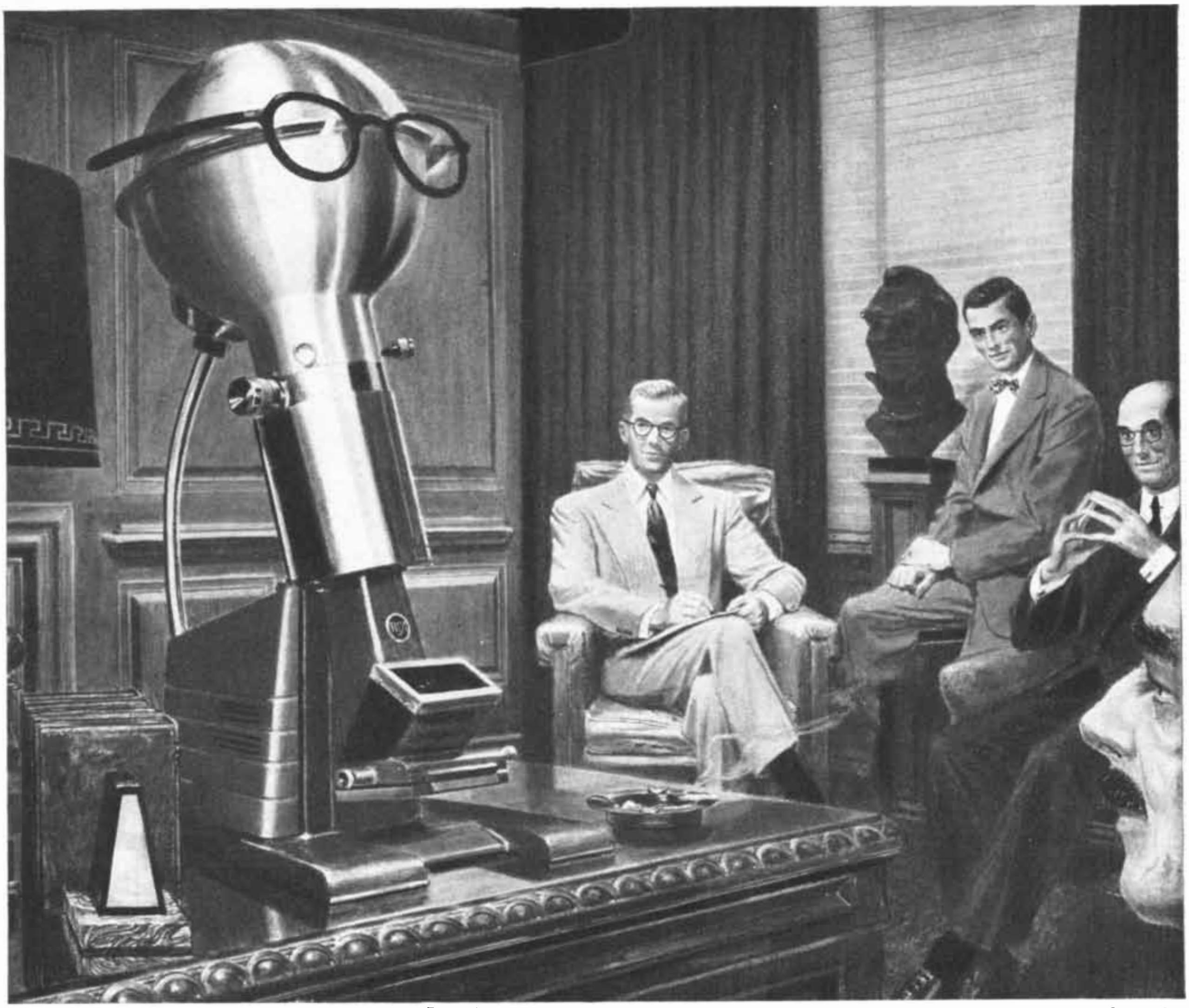

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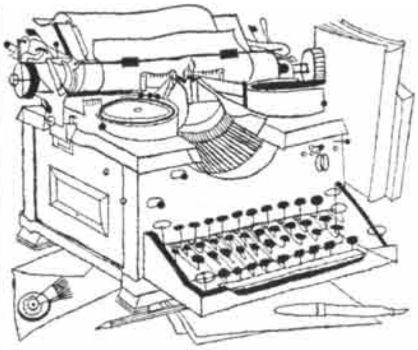

Sirs:

It was with much pleasure and interest that I read your September issue, "The Age of Science, 1900-1950". . . . I feel, however, that I must register a slight complaint. An article on the advances in engineering would, in my opinion, have been entirely in order. In my own field of electrical engineering, one has but to look at the tremendous place which electricity plays in our lives, a place which was gotten only in the last 50 years. The increase in size of power units which are common now; the increase in transmission voltages from only a few thousand volts at the turn of the century to the experimentation with 500,000 volts at the present; the conquering of the effects of lightning on electrical equipment; the exploitation of the entire radio spectrum including television and radar and microwave transmission—all these advances were made primarily by the dogged research and work of many engineers after the basic theories were thrown forth by the pure scientists. And then I haven't even mentioned the tremendous advances made in the other fields of engineering—in automobiles, in heavier-than-air aircraft, in jet propulsion, the plastics and chemicals industries, and so on. . . .

G. I. STILLMAN

New York, N. Y.

Sirs:

Your September issue is of such monumental importance that criticism seems unjust. However, I cannot help regretting that it contains no article devoted to biology.

The sciences of physiology, biochemistry and genetics do not embrace the whole of biology. The subject is far bigger than that. One might point out that Darwin propounded the greatest of all biological principles despite the fact that he knew little physiology and nothing of biochemistry or genetics. . . .

The failure to include an article on medicine was another serious omission from your last issue. The whole of medicine certainly cannot be embraced by physiology and biochemistry. For example, some physicians are impressed by

LETTERS

the correlation between disease and physical type. Here is a group of problems calling for a new advance in principles.

Too many sciences are waiting patiently for physics (or chemistry) to drop something into their laps. Meanwhile, the general public—and, unfortunately, many scientists—is complacently certain that science is advancing at a dizzy speed. There is a failure to discriminate between a proliferation of unimportant detail and a broad advance in general principles.

Chemistry is not moving forward so swiftly as in the great days of Mendeleyev, Kekulé and van't Hoff. No Darwin is practicing in biology today. Medicine is not advancing so swiftly as in the years when Pasteur and Koch were sweeping away centuries of false speculation about the nature of contagious disease.

Every science should learn all it can from others. But no science should be relieved of the duty of running under its own power. And this it can do only by seeking new principles peculiarly its own.

PATRICK B. HENRICKSON

East Setauket, Long Island, N. Y.

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50 AND 100 YEARS AGO

NOVEMBER 1900. "At the recent meeting of the International Electric Congress at Paris, some interesting developments regarding wireless telegraphy were explained. In connection with the possibility of being able to communicate over great distances, M. Willot, of Paris, contended that it was impossible to telegraph satisfactorily over distances exceeding 28 miles, owing to the adverse influence offered by the curvature of the earth. This contention, however, is disproved by the results of the experiments carried out by Marconi himself, who has been successful in transmitting messages on several occasions over far greater distances than the limit mentioned by M. Willot. Marconi is of the opinion that the Hertzian waves follow smoothly round as the earth curves. For instance, the curvature of the earth between his station at Poole, in Dorsetshire, and the station at the Needles, in the Isle of Wight, a distance of about 25 miles, amounts to at least a dip of 500 feet, and yet messages have not been influenced in the slightest."

"The population by the Twelfth Census of the United States was officially announced by Director Merriam to be 76,295,220, compared with 63,069,756 in 1890; this is a gain of 13,225,464 in ten years, or an increase of 21 per cent. Seventy-four million six hundred and twenty-seven thousand nine hundred and seven persons reside in forty-five States, the remainder in the Territories, Alaska, Hawaii, etc."

"John D. Rockefeller has given $100,000 to the psychological laboratory at Columbia University."

"In a communication recently made to the Académie des Sciences, M. Curie states that he has succeeded in making an approximation toward the atomic weight of the new element radium. Since the commencement of his researches for isolating the new element, the progress of its concentration in the chloride of barium has been constantly observed by the study of the spectrum and determinations of atomic weight. The weight found for barium gives the number 138, and that of the product containing radium, 174.1 and 173.6 in two cases. There is no means of finding the relative amount of radium and barium in the latter product, but M. Demarçay concludes from the spectrum that there is a greater proportion of radium. It is, therefore, certain that the atomic weight of radium is much greater than 174. The quantity of pure chloride of radium isolated is not sufficient to allow the study of the properties of this element in a pure state, but its existence is no longer a matter of doubt."

"At the annual meeting of the National Academy of Sciences, held in Providence, R.I., on November 13, Prof. A. A. Michelson in two papers described improvements in the echelon spectroscope, and a very interesting analysis of the spectrum of sodium in a magnetic field. The discovery by Zeeman that the lines of the spectrum of sodium are broadened when the sodium vapor is within the field of a magnet, he characterized as one of the most interesting of recent times. Michelson soon found that these lines were double; then Zeeman found them to be triple, and Michelson found that they separated farther as the density of the vapor increases; also a central line not previously present appears, which again disappears if the density becomes excessive. When the sodium vapor is very dense, it shows a double line even when not in a magnetic field. These studies may throw light on the motions of molecules and their relations to the interstellar ether."

NOVEMBER 1850. "A new invention by a Mr. Jordan, of Liverpool, by which he proposes to substitute iron for the wooden framing of vessels, is attracting a good deal of attention in that city. The inventor has taken out an American patent."

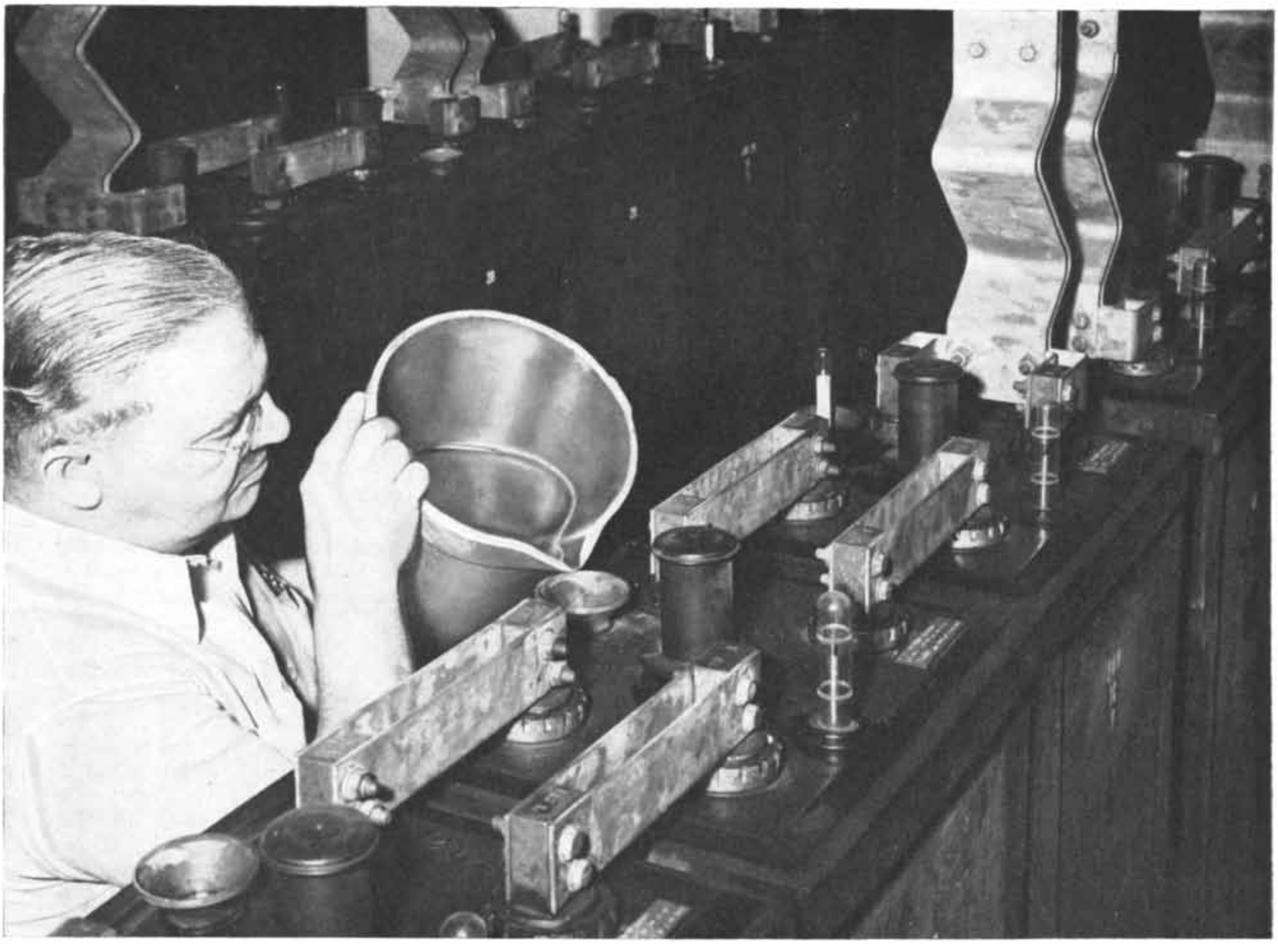
"Doctor Grange, a learned physician of Paris, was commissioned some time ago by the government, to pursue, in France and other countries, inquiries into the causes of *goiter* and *cretinism*. His official report has just appeared, and will be deemed by the medical faculty a valuable document. He has come absolutely to the conclusion that they are independent of latitude, altitude and climate. Their presence appears to be connected with that of magnesia in food or drink; their absence often proceeds from the *iodine* which the article consumed offers to chemical analysis. In some localities the substitution of spring for well water has sufficed to banish *goiter*. The Doctor recommends marine salt—ioduret of potassium—and he thinks that much can be done by government towards the cure and future security of the populations among whom the distemper is found."

"In about two years from the present date, it may be predicted with certainty that we will be able to step on board a railroad car at the corner of Hudson and Chambers Street, this city, and proceed on our way, by uninterrupted railroad, to the Mississippi River in Illinois. From New York to Galena, on the Mississippi River, Illinois, the distance is 1,200 miles, and railroads are now in the course of construction, which, along with those in operation, will complete the whole chain in about the time we have specified, affording the longest and most splendid internal railroad communication in the world, excepting it may be the great Russian line. In the course of ten years from the present moment, it is not too much to expect an interior line of railroad communication from New York to San Francisco."

"A number of scientific gentlemen of Belgium have lately made some meteorological observations on the heights of Belleville, Paris. They sent up to a certain height several kites, to which were affixed a number of needles, and although the weather was perfectly serene at the time, they drew from the clouds flashes of electricity similar to those which accompany a storm."

"We learn from the 'Boston Traveller' that on Friday night the existence of a third ring around Saturn, which had been for some time suspected, was ascertained by the astronomers at Cambridge. It is interior to the two others, and therefore its distance from the body of Saturn must be small."

"A ship is about to be built in this city, by W. H. Webb. Of 230 feet in length, 42 breadth of beam, 25½ depth of hold, and clipper built, she will be 25 feet longer than any merchant vessel sailing from this port. She is to be finished in about six months, and will run from New York to Canton, via California, and thence home, completing the circuit of the globe with each trip. She will measure near 2,600 tons."



At the New York Telephone Company's Triangle exchange in Brooklyn, emergency batteries stand ready to deliver 3000 amperes for several hours.

How a whiff of stibine led toward lower telephone costs

In the Bell System there are a million lead storage battery cells connected to telephone circuits in the central offices. Current seldom flows in or out of these cells beyond the trickle which keeps them charged. In the rare event of power failure, however, they stand ready to supply the current for your telephone service.

Even in this stand-by service, cells require water to make up for electrolysis. And they consume power and eventually wear out. But Bell Laboratories chemists discovered how to make a battery which lasts many more years and requires less attention – by changing a single ingredient, the clue to which came unexpectedly from another line of their research.

The clue was a minute trace of stibine gas in battery rooms which electrochemists detected while on the lookout for atmospheric causes of relay contact corrosion. In small traces the gas wasn't harmful but to battery chemists it offered a powerful hint.

For stibine is a compound of antimony—and antimony is used to harden the lead grids which serve as mechanical supports for a battery's active materials. Tracing the stibine, the chemists discovered that antimony is leached out of the positive grid and enters into chemical reactions which hasten self-discharge and shorten battery life.

Meanwhile, in the field of cable sheath research Bell metallurgists had discovered that calcium could be used instead of antimony to harden lead. And theory showed that calcium would not react destructively in a battery. The result is the new long-life calcium-lead battery which cuts battery replacement costs, goes for months without additional water, and needs but 1/5 the trickle current to keep its charge.

It demonstrates again how diverse lines of research come together at Bell Telephone Laboratories to keep down the cost of telephone service.

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THE COVER

The painting on the cover is a top view of Simple Simon, the smallest complete mechanical "brain" (*see page 40*). The basic elements of Simon are war-surplus relays, 122 of which are shown in the painting. Sharp-eyed readers may notice that the photograph of Simon on page 43 shows 128 relays. These were added shortly after the completion of the painting. The relays are painted in various colors to distinguish their specialized functions. At the lower right-hand corner of the chassis is a device which reads the punched-paper tape that bears the instructions for the machine. Slightly above and to the left of it is a stepping switch. Below these two devices is the front panel of Simon. At the left end of this panel are the controls of the machine. In the center of the panel are five lights which flash the answers to problems and the stages of their solution. Beside these five lights is a sixth which indicates whether the power is on or off. At the bottom of the painting is a device for punching the tape.

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Cover by Stanley Meltzoff

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SCIENTIFIC AMERICAN

NOVEMBER 1950 VOL. 183, NO. 5

Votes in the Making

What are the factors that influence voters and decide elections? The investigations of social science have begun to add to the knowledge of the politician

by Paul F. Lazarsfeld

EXPLAINING the results of elections is an old American game, almost as popular as post-mortems on World Series. Our legends about how elections are won go back to the early days of the republic. When William Henry Harrison defeated Martin Van Buren for the Presidency in 1840, post-election analysts decided that it was the slogan "Tippecanoe and Tyler too" and his log-cabin symbol that had won for him. Grover Cleveland triumphed in 1884 because a parson who attacked him with the slogan "Rum, Romanism and Rebellion" was not repudiated quickly enough by James G. Blaine, his opponent. Woodrow Wilson won in 1916 because Charles Evans Hughes was not nice enough to Senator Hiram Johnson in a San Francisco hotel. To this sport of hindsight interpretation a new game has recently been added: the prediction of elections by means of public opinion polls.

Below this surface of popular interest, there has also developed a tradition of systematic study of elections which is beginning to make contributions to our knowledge of public and human affairs. Elections represent an outstanding opportunity for the social scientist. They are a regularly recurring phenomenon, like the cycle of the seasons, in which many factors remain constant. Usually only two major parties are involved; the electoral procedures are fairly constant; even the techniques of propaganda do not change very much. Thus elections offer an opportunity to make repeated observations and to build up a solid body of knowledge, the precondition of all truly scientific development.

What do we want to know? One question that interests social scientists is the extent to which voting is correlated with the voters' income, education, race, religion, age and so on. The most convenient way to study this is to make a careful correlation analysis of election returns in small units, preferably precincts. To illustrate the technique used let us take a study that was made of a question raised by *The Age of Jackson,* the well-known historical work of Arthur M. Schlesinger, Jr.

Schlesinger's thesis was that class divisions in voting did not begin during the New Deal but were an old story in American politics, going back to the election of Andrew Jackson. A number of historians contested this thesis, arguing that election data showed that Jackson was by no means favored by the low-income voters of his time. One young historian dug up election figures in Boston for several elections between 1826 and 1840; they showed that the Democrats lost every ward, even the poorest.

But a more precise analysis by Robert Bowles, who correlated voting with the wealth of each ward, as measured by its per capita assessed valuation, bore out Schlesinger's contention. A comparative analysis for the election of 1836 is summarized in the table on the next page. The Democrats did indeed lose most of the wards, but their percentage of the vote paralleled fairly closely the financial figures. By and large, the greater the wealth of the ward, the smaller the number of Democrats. The correlation in such a study is measured by a coefficient which varies from zero to one. If the parallel is perfect, the coefficient is one; if there is no relation whatever between one factor and the other, the coefficient is zero. In this case the coefficient of correlation between the Democratic vote and wealth (*i.e.,* lack of it) was .73, indicating that the economic factor played a considerable role.

When the analysis of Boston's voting was extended to a series of elections during the Jackson Era, an even more striking result emerged. This was that the importance of the economic factor had steadily increased; *i.e.,* the coefficient of correlation between the Democratic vote and wealth rose from election to election. For example, the coefficient in the election of 1828 was .53; in 1832 it was .56, and in 1836 it was .73. These figures give good support to the view that Andrew Jackson's policies made for ever sharper clashes of interest between economic classes—at least in Boston.

SIMILAR analyses of elections in our own time have been made by a number of social scientists, notably Charles E. Merriam and Harold F. Gosnell of the University of Chicago and the Government economist Louis H. Bean. They have amply corroborated the preference of the low-income groups for the Democratic Party. They have also disclosed many other interesting specific correlations. During the depression the amount of relief spent in certain counties of the U. S. was correlated with the strength of the Democratic vote. Crop failures due to natural causes in the Midwest farm belt were correlated with a decrease in vote for the party in power. During prohibition days a stand in favor of the continuation of anti-liquor laws was correlated with a high female vote for the candidate. In Europe the Swedish political scientist Herbert L. G. Tingsten showed that in countries where the Catholic Church was identified with a political party, the strength of this party was clearly correlated with the proportion of female voters; and that in Germany the pre-Hitler Communist movement and later the Nazi movement both were strongest in areas where the younger voters were most numerous.

CORRELATION studies of this kind have, however, one serious shortcoming. It is never easy, and often quite impossible, to separate certain factors which are themselves related to each other. For example, Polish people in the U. S. in recent decades have tended to vote for the Democratic Party. So have Catholics. But most Poles are Catholics, so it is difficult to tell in a simple correlation analysis of voting in a Polish district whether religion or national origin is the decisive factor.

It is in problems of this kind that the public opinion polls have made their greatest contribution. They can provide no end of information about the individual voter, and thereby make fine distinctions possible. Take, for instance, the question as to why Catholics have so strong a tendency to vote for the Democratic Party. Probably this is deeply rooted in their immigration history, among other things. Does this mean that the primary factor is economic? The theory may be tested by examining a specific group of voters, say voters of German extraction living in northern Ohio, some of whom are Catholics and some Protestants. As expected, we find the Catholics more prone to vote Democratic than the Protestants. We may suspect that the reason is that Catholics are, on the average, poorer than Protestants. But even among voters in the group who belong to about the same economic class, we find that Catholics are markedly more likely to vote for the Democrats than are Protestants. Consequently economics is not the immediately decisive factor here.

The analyst of the political scene wants to know answers to a great many other questions. What, for example, are the factors behind a failure to vote at all? Surveys of elections over the last 20 years or so show that poor people are consistently less likely to vote than those with higher incomes, women less likely than men, young people less likely than older ones. From the latter finding anyone may draw his own moral. Some may lament it as evidence of a lack of active interest in public affairs among American youth; others may welcome it as a sign that Americans begin to get interested in politics only after they have reached a certain amount of experience and maturity.

This type of analysis often produces information of considerable practical value to political workers. The 1944 Presidential election, it will be remembered, was notable for the special efforts made by labor unions' political action committees to bring out the vote. But this effort apparently was not effective among women, for a survey of a representative sample in four industrial centers (New York, Chicago, Cleveland and Kansas City) shows that a large proportion of the women in the labor group failed to vote. Clearly they represent a reservoir of possible votes upon which the political workers could profitably concentrate in the future.

IT HAS always been suspected, and the survey data have verified, that most Americans do not wait for the arguments of an election campaign to make up their minds on how to vote. They vote the same party all their lives, usually the same as their parents have voted before them. In a poll, therefore, it is important to make a distinction between this large majority of "congenital" Democrats and Republicans (probably at least 70 per cent of the total) and the minority who make up their minds in the course of the campaign or at least over a period of time reasonably related to the current issues and candidates. The latter group is of special interest to the social scientist, first because they are the people from whom we can learn something about the effect of propaganda efforts, and second because their shifts contribute greatly to the swings in the political history of the country. To study them voting analysts have devised the so-called "panel technique." A sample of citizens is kept under observation for perhaps six months before a Presidential campaign. Each member of this panel is interviewed repeatedly, beginning before the nominating conventions and ending after Election Day.

Such an investigation was made in 1948 as part of the well-known Elmira Study, sponsored jointly by Columbia, Chicago and Cornell Universities and a number of private agencies. In the August interview a sample of voters were asked how they intended to vote in the Presidential election. They were classified as strongly Republican, mildly Republican, neutral (does not intend to vote), mildly Democratic and strongly Democratic. Ultimately they were interviewed after the election to determine how they had actually voted.

The main results are shown in summary form on the opposite page. It must be borne in mind that Elmira is a strongly Republican city, which accounts for the large Dewey majority and insignificant Wallace vote. The study yielded a wealth of interesting information: *e.g.*, that people with only a mild leaning toward a candidate frequently vote for his opponent or do not vote at all in the end; that a considerable proportion of the voters who intended to vote Democratic in this city failed to carry out their intention; that in a disproportionately large number of cases the "neutrals" finally voted Democratic.

FROM this study and similar ones in the two preceding Presidential elections we can draw, among others, this significant generalization: people group themselves in quite a homogeneous political environment. The overwhelming majority, asked to tell how their three best friends would vote, said their

WARD NUMBER	1835 ASSESSED VALUE PER PERSON	1836 DEMOCRATIC VOTE AS PER CENT OF TOTAL
12	171.04	51
3	214.93	49
1	234.06	53
5	240.61	36
2	356.06	65
11	367.80	35
10	469.28	29
4	617.95	40
6	712.34	34
9	739.59	29
8	868.08	20
7	1,188.78	23

PRESIDENTIAL ELECTION OF 1836 was analyzed to test the hypothesis that Jackson was favored by the low-income voters. An analysis of voting records in 12 Boston wards showed that the hypothesis was generally correct.

friends would vote as they themselves would. This, of course, is not surprising. The primary groups in which people live are rather homogeneous. Our friends have about the same income and tend to be of about the same age as ourselves; Catholics and Jews are likely to be associated in their private lives mainly with their coreligionists. All these factors, as we have mentioned, are more or less related to the way people vote. One might say that voting the same way is partly an expression of solidarity with our immediate face-to-face environment. In the course of a campaign this solidarity seems to become further accentuated. In the 1948 election the people of the Elmira panel who considered themselves in the middle class showed a tendency to switch to Dewey during the campaign if they were not for him in the beginning; working class people had a similar tendency to stay with Truman or switch to him.

The family group, of course, shows the same tendency to uniformity. In a family whose members are all in political agreement their pre-election voting intentions seldom shift. But where there is only partial agreement or considerable disagreement in party preferences, changes in voting intentions are much more common, showing a clear tendency to adjust to one's own environment.

People tend, in short, to avoid the tensions of disagreement in their own primary group. What happens when they are subjected to cross-pressures? Catholics tend to vote Democratic and rich people Republican. What will a rich Catholic do? How do members of a family with a tradition of voting for one party reconcile their conflict when they feel very strongly in favor of another party in some special election? There is no general answer. But one point can be made safely: the greater the number of such cross-pressures, the longer people will delay making up their minds. In the 1940 election a study of the effects of cross-pressures was conducted among a sample of voters in Erie County, Ohio. Individuals who were subject to two or more cross-pressures in their environment were slow to decide how they would vote: nearly a third did not make up their minds until the last two months of the campaign. On the other hand, of those who were entirely or almost entirely free of cross-pressures, 58 per cent knew how they intended to vote as early as May, and only 16 per cent waited until the final weeks to decide.

These findings concerning the great importance of the social environment in the area of politics are in accord with the data from other social investigations. For instance, the monumental study, *The American Soldier* (SCIENTIFIC AMERICAN, May, 1949) has shown how important a role the primary group plays in determining how a soldier will stand the ordeal of battle.

IN the political field one might say that most people do not vote for a President but for the kind of friends and neighbors they would like to have. This clearly has tremendous implications for the conduct of election campaigns. The whole orientation of propaganda will be affected. The role of pamphlets, speeches and other more formal devices probably depends upon whether they can be integrated into the processes by which primary groups are formed and developed.

Not only the voter's occupation and income but the whole social context in which he lives plays a part in determining how he will vote. Thus in the traditionally Republican rural Middle West sales clerks tend to vote Republican, while in large cities, where the prevailing atmosphere is Democratic, they are more likely to vote for that party. Likewise in England workers living in a solid working-class district are more likely to vote Labor than workers of the same occupations who live in a middle-class district.

The practical politician has always known that political machines are the most important way to win elections. Social scientists appear to be on the road to adding more precise information to this general observation. In the 1952 Congressional election the committee that conducted the 1948 Elmira Study, together with the American Association for Public Opinion Research, plans to continue the investigation by means of a number of smaller regional panel studies. It is hoped that this kind of work, systematically carried out over many years and in a variety of situations, will increase our knowledge about votes in the making.

Paul F. Lazarsfeld is professor of sociology at Columbia University.

NOVEMBER VOTE	AUGUST INTENTION					
	REPUBLICAN STRONG	REPUBLICAN MILD	NEUTRAL	DEMOCRATIC MILD	DEMOCRATIC STRONG	MORTALITY
DEWEY	206	144	30	8	2	28
TRUMAN	11	28	16	86	49	32
WALLACE	0	0	0	1	0	0
DIDN'T VOTE	38	41	99	31	12	38
MORTALITY	9	9	15	1	6	44
REFUSED	3	14	5	7	2	5
TOTAL	267	236	165	134	71	147

PRESIDENTIAL ELECTION OF 1948 was analyzed to determine shifts by voters during campaign. A group of voters in Elmira, N. Y., was interviewed in August and November. The results may be read: 206 who were strongly Republican in August voted for Dewey, 11 for Truman, etc. Mortality: voters not reached at given time.

GROUND WATER

The subterranean rocks of the U. S. hold more water than all its surface reservoirs. Yet the present demand on this mighty store raises the question of whether it is being permanently depleted

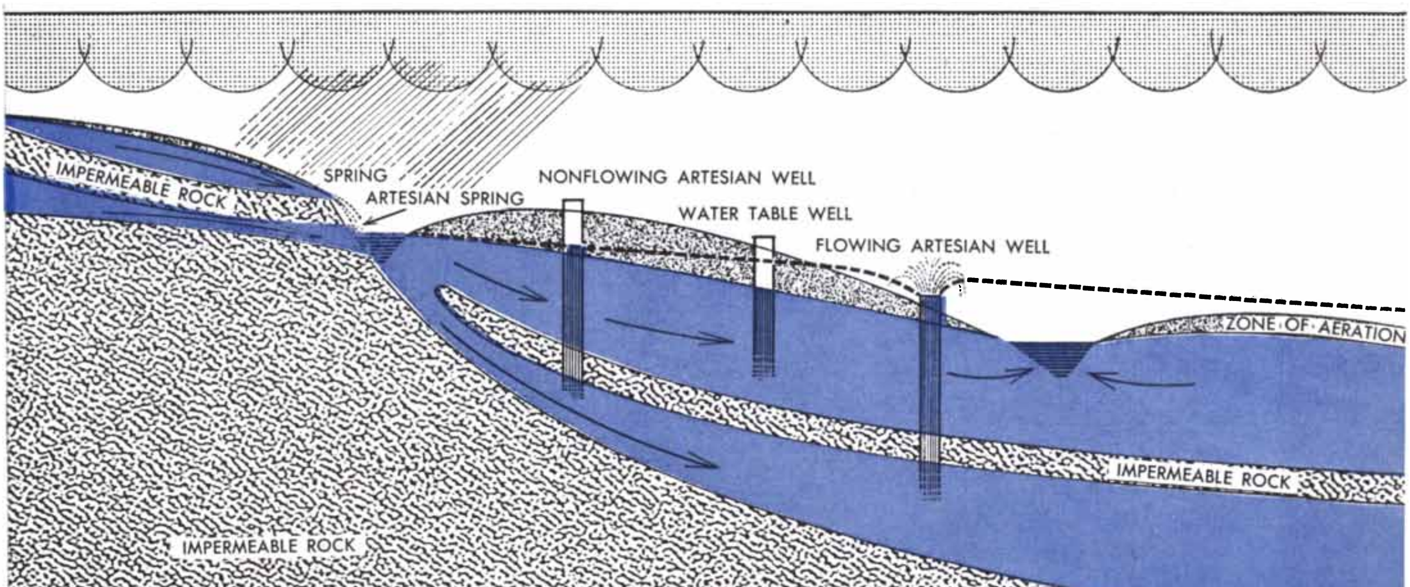
by A. N. Sayre

THE average city-dweller usually has little appreciation of the value of water. Generally he is able to get all he needs simply by opening a faucet, and he takes it so much for granted that he has ceased to be conscious of the fact that water is a necessity of life; that, moreover, modern civilization is more dependent on water than on almost any other commodity. Without water our great refineries, chemical plants, steel mills, power plants—our industry generally, to say nothing of commerce and agriculture, would be helpless. What most city dwellers have also failed to realize, until recently, is that water, like other raw materials, is not an unlimited resource.

Is it possible that the U. S. may actually run short of water? In some parts of the country, notably the arid sections of the West, water has always, of course, been something to worry about. In frontier days men often fought pitched battles with six-shooters for possession of a water hole, spring or stream. It was not very long ago that Arizona mobilized its militia to prevent construction of the Imperial Dam, which would divert Colorado River water from Arizona to California. The scene of battle in such disputes over water rights has shifted to the courts, commissions and legislatures, but the battle goes on with undiminished intensity.

During the past few years worries about water have become widespread in the U. S. Local water shortages have appeared in many places in all parts of the country. The problem was dramatically brought to national attention in the fall of 1949, when the nation's largest city, New York, suddenly found itself confronted with a severe water shortage and had to call on its people to reduce water consumption. President Truman considered the general situation so serious that he appointed a commission to develop a national water policy.

This national concern is well merited. We need to take steps to conserve water. But it is also possible to become too alarmist about the situation. The nation's press has recently published some disquieting predictions by writers who hold that our water supplies are steadily and irretrievably diminishing. They have



GROUND WATER is part of the hydrologic cycle, in which water is ceaselessly evaporated from and precipitated on the surface of the earth. When a well is sunk into permeable rocks, the water stands at the level stressed a supposed general dropping of the water table. Let us examine the evidence.

THE contention that the nation's water resources are declining has been based in large part on two surveys, each made a number of years ago. The first was by the late W. J. McGee, of the Department of Agriculture, who was one of the earliest champions of the conservation of natural resources. In 1910 McGee sent a questionnaire to 33,000 township crop-reporters of the Department of Agriculture asking them to report on ground-water levels, as measured by the depth of water in wells. From their replies he concluded that over a period of 25 to 30 years water levels had steadily declined at a small but appreciable rate.

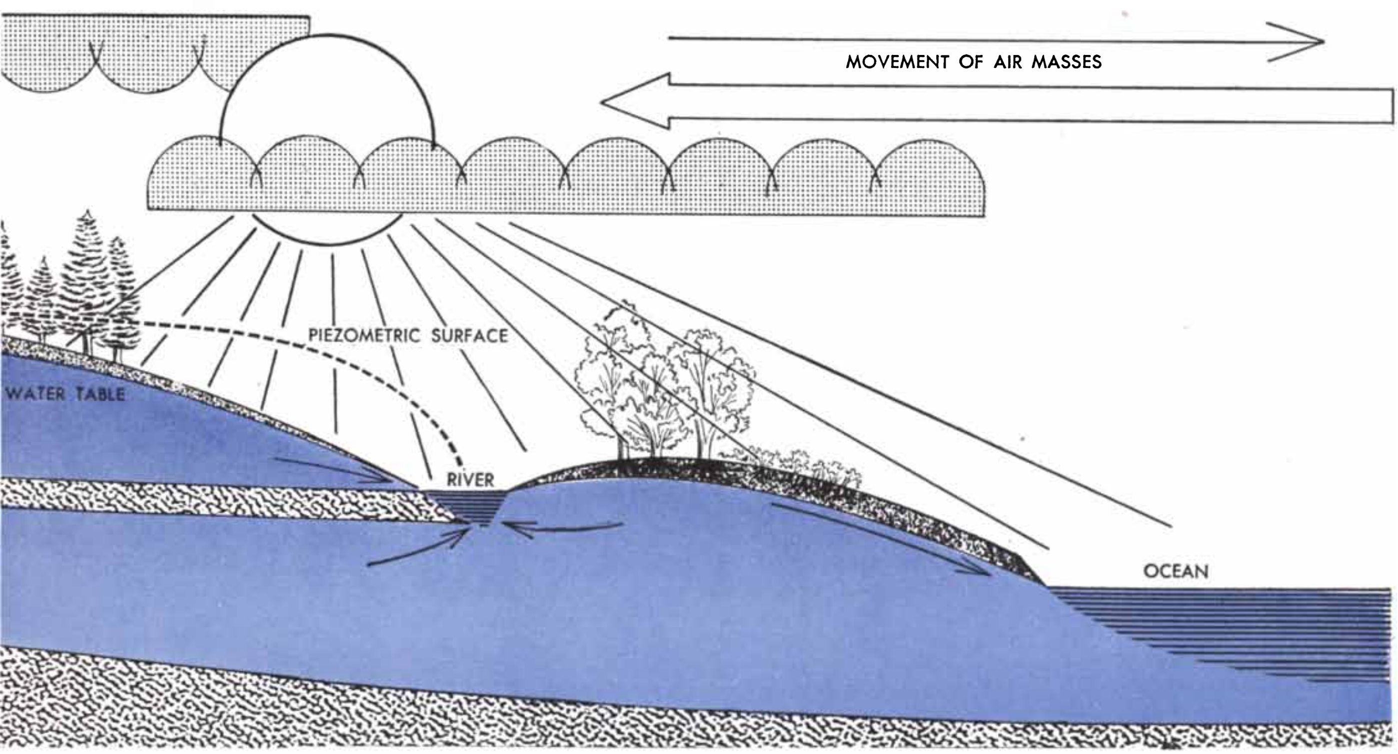
But McGee's conclusions were later refuted in a careful analysis by the late O. E. Meinzer, formerly Geologist in Charge of the Ground Water Branch of the Geological Survey. Meinzer pointed out several errors in McGee's fundamental assumptions. In the first place, the measurements had recorded the depth of water in the well rather than the distance of the water level from the land surface. Inasmuch as wells commonly fill at the bottom because of caving and deposits of material from the outside, a reduction of the water depth in an old well does not necessarily mean that the water level has actually fallen. Secondly, the 1910 measurements were made in the fall, when water levels are commonly at or near the lowest stage of their annual cycle. Thirdly, 1910 was an exceptionally dry year in much of the country; in the upper Mississippi basin it was the driest year since 1878.

The other survey commonly cited by pessimists was made by H. E. Simpson, formerly State Geologist of North Dakota, and presented in the Report of the Mississippi Valley Commission in 1934. On the basis of questionnaires sent to well drillers Simpson reached conclusions similar to McGee's. He reported that over periods ranging from one to several decades water levels in shallow water-bearing formations had fallen generally in the upper Mississippi basin, declining as much as 35 feet in western South Dakota, and that the deeper artesian levels, especially in the Dakotas, had declined much farther. The fall in artesian levels is well substantiated. But the decline in the shallow water-bearing formations was only temporary; it was due to shortages of precipitation during the drought years of the early 1930s.

Actually exact measurements of ground-water levels made in recent decades by the U. S. Geological Survey and its cooperating state and Federal agencies show that the pessimism of McGee and Simpson was unwarranted. It is true that there have been substantial declines in many areas, notably Memphis, Tenn., Houston, Tex., Long Beach, Calif., Mobile, Ala., the Philadelphia-Camden area, the Grand Prairie region in Arkansas, the great Dakota artesian reservoir in North Dakota and South Dakota, the High Plains area of Texas and New Mexico, and most of the irrigated valleys of Arizona and New Mexico. But in nearly every case the areas of decline are areas where the ground-water reserves have been heavily pumped. The declines reflect increased use of ground water rather than a general falling off of resources. Outside the areas of heavy pumping there has been no apparent regional net decline in water levels within the period of record. Ground-water levels have fluctuated with precipitation, declining in periods of low precipitation and rising during periods of heavy precipitation.

Records of the measured flow of streams likewise fail to show any generally significant long-term trend. According to Engineer W. B. Langbein of the U. S. Geological Survey, stream flow did decline during the early part of this century, reaching a low point during the 1930s, but since 1940 there has been an upward trend in the flow of most streams. One of the few striking exceptions is the Southwest, where stream flow has continued to decrease since 1940.

In considering whether our water resources are diminishing, it should be remembered that the records are scarcely long enough to permit valid conclusions. Most of our water-level and stream-flow observations were begun within the past 30 or 40 years; very few go back as far as 100 years. Our longest records of pre-



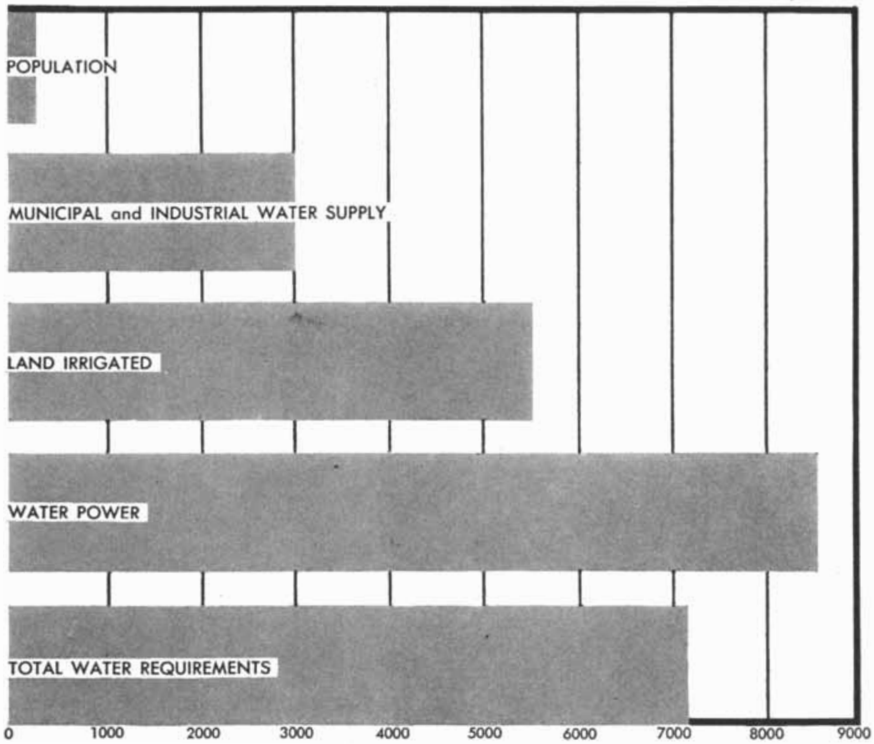
of the water table. When a well is sunk into permeable rocks beneath an impermeable formation, the water rises. Such a well is called artesian. The level to which artesian water will rise is called the piezometric surface.

cipitation and temperature cover only a little more than 200 years. We know from geologic and other evidence that precipitation and other climatic factors bearing on water supply have fluctuated widely. By a synthesis of all lines of evidence eventually we may be able to make some deductions about our long-term water prospects. But at the present time it is difficult to say with assurance whether our water supply is likely to increase or diminish.

THE PRESENT shortages of water in a growing number of communities in the U. S. are due primarily to increased consumption of water rather than to any important change in the natural supply. Not only has our population increased but our per capita use of water has risen—and at a much greater rate. In Texas, for example, while the population tripled in the 50-year period ending in 1940, the use of water for industrial and municipal purposes increased about 30 times, for irrigation about 55 times, and for water power about 85 times; for all purposes the average over-all increase was almost 71 times. Similar increases in the use of water have occurred throughout the nation.

Thus far most communities have been able to obtain the necessary additional water supplies by tapping new and generally more distant sources of water. This is the method by which New York City expects to overcome its present water shortage. It seems likely that under present rates of water use, and allowing for a normal population increase, most communities will be able to satisfy their increasing water needs for many years to come by reaching out farther for their water supplies. Yet for some communities, less favored by nature, this procedure may be too costly, and eventually new agricultural developments or industrial processes that require large amounts of water (*e.g.*, the hydrogenation of coal and oil-shale) may bring water shortages home to many U. S. areas.

We can no longer afford, therefore, to dally with the problem. Clearly we need to proceed as rapidly as possible to take an inventory of what and where our water resources are. Already some industries are finding it necessary to search for areas of abundant water as sites for new plants. It seems likely that this will take place, industry by industry, until a rather thorough decentralization, based on availability of water supplies, has resulted. The finding of the necessary undeveloped resources of water will not, however, be a simple matter. It is not a problem that can be solved with a divining rod or by witchcraft. We shall need a survey, area by area, of current water supplies and long-term variations in them, and research into a multitude of other problems in hydrol-



INCREASING DEMAND FOR WATER is illustrated by example of Texas. From 1890 to 1940 population increased 287 per cent; water supply, 2,960; land irrigated, 5,480; water power, 8,500; total water requirements, 7,070.

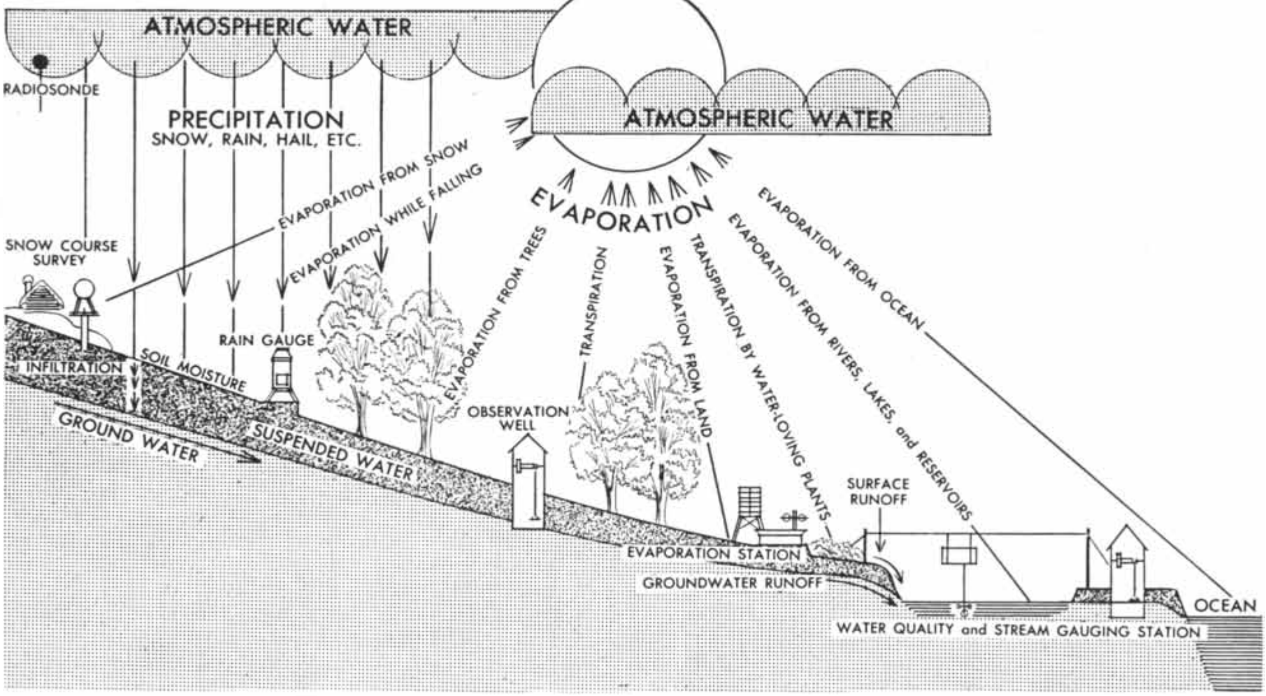
ogy that have scarcely been touched.

The resource that concerns us here is ground water, a huge reserve that amounts to many times the total volume of water that is or could be stored in all the nation's natural and artificial surface reservoirs. Ground water, roughly speaking, is the great pool of water stored in and transmitted through the porous rocks below the land surface.

Hydrology, the science that deals with the study of water, goes back to Marcus Pollio Vitruvius, a Roman architect and engineer who lived about the time of Christ. He was the first to outline clearly the theory that the water of springs and rivers is derived from rain and snow, which filters through the soil and rock strata and eventually emerges at the surface. Obvious as it may seem, this idea was not generally accepted by savants until near the end of the 17th century and was not realized by the average layman until comparatively recent times. Leonardo da Vinci, Bernard Palissy and perhaps a few others, by their own shrewd deductions, reached conclusions similar to those of Vitruvius. But no quantitative tests of the theory were made until the measurements of the 17th-century Frenchmen Pierre Perrault and Edmé Marriotte and the Englishman Edmund Halley (who is better known for his work in astronomy). Perrault measured the rainfall and the discharge of the Seine River during a period of three years and computed that the precipitation in the Seine Basin was about six times the quantity of water discharged by the river. Marriotte essentially verified Perrault's results. Halley, by measuring evaporation rates, demonstrated that the water evaporated from the Mediterranean was ample to supply the rivers flowing into that sea. These pioneering studies were followed by a great number of investigations by many scientists which filled in the picture.

It is now recognized that there is a vast circulation of water from the sea to the land and back to the sea again—the "hydrologic cycle." The cycle is imperfect. Much of the water evaporated from the sea is precipitated on the sea itself. Of the part precipitated on the land, some is returned directly to the atmosphere; some flows off directly through streams; some is locked more or less permanently in chemical combination with minerals; some filters through the soils and rock strata of the earth and eventually returns to the streams or to the ocean.

Thus essentially all fresh water is derived from precipitation. It becomes available for human use only when it is collected in some kind of natural or artificial catchment. In many parts of the world people still get water for domestic use by collecting rainfall from roofs and storing it in cisterns. On Gibraltar and in the Virgin Islands rainfall is caught on paved hillsides and conducted to storage reservoirs. Man has devised all sorts of methods for collecting precipitation. But the great catchment system from



MEASUREMENT OF WATER is accomplished by instruments stationed at key points in the hydrologic cycle. The snow-course survey and the rain gauge measure the rate of precipitation. The evaporation station measures the rate of evaporation. Observation well and stream-gauging station measure the balance of the cycle.

which he gets most of his water is nature's rivers and lakes and her vast underground reservoirs of permeable rocks.

THE water-bearing formations that make up the natural underground reservoirs are called "aquifers." They differ greatly in shape, thickness and extent. For example, in Texas the geologic formation known as the Carrizo sand ranges from about 100 to 200 feet in thickness and provides potable water in an area 20 to 50 miles wide and hundreds of miles long; by contrast, some of the permeable glacial deposits of the Middle Western States have a thickness of only a few feet and an extent of less than a few square miles.

Two important factors, among others, govern the amount and availability of water in an aquifer. One is the porosity of the rock, *i.e.*, the proportion of the total volume that consists of voids or interstices that can be occupied by water. The porosity, of course, determines how much water the formation can hold. The other factor is the permeability of the rocks, which determines how freely water can move through them. Permeability and porosity are not synonymous. Shales and clays, for example, are highly porous and can hold a great deal of water, but their pores are so tiny that they are relatively impermeable; under ordinary gradients water moves very slowly through them or not at all. Hence wells drilled into such rocks may be dry or produce only small amounts of water. The permeable rocks are sands, gravels, cavernous limestones and any dense rock that has been fractured, as by earth movements.

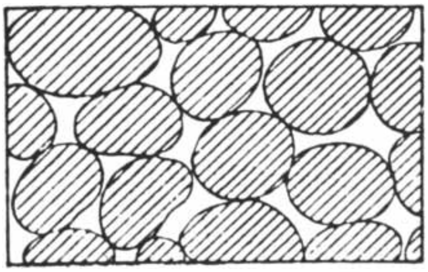
Ground water may be loosely defined as the water in the saturation zone where all the spaces in the rocks are filled with water. The upper surface of the zone of saturation in unconfined permeable rocks is called the water table. If all the rock through which a well passes is permeable, the water will stand in the well at the level of the water table. If the rock overlying the water-bearing bed is impermeable, the water is under pressure, and when a well is sunk to it the water will rise. Such water is called artesian, after the French province of Artois, where the first flowing wells were constructed in 1126.

Contrary to a widespread impression, the water table is almost never a flat surface; it is higher under hills than in valleys. Moreover, it is not static but rises and falls as water is added to the zone of saturation or is taken from it. Where the water table intersects the land surface, water issues as springs or seeps, and under certain conditions a marsh or lake may be formed.

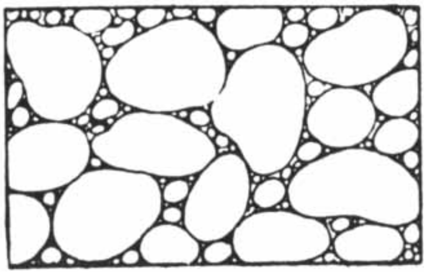
Artesian aquifers are generally recharged at a considerable distance from the area of flow, sometimes several hundred miles away, as in the Dakota artesian basin. Local rainfall in the area of flow does not help to recharge such aquifers. Nonartesian aquifers, on the other hand, are ordinarily recharged by local rains in the area where pumping occurs.

Because a great many factors affect the fate of the precipitation that falls on the earth, much of it is prevented from replenishing the ground-water supply. The absorptive capacity of the soil and underlying rocks, the topography, the kind of vegetal cover, the form, intensity and total amount of the precipitation itself—all these determine whether precipitation will sink into the land surface or run off over it. A light rainfall may be evaporated from the soil or the leaves of plants without sinking in at all.

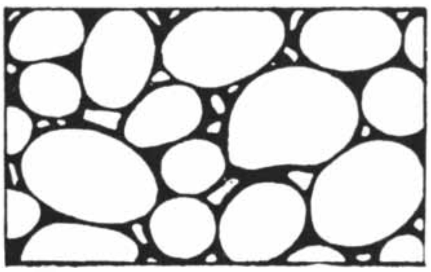
In large areas of the U. S. the rocks beneath the surface are impermeable and there are no good aquifers. Thus much of the precipitation runs off, eroding the soil. Erosion can be retarded and infiltration capacity substantially increased by establishing vegetal cover and by other beneficial land-use practices. A cover of vegetation is not an unmixed blessing, for the plants themselves take up much of the water, but it can often increase the yield of shallow wells and springs and seeps which help maintain the flow of streams in dry seasons. In areas where the subsurface is highly permeable so that good aquifers are available, the soil's absorptive capacity is high already, but man can still improve matters by storing flood waters from adjacent areas and artificially recharging the underground reservoirs when necessary. On the other hand, industrial or housing developments, with



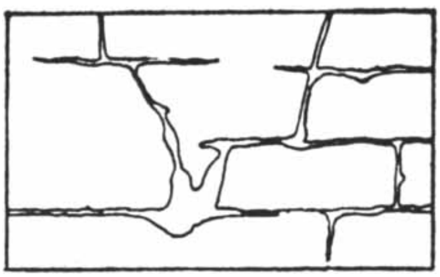
WELL-SORTED sedimentary deposit has a high degree of porosity.



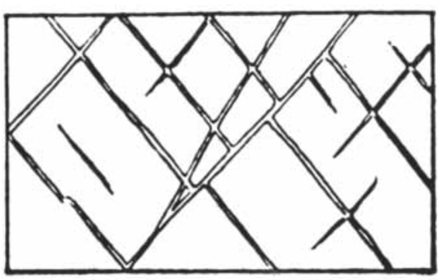
POORLY SORTED sedimentary deposit has a lesser degree of porosity.



MINERAL-FILLED sedimentary deposit has a small degree of porosity.



SOLUBLE rock is often porous because water dissolves cavities in it.



FRACTURED rock has porous structure similar to that of soluble rock.

their large areas of roofs and paving, greatly reduce the opportunity for ground-water recharge.

Of the water that sinks into the ground a very large part is held by molecular attraction to the walls of the pore spaces in the soil above the water table. It remains there as "suspended water" until plants draw it up through their root systems and transpire it into the atmosphere through their leaves. Especially during the growing season, when the demands of the vegetation are large, most of the precipitation may be used up in this manner. Even when there is so much water that some of it can sink to the zone of saturation in the underlying rocks, it is still not entirely safe from the demands of certain plants, such as alfalfa, salt cedar and cottonwood, which send their roots so deep that they reach the zone of saturation unless the water table is extremely deep.

WHEN water reaches an impermeable layer or the zone of saturation, it moves laterally under the force of gravity until it emerges as springs or seeps and thus returns to the streams. About 40 per cent of the flow of surface streams in the U. S. is derived from ground water. There is a close interrelationship between surface water and ground water, and the flow is not all one way. In humid areas ground water feeds the streams, but in many arid and semi-arid regions and in areas of heavy ground-water pumpage adjacent to streams, the streams feed the ground water.

The proportion of the precipitation that returns to the sea through streams and through subterranean courses has been determined in only a few places. It varies widely from place to place and from time to time at the same place. For example, data from Ohio indicate that of the 38 inches average annual precipitation, approximately 13 inches is discharged by ground water and stream flow and about 25 inches is evaporated or transpired; in the Miami, Fla., coastal area, of the 60 inches average annual precipitation, approximately 25 inches is discharged through the streams and about 35 inches is lost by evapo-transpiration.

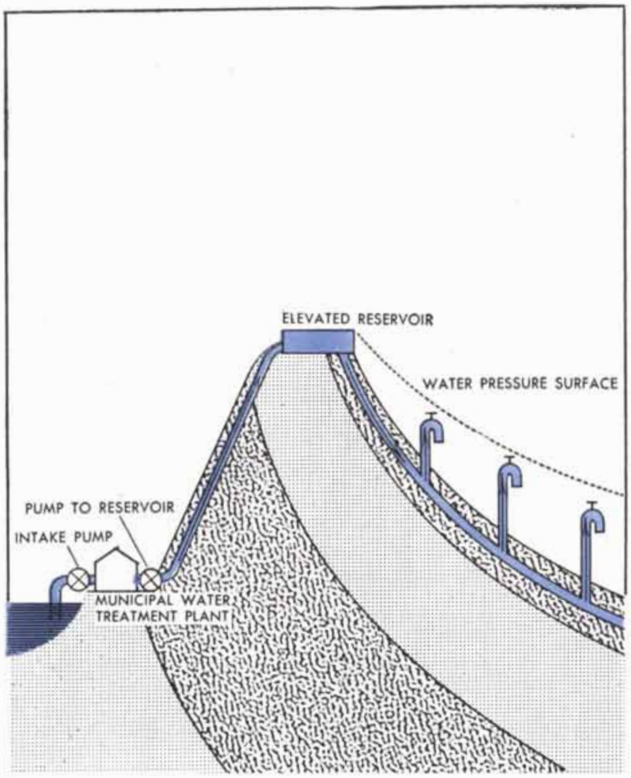
There is a wide range of ground-water conditions in the U. S., as might be expected from the great differences in climate, topography, geology, permeability of rocks and the extent to which individual aquifers are exposed to recharge from precipitation or, in some arid regions, from stream flow. Among the most productive ground-water regions are the Atlantic and Gulf coastal plains; part of the North Central area, especially Michigan and northern Indiana; parts of the northern High Plains in Nebraska; certain alluvial basins in the West that are adjacent to high mountains which receive abundant precipitation, and parts of the Pacific Northwest. Among the least productive ground-water regions are a mid-continent belt extending from Kentucky and Tennessee to the eastern margin of the High Plains, parts of the northern Great Plains in the Dakotas and Montana, and the low mountains and high plateaus of the arid West.

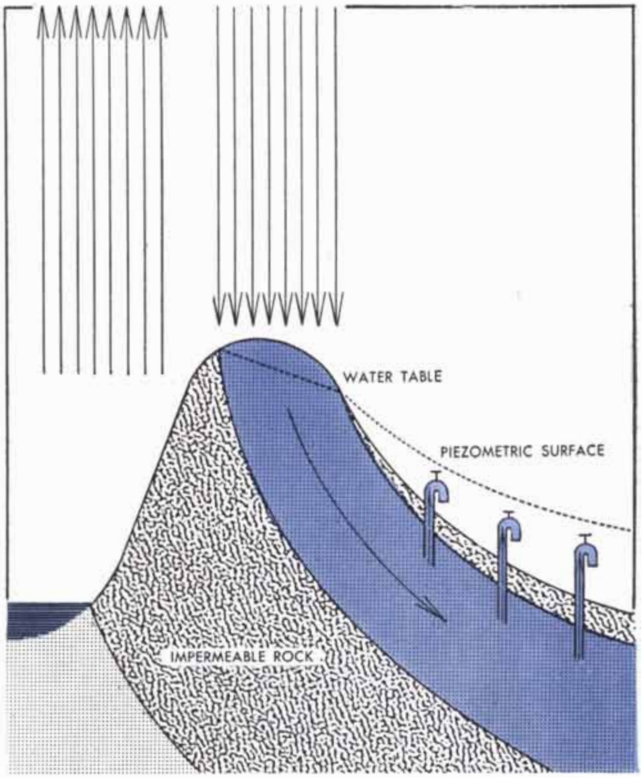
The U. S. is blessed with enormous and generally underdeveloped ground-water resources, but the geographical distribution of the ground water is far from uniform, and it is this factor, rather than an over-all shortage of water, that is responsible for most of our ground-water problems. Unfortunately we know too little of our ground-water resources in detail. The study and appraisal of them have been carried out on a gradually increasing scale. But only a small percentage of the nation has been covered by the systematic, comprehensive and integrated investigations that are required.

Ground-water investigations often are very complex, time-consuming, and, in some places, costly. They include not only geologic and geophysical mapping to determine the location, extent and thickness of water-bearing formations, but also hydrologic mapping and physical studies to determine the permeability and porosity of the rock, the amount of water that enters the aquifers, the direction and rate of movement of the water and the areas of recharge to and discharge from the aquifers. Inasmuch as water beneath the land surface is invisible, the relevant data are often determined by indirect methods such as electric and gamma-ray logging and examination of the geologic strata in drilled wells, as well as by actual pumping tests.

IN ORDER to utilize our ground-water resources effectively and thus maintain our industrial and agricultural expansion, it is essential to proceed with these studies as rapidly as is practicable. The slow rate of progress in this field was pointed out in 1940 in a report by the National Resources Planning Board called "Deficiencies in Hydrologic Research." It was reiterated by the Natural Resources Task Force of the Hoover Commission in 1949. The need for research will doubtless be one of the prime considerations of President Truman's Water Resources Policy Commission. The evidence that the water problem has finally aroused interest among the public and in high places in government gives hope that we can look forward to full development of our water resources.

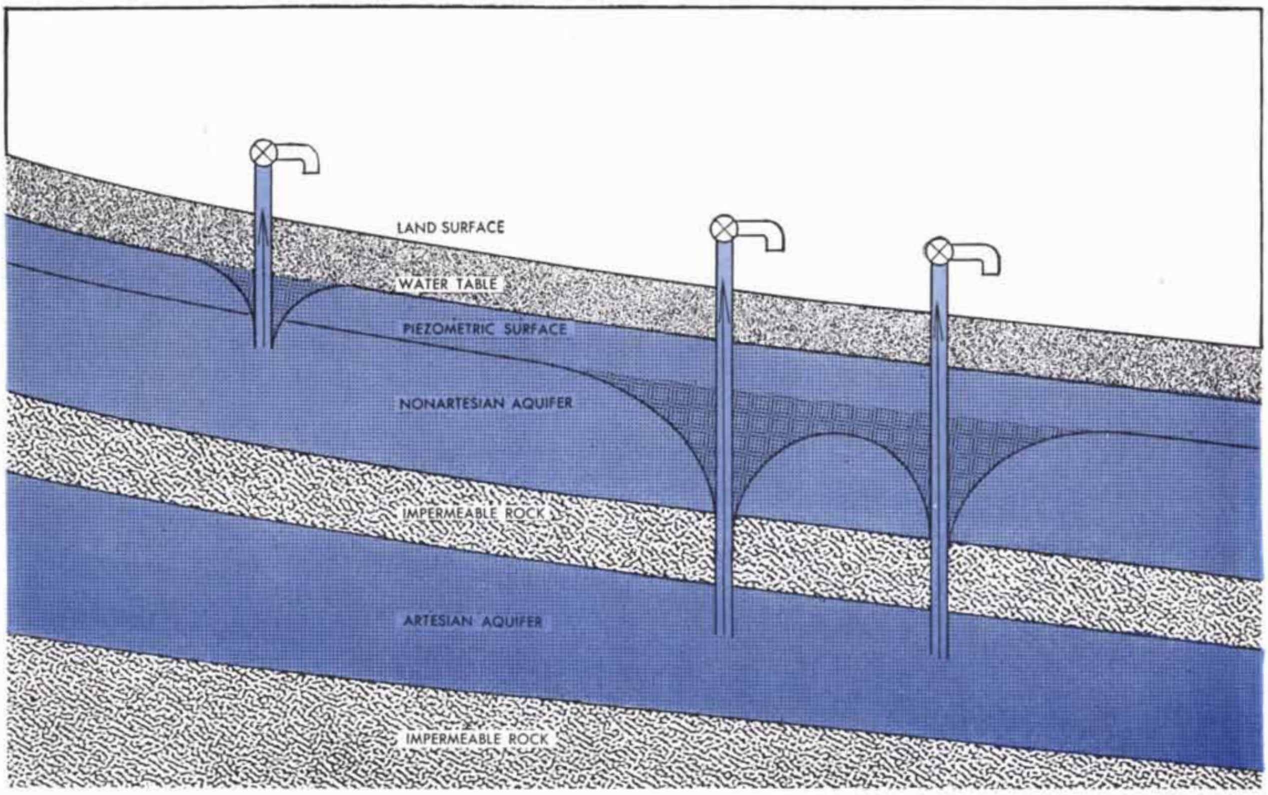
A. N. Sayre is Geologist in Charge of the Ground Water Branch of the U. S. Geological Survey.





NONARTESIAN WATER SYSTEM draws water from a low-lying well or reservoir, treats it and pumps it into an elevated tank. The water then flows freely from the outlets that are lower than the water pressure surface.

ARTESIAN WATER SYSTEM requires no pumps or tanks. The water is precipitated on a "recharge area," and is drawn from the same stratum below it. Piezometric surface is analogous to the water pressure surface.



ARTESIAN AND NONARTESIAN SYSTEMS may be used in the same area without interfering with each other. In this diagram water is pumped from both artesian and nonartesian aquifers, or water-bearing strata. The nonartesian well at the left causes a drop in the water table, but does not affect the piezometric surface. The artesian wells at the right cause drops in the piezometric surface, but do not affect the water table.

SPINAL CAT has a characteristic attitude. One hind leg is thrust out stiffly; the other is twisted backward.

"Spinal" Cats Walk

When the spinal cord of an animal is cut, a permanent paralysis has been thought to result. Now some remarkable experiments show that in some animals the severed system is capable of learning

by P. S. Shurrager

LEARNING, students of the nervous system have long been taught, can occur only in the brain. This theory is founded on the well-established fact that the brain is the master of the senses and of all voluntary activity. An animal can feel a stimulus and make a voluntary response to it only if the nerve impulses involved pass through the brain. The brain receives an impulse from the stimulated organ (eyes, ears, nose, tongue or skin), translates this impulse into some sensation and then responds by sending an impulse calling for action to an effector organ, such as a muscle or a gland. If the nerve pathways over which these impulses travel are blocked, by injury or disease, the animal loses sensation or the power of voluntary movement or both, depending on the location and extent of the damage.

The spinal cord, though also a part of the central nervous system, can feel nothing nor initiate any voluntary activity. If the spinal cord is cut through, the part of the body below the cut, having lost nervous contact with the brain, is completely paralyzed and loses all sensation. The functions of the spinal cord have been carefully studied through experiments on animals by many investigators, and the general picture is as follows: Immediately after the cord is severed the animal goes into a state of "spinal shock." The part of the body below the cut shows no nervous response whatever; even reflexes are absent. If the animal lives, it eventually recovers from shock and "spinal reflexes" reappear below the cut. The animal's lower limbs can respond to a stimulus: when a leg is touched or stimulated by a mild electric shock, it moves. But it is not a response that can be controlled or made intentionally. When not artificially stimulated, the body below the injury is completely limp, or it may become rigid, with certain muscles more or less permanently contracted. The animal typically drags itself about and, since there is no sense of pain in the lower part of the body, it often rubs raw, infected sores there. The unused muscles atrophy. Circulation and processes of digestion and elimination are depressed.

Yet the powers of the isolated part of the nervous system are not entirely lost. The great English physiologist Sir Charles Sherrington, who made many experiments with spinal animals, found that if a spinal dog's feet were placed so that the body was balanced, the animal could stand alone for a short period. When the animal was held up in the air, its hind legs made rhythmical stepping movements. Was it possible that this standing and stepping behavior could be integrated and trained so that a spinal animal could actually walk? Sherrington concluded that it was not, and the accepted theory has been that the spinal reflex responses are not modifiable—in short, that no learning can take place in a spinal nervous system cut off from the brain.

The writer does not agree with this theory. In a series of experiments started at the University of Illinois and continued at the University of Rochester and, during the past two years, at Illinois Institute of Technology, it has been demonstrated that a simple form of learning in the severed spinal system is possible; indeed, that spinal animals can be trained to walk. Although sensation and the power of voluntary activity are missing, the system of spinal reflexes can be coordinated into a functional pattern of behavior.

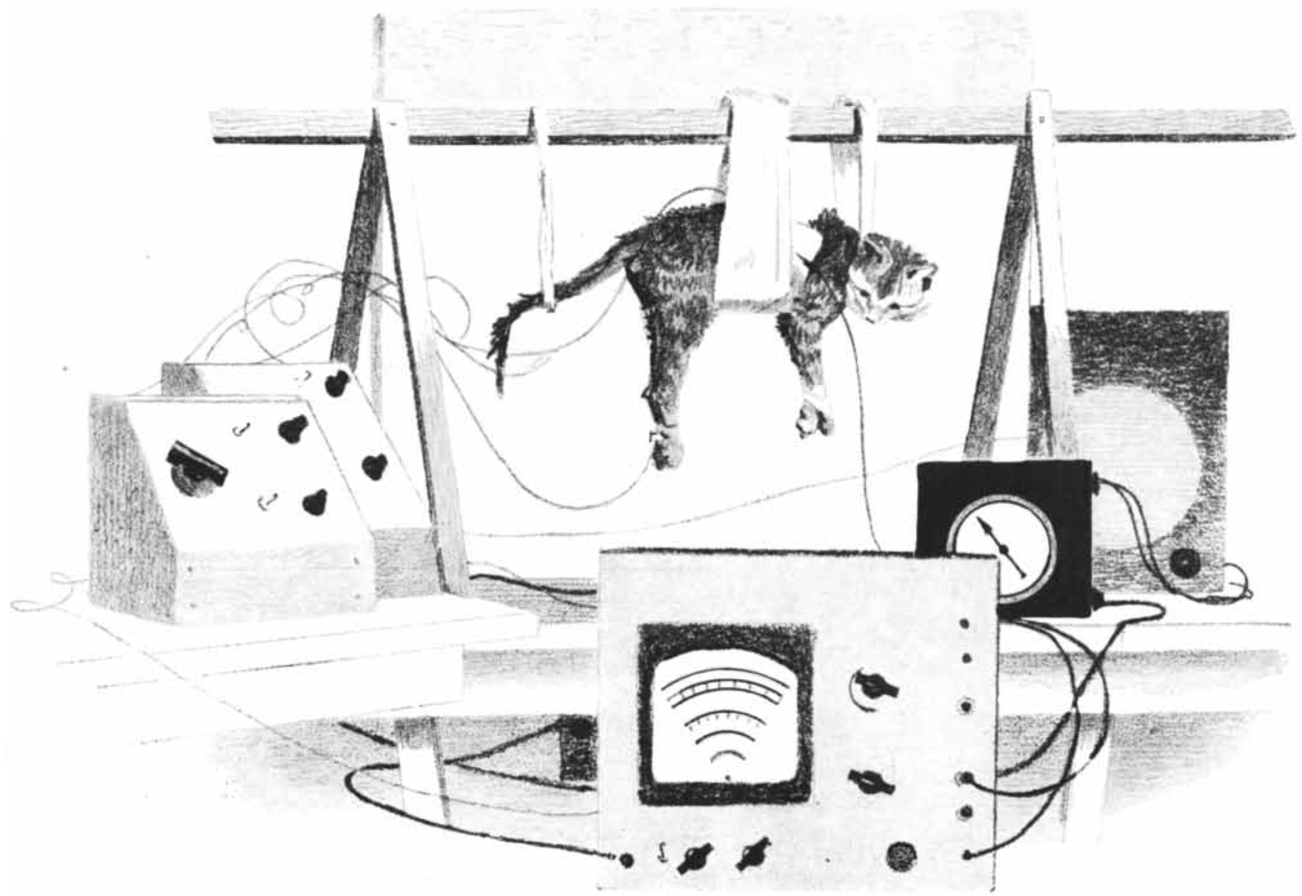
The technique we used to determine whether the spinal cord is capable of learning was the "conditioning" of reflexes. For example, a weak stimulus, such as the stroke of a soft brush or a mild electric shock, was applied to the tail of a spinal animal. There was no response, beyond perhaps a twitch of the tail. A second later a much stronger stimulus was applied to the paw; this made the leg muscles flex. After this combination of a weak tail stimulus and strong paw stimulus had been applied a number of times, the tail stimulus alone was sufficient to cause flexing of the leg muscles.

Having demonstrated in this way that spinal responses could be modified, my colleagues R. A. Dykman and H. C. Shurrager and I proceeded to attempt to train spinal animals in more elaborate conditioned responses. The abilities achieved by some of them exceeded anything we had thought possible.

The subjects were young cats and dogs under three months old. Under ether anesthesia their spinal cords were exposed by breaking away the tops of the spinal vertebrae, which are comparatively soft in young animals. The exposed cords were then tied tightly with silk thread at two points approximately one centimeter apart and cut through between these ligatures. The cut was made between the tenth thoracic and third lumbar vertebrae—roughly the middle of the back. Aseptic operating conditions were maintained; infections were controlled with penicillin and sulfa drugs. Some of the subjects on which the operation was performed were kittens a few days old. These kittens were put back with their mothers immediately after the operation. The old cats accepted them without demur, fed them and cleaned them, and the kittens were apparently as healthy as their normal litter mates. The older spinal animals, capable of feeding themselves, had a diet of diluted condensed milk, raw egg, liver and kidney and commercially prepared canned foods.

All the spinal animals were kept in boxes filled to a depth of at least a foot with paper excelsior. This permitted the animals to move about without injuring the insensitive hind part of the body on hard or rough surfaces. It also stimulated movements of the paralyzed hind limbs and provided resistance against which they pulled when entangled. Within 24 hours after the spinal operation, electrical stimulation of the hind legs was begun. Stimuli were applied at 30-second intervals for at least an hour every day. During the stimulation the animals were comfortably supported on a padded board, with their hind legs free above a table. Electrodes were attached to the hind paws, and a stimulus of sufficient intensity to induce full flexion of the stimulated leg was applied alternately to the left and right legs. When one leg flexes, the opposite leg extends, so this treatment elicited a series of such "crossed extensor" responses.

WHEN the kittens and puppies were old enough, they received a great deal of handling and attention in addition to the controlled electrical treatments. They were exercised daily on wide strips of corrugated cardboard stretched on the floor. The corrugated surface gave their hind feet something to push against; on bare floors they would have slipped. The animals were coaxed to climb over folds of the cardboard. They were given balls, corks and bits of string to play with, were rolled on their backs so they could wrestle with



SPINAL CAT IS SUSPENDED in apparatus for conditioning and stimulating responses of the hind legs. A weak stimulus was applied to the tail and, almost simultaneously, a stronger stimulus to one of the hind paws, causing the leg to flex. After a time the weak stimulus applied to the tail was sufficient to cause the leg to flex.

the experimenter's hand, and in general were encouraged to be as active as possible. They also received regular massage treatments of their hind legs.

This constituted the spinal animals' "training." What were the results? Immediately after the operation the animals lay in grotesque positions, with their legs thrust out or twisted under them. Their limp hind legs offered no resistance when flexed with the hand. But after a few days of training, resistance to flexion began to develop. At rest in their boxes, some of the animals assumed a more normal crouching position with their legs drawn up. Three quarters of the animals in our experiments never progressed much beyond this stage. But others continued to improve. They first attempted to rise, then learned to balance on all four feet and to take a few tottering steps. As time went on, they stood for longer periods and walked farther without falling.

It must be emphasized that a spinal animal's walking does not approximate that of the normal animal in speed, smoothness or continuity. It is, however, a complex form of coordinated and functionally adequate behavior. Among these spinal animals, one remarkable cat could remain on its feet for as long as 15 minutes at a time, could step up six inches and down six inches, could crouch and spring, could run for a few feet, change direction and even turn corners without falling—all on bare wooden floors.

How can a spinal animal attain the coordination between fore and hind legs that is necessary for walking? One possible explanation might be that the animal re-establishes nerve connections between the hind part and the brain, either by a regeneration of nerve fibers or by way of indirect pathways in the nervous system whereby nerve impulses can by-pass the interruption in the spinal cord. To test this interpretation we took two cats that had developed some spinal walking ability and cut their spinal cords in a second place above the point where they had been cut originally. After recovery from this new operation, the two cats were able to walk as well as before. This seemed to be clear proof that their coordinated leg movements depended only on the nerve system within the originally isolated section of spinal cord. Moreover, it must be remembered that spinal animals feel no sensation in the part of the body behind the cut and have no voluntary control of movements—another indication that no nerve connections with the brain are re-established.

OUR conclusion is that learning does occur in the isolated part of the nervous system, by a process analogous to reflex conditioning. In the earliest stages the animal's movements probably are purely mechanical: its hind limbs make compensatory adjustments when it is off balance in much the same way as a hinged doll walks down an incline. If a front leg steps forward, pulls are exerted on the muscles and tendons of the rear body and legs. When these stimuli become strong enough, there is a reflex response of a hind leg which in effect is a step. Then the other front leg moves forward and the other hind leg follows. At first progression is very unsteady and the animal soon falls, but its coordination and speed improve with practice and this improvement must be the result of learning. Undoubtedly much of this learning occurs in the front part of the body still served by the brain. Movements of the rear end exert pulls on structures of the front end, and the animal learns to interpret these stimuli as cues to the position and movements of the hind legs it cannot actually feel. It can then manipulate the parts of the body it can control so as to initiate appropriate movements in the rear end. This is not meant to imply that these are conscious postural adjustments, but rather that certain responses, after occurring repeatedly in conjunction with given stimuli, come to be evoked by these stimuli. They are, in Pavlov's terminology, "conditioned reflexes."

There are several reasons for believing that learning by conditioning also occurs in the rear end of the body. Among them is the fact that when training is discontinued, the acquired skill in walking deteriorates. This conforms to an established law of conditioning: when a conditioned stimulus occurs repeatedly and is not reinforced, the conditioned response weakens and disappears. When a spinal animal is confined to its box and has no opportunity to move about, stimuli still impinge upon its receptors, but the conditioned walking responses are prevented from occurring. In general terms, the animal first learns to make responses and then learns not to make them.

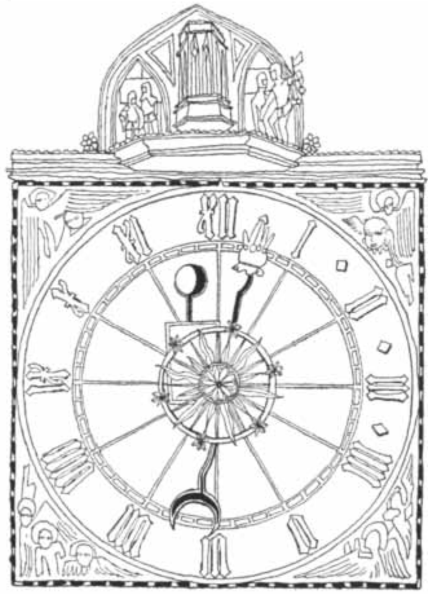
It may be argued that the degeneration of walking ability in these animals is attributable to a lowering of their physical vitality due to confinement and inactivity. Undoubtedly the remarkable performances of our experimental animals can be accounted for partly by the fact that they were kept in superior physical condition. But among animals that were all apparently at the same level of health, the efficiency of performance tended to depend on the relative amount of training and practice.

Our spinal animals were able to perform more complex acts than any reported in previous attempts to train such animals. What factors in our experimental situation might account for this? Several possible explanations suggest themselves. All of our animals were very young. Perhaps the modifiability of central nervous tissue decreases with age. Even within the narrow age range (a few days to three months) of the animals on which we operated, there was a tendency for those whose spinal cords were cut at the earliest ages to show less evidence of spinal shock, to recover more rapidly and ultimately to demonstrate better walking ability. Another factor, as we have already suggested, was the intensive course of electrical treatments, exercise and handling given the animals. Because many of the animals failed to respond to these treatments, it is not possible to assert definitely that the training itself was responsible for the success of those animals that learned to walk, but it seems significant that no walking behavior developed in animals that were not systematically stimulated and exercised. Still another factor was the close relationship between the animals and the experimenters. The kittens and puppies were not confined in standard cages nor isolated in the animal room, but were kept in the laboratory and became pets. Students and staff members, who came and went all day, stroked them and talked to them and offered them bits of food. Without exception the cats and dogs were very responsive and exceptionally gentle and easy to handle. It is perhaps not too fantastic to suggest that all this had some stimulating effect on the animals' learning.

THE major contribution of this work is that it shows that spinal cats and dogs are capable of much more complex and useful patterns of responses than had previously been thought possible. The involuntary movements of the hind legs can be organized so as to enable some of these apparently hopelessly paralyzed animals to move about with relative ease. There is, of course, a temptation to generalize from spinal cats and dogs to spinal human beings, *i.e.*, people whose spinal cords have been damaged by accident or disease. The work reported here has given rise to optimistic interpretations that have aroused considerable public interest. It must be emphasized that so far as our work is concerned there is absolutely no experimental evidence to support such interpretations. The fact that a kitten whose spinal cord is severed can learn to walk is far from presumptive evidence that a man whose spinal cord is severed or damaged can also learn to walk. The higher an animal is in the evolutionary scale, the more complex are its response systems and the more dependent it is upon its brain. In any case, it is for medical men to investigate what implications, if any, this research may have for human paraplegics.

P. S. Shurrager is chairman of the department of psychology and education at the Illinois Institute of Technology.

SCIENCE AND



Organized Self-Protection

IN California, Michigan, Missouri, Connecticut, New Jersey, upstate New York and many other areas, real-estate brokers have noted signs of an accelerated movement to the country. Some of them report that since the publication of the Atomic Energy Commission's best-selling book, *The Effects of Atomic Weapons,* inquiries from city-dwellers about farm properties have doubled. Advertisements of "Country Retreats" have begun to appear in the newspapers. In Teaneck, N. J., three enterprising World War II veterans have gone into the business of building concrete atomic bomb shelters. They offer to construct a shelter 10 by 10 feet with 18-inch walls under the garage for $1,500, and point out that the shelters will not be a total loss "even if there are no atomic bomb explosions, because they can be used as wine cellars or utility rooms." In New York City the skyscraper Sherry-Netherland Hotel has arranged to shelter its guests in its deep cellars, and one projected Madison Avenue office building has included shelter accommodations for 4,000 in its plans. A resolution proposing that the city take steps toward building shelters under parks, playgrounds and buildings, at a cost of about $450 million, has been introduced in the City Council. In California, gubernatorial candidate James Roosevelt demanded that the state build accommodations in the country for four million possible evacuees from coastal cities.

In recent weeks the nation's increasing civil-defense consciousness has been reflected in many sporadic indications such as these, but the wide interest in the subject has not yet crystallized into much organized activity. The U. S. has been presented with a "master plan," prepared by the Civilian Mobilization Office of the National Security Resources Board and submitted to Congress by President Truman. The plan, however, places "the primary responsibility for civil defense" on the states and local communities. Its philosophy is summed up in the phrase "organized self-protection."

The report proposes that the responsibility of the Federal government be limited to over-all planning, issuing informational material, training technicians, coordinating interstate operations, furnishing some essential equipment and possibly contributing funds to the states for distribution to communities. These activities would be carried on under a basic law creating a new Civil Defense Administration. The control and direction of operations would be in the hands of the states, which would be responsible for providing leadership and organizing intercommunity cooperation. The plan includes proposals for a national civil-defense law and a model state law.

"Civil defense is conceived as a system which will depend largely on cooperation between critical target areas and the communities around them," says the report. "To make every critical target community completely dependent upon its own resources would dislocate the national economy and jeopardize the rest of the defense effort."

The proposed preparations for defense are essentially the same as those used in World War II by Britain and Germany, with modifications to take into account the peculiar characteristics of the atomic bomb. Thus the program includes air-raid warnings, bomb shelters, wardens, fire, health and rescue service. It omits, however, any discussion of long-range measures such as dispersal of cities or industries. (In a separate action, President Truman has asked Congress for $139 million to begin long-range planning for dispersal of Federal government offices from Washington.)

So little has thus far been accomplished at the state and local level that many believe the Federal government may have to take a more active hand than is contemplated in this plan. The *Bulletin of the Atomic Scientists,* surveying existing state legislation, recently reported that 23 states still lack a civil-defense plan, a state civil-defense director or both. And the U. S. Conference of Mayors, meeting last month in Washington, revealed an almost total lack of progress in civil-defense measures thus far.

One mayor reported that he had appealed for 5,000 civil-defense volunteers in his city and at the end of a month had received only 20 responses. Many of the mayors indicated that they were confused as to what was expected of them or how to start to organize a civil-defense program. Mayor Elmer E. Robinson of San Francisco, apparently speaking for many others, declared that Washington must provide more aggressive leadership.

It is reported that the Administration will ask Congress at its coming session for somewhere between $100 million and $300 million for civil defense. This, however, appears to be far below the demands that will be made by the states. The New York City resolution urges that the Federal government provide $2 billion for shelter construction alone.

NSF in Business

WITHIN the next few weeks, when Congress reconvenes, President Truman is expected to nominate the 24-member governing board for the National Science Foundation. The Foundation was narrowly rescued during the last days of the recent Congressional session after the House Appropriations Committee had voted down an appropriation necessary to put it in business. The Senate Appropriations Committee, on the urging of the President and scientists' organizations, restored $225,000 of the $475,000 the President had asked for the Foundation's first year. The reduced sum was finally approved by both houses.

The Federation of American Scientists, one of the groups actively backing the Foundation, said: "It is clear that continuing scientist support for NSF is needed. At best, its activities this year will be limited. Restricted funds will probably reduce the estimated staff of about 100. The agency will not be in a position to support research and training of young scientists for at least another year. The scope of activities of NSF from now on will depend largely on the Appropriations Committees of the House and Senate. An annual campaign may be necessary to wring adequate funds from these 'hard-boiled' groups."

Vaccination and Polio

ONE of the few well-established facts about poliomyelitis is that physical exhaustion or severe physical stress can make people vulnerable to the disease. Physicians advise against tonsillectomies during the polio season. Now they have found some evidence that preventive inoculations against diphtheria or whooping cough may also predispose some children to attacks of polio.

In a polio epidemic last year in Melbourne, Australia, a number of children who came down with the disease developed paralysis in the same limb in which they had received inoculations within the three months preceding the attack. The more recent the injection, and the younger the child, the more severe the polio reaction. A careful check ruled out the possibility that contamination of the hypodermic needle with polio virus was responsible. The Melbourne findings have been confirmed by independent investigations in Great Britain.

Investigators have taken pains to point out that only a small percentage of those inoculated against diphtheria contract polio, and that inoculation saves far more lives than it endangers. Nevertheless, *The Journal of the American Medical Association* concludes: "In view of available evidence, it might be advisable to postpone diphtheria and/or pertussis [whooping cough] immunization during a poliomyelitis epidemic. Postponement of such immunizations for a few months, until the end of the epidemic, would appear particularly discreet when during these few months the children are not likely to be exposed to diphtheria or pertussis, *i.e.*, when these diseases are not unduly prevalent in the community at the same time as the poliomyelitis epidemic."

Natural Tritium

TRITIUM, the radioactive isotope of hydrogen with mass 3, is so short-lived (half-life: 12 years) that physicists have supposed it would never be found in nature. Now Willard F. Libby of the University of Chicago and Aristid V. Grosse of Temple University have unmistakably identified traces of it in concentrated samples of heavy water. According to their measurements there is only one atom of tritium to every million million million atoms of ordinary hydrogen in natural water, which makes it the rarest natural isotope found so far. It is of course much too rare to be extracted in any useful amount, for hydrogen bombs or any other purpose.

Tritium is produced in nature by the action of free neutrons liberated by cosmic rays in the upper atmosphere. Its source is nitrogen 14. Usually when nitrogen 14 captures a neutron, it is converted to radioactive carbon 14, but occasionally it splits into three helium 4 nuclei and one tritium nucleus, or into one carbon 12 and one tritium nucleus. The tritium formed quickly encounters a molecule of water vapor and displaces one of the ordinary hydrogen atoms. Eventually it is precipitated to earth.

Fifteen years ago, before it was known that tritium was radioactive, Hugh S. Taylor and his associates at Princeton University believed they had isolated some of the isotope from heavy water by a mass separation method. The great British physicist Lord Rutherford, scoffing at this result, gave Taylor a sample of heavy water and defied him to find tritium in it. Taylor could not, but with the sensitive new techniques they have developed Libby and Grosse succeeded in detecting tritium in this very sample.

Natural tritium is not likely to become such a useful research tool as natural carbon 14, which was found by Libby and Grosse in 1947 and has become an accurate means of determining the age of archaeological materials. But it may be helpful in oceanic research. If, as is suspected, tritium is more abundant at the poles than at the Equator, because of the focusing of cosmic radiation by the earth's magnetic field, it could be used to differentiate equatorial from polar waters, and thus to trace ocean currents.

Antiquity of the Indians

WHEN the Great Pyramids were being built on the Nile 5,000 years ago, the area that is now New York State had already been settled by American Indians. There were human beings in Mexico at least 7,000 years ago, in Oregon and Nevada 10,000 years ago. These discoveries, which lengthen previous estimates of the antiquity of these peoples by thousands of years, were reported by Willard F. Libby and James R. Arnold of the University of Chicago at the recent meeting of the National Academy of Sciences in Schenectady, N. Y.

Libby and Arnold made their determinations by the radiocarbon technique (*see above*). They were given charcoal from Indian cremation pits in New York, sandals from a cave in Oregon, carvings from Mexico. Knowing the rate of decay of radioactive carbon 14, which all living plants absorb from the air, they were able to measure the radioactivity of these materials as compared with that of living plants, and arrive at an estimate of their age.

For the Mentally Ill

"THE allegedly mentally ill person may be arrested by a sheriff with a warrant, charged with insanity by a judge, detained in a jail pending the hearing, tried in open court before a jury, remanded to jail pending a vacancy in a mental hospital, and finally transported to the hospital by a sheriff." This description by the *Yale Law Journal* of the handling of the mentally ill applies, in part or in whole, to most of the 48 states.

The Federal Security Agency believes that this is a poor way to handle mentally sick people. It has submitted to all the states a model law covering procedures for hospitalizing the mentally ill.

The model law, said FSA Administrator Oscar R. Ewing, is designed to assure mentally ill: "first, maximum opportunity for prompt medical care; second, pro-

THE PERKIN-ELMER INSTRUMENT DIGEST

A condensation of some of the articles appearing in the Fall 1950 issue of THE PERKIN-ELMER *INSTRUMENT NEWS*, a quarterly publication of The Perkin-Elmer Corporation, manufacturers of scientific instruments—Infrared Spectrometers, Tiselius Electrophoresis Apparatus, Universal Monochromator, Flame Photometers, Continuous Infrared Analyzer, Low-Level Amplifiers—as well as Astronomical Equipment, Replica Gratings, Thermocouples, Photographic Lenses, Crystal Optics, and Special Instruments for the Government. **For further information, write The Perkin-Elmer Corp., Glenbrook, Conn.**

Glenbrook, Conn. November, 1950 Vol. 2, No. 3

NEW OPTICAL METHODS EXTEND MICROSCOPE RANGE

Three principal systems of instrumentation have been developed for extending the spectral range of the microscope through the infrared, visible, ultraviolet and vacuum ultraviolet regions.

The importance of such systems lies in the small order of magnitude of the analytic sample. Minute quantities (10^{-7} to 10^{-8} gm) of scarce organics have yielded infrared spectra; ultraviolet records have been obtained on even smaller samples.

The first system employs a reflecting microscope illuminated with an achromatic monochromator, plus radiation detector, or image converter.

In the second system, the object image at the entrance slit of a spectrograph is seen on film as a series of discrete or overlapping monochromatic images.

System three employs illuminator and reflecting microscope followed by monochromator and radiation detector. The image is relayed to the entrance slit of the monochromator in a single-beam-recording infrared spectrometer.

The above is a digest of a complete article by R. C. Mellors of The Sloan-Kettering Institute for Cancer Research.

You can receive the complete publication from which these articles were digested.

Write The Perkin-Elmer Corporation, 535 Hope St., Glenbrook, Conn., and you will receive regularly THE PERKIN-ELMER INSTRUMENT NEWS—an 8-page quarterly devoted to news of the latest advances in electro-optical instrumentation. Here are some of the features of the current issue:

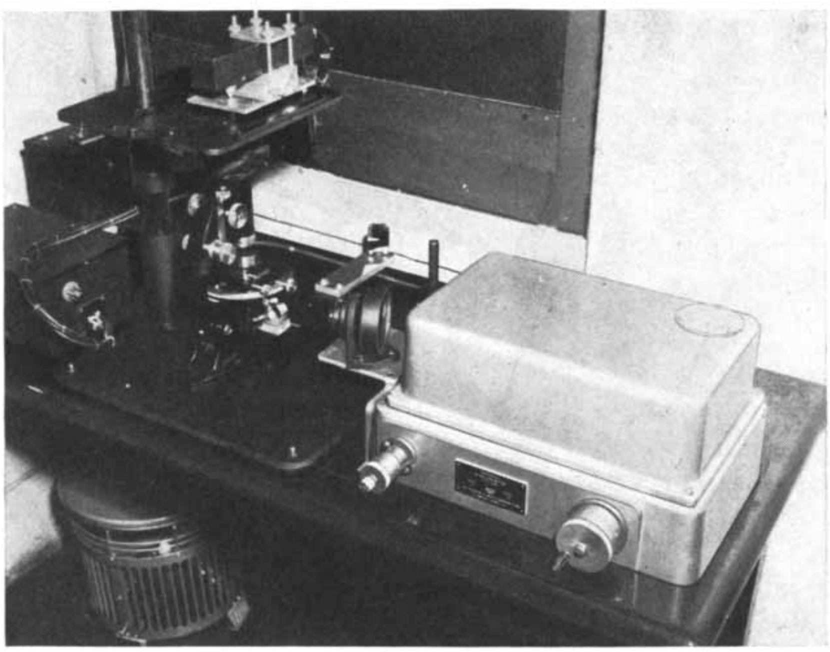
ASPECTS OF ACTH & CORTISONE TREATMENT
Flame Photometer Aids Hormone Research

PERFORMANCE OF THE MODEL 12-C
Data on Spectrometer Design Changes

U. OF MICHIGAN NEW SCHMIDT TELESCOPE
To Study Milky Way Structure

AMPLIFIER ADAPTED FOR VARIETY OF DETECTORS

The Perkin-Elmer Model 81 Amplifier, originally developed for amplifying the output of thermocouples in the Perkin-Elmer Model 12-C Spectrometer, has been adapted for use with other detectors. With relatively simple external circuits, the amplifier will work satisfactorily with lead sulfide cells, phototubes and photomultiplier tubes. Observed signal to noise ratios are close to calculated theoretical imposed values.



Perkin-Elmer Model 83 Monochromator used as an ultraviolet illuminator for microphotography at Sloan-Kettering Institute for Cancer Research, New York.

INTERNATIONAL CRISIS AGAIN CHALLENGES INSTRUMENT-MAKERS

Grave responsibilities once again face American instrument-makers as a result of the Korean crisis and its impact on U.S. defense plans, writes Walter J. Murphy, American Chemical Society Editor, in the Fall 1950 issue of INSTRUMENT NEWS.

Instrument manufacturers achieved "a distinguished but little appreciated record" during World War II and, if plans are made now, they can readily duplicate and exceed their former records.

Dr. Murphy urges that instrument-makers take immediate steps for greater expansion to meet the increasing demand for instrumentation in all types of industry. Rapid expansion of the atomic sciences and growth of special atomic techniques call for a new instrument line designed specifically for an atomic age.

Automatic recording and control instruments can help industry overcome its shortage of trained technical personnel. The development of devices aimed toward such an end should be of primary concern to American instrument-makers, concludes Dr. Murphy.

A digest of an article by Walter J. Murphy in the FALL 1950 INSTRUMENT NEWS.

ADRENAL HORMONES MENTAL DISEASE FACTOR

ACTH and adrenal cortex hormones are important factors in schizophrenia, according to recently published investigations by Dr. Gregory Pincus and Dr. Hudson Hoagland of the Worcester Foundation for Experimental Biology. Perhaps these findings will pave the path for a national chemotherapy of this prevalent illness.

Fatigue and stress studies conducted during World War II showed that increased output of adrenal cortex hormones was an important part of the normal reaction to stress. This stress-response mechanism is deficient in schizophrenia. Although their output of cortical hormones as a whole is normal, stress situations in schizophrenics fail to bring about the expected enhanced output.

Injections of ACTH result in some improvement but cortical hormone output is still below normal. Electric shock treatments similarly stimulate output of adrenal cortex hormones. Prognosis of improvement with electric shock therapy can be made by studying prior reactions of patients to injections of ACTH.

tection against emotionally harmful or degrading treatment; and third, protection against wrongful confinement and deprivation of rights."

The model law would:

1. Make voluntary hospitalization for mental illness more readily available.

2. Place emphasis on medical judgment in admission procedures.

3. Stop the practice of handling the mentally ill like ordinary criminals; instead of being tried in court before a jury or held in jail pending a hospital vacancy, the patient would be examined and handled in a manner "not likely to have a harmful effect" on his mental health.

4. Permit a mentally ill person to be committed to a hospital temporarily in an emergency without a court hearing.

5. Protect the personal rights of the hospitalized patient, particularly to allow him to have visitors or communicate with people outside the hospital and to prohibit his being placed under mechanical restraints except when medically required and on specific written order of the hospital head.

Funerals

AMERICANS spend $700 million a year for funerals—more than they do as patients in hospitals. William M. Kephart of the University of Pennsylvania has made a survey of funeral practices and published his findings in *American Sociological Review*. He concentrated on Philadelphia.

Kephart finds that class distinctions which separate rich Philadelphians from poor Philadelphians persist into the grave. Among the poor, friends, relatives and neighbors are invited to "view the body"; the upper class restrict this privilege to members of the family, and make no comments on the appearance of the deceased. One social registerite out of 10, he reports, has no viewing at all.

On the way to the cemetery, the poor man is accompanied by all who attended the funeral services. Among the upper class, most of them just go home. On the poor man's grave go wreaths, pillows of flowers and "bleeding hearts"; the rich prefer simple baskets and sprays.

Although the rich are no longer so addicted to mausoleums as in the gaudier past, they still find their distinctive resting place in a plot on high ground, in a cemetery with "restricted clientele." Cremation, a spreading upper-class custom, may enable them to economize on the casket and on cemetery space. The poorest poor, on the other hand, arrive at last in potter's field, where they are buried without flowers, clothes or names in long trenches with only a number on a wooden paddle. If their remains are unclaimed, they share a final distinction, or extinction, with the rich: their bodies are dug up and burned to make room for new tenants.

What GENERAL ELECTRIC People Are Saying

G. B. WARREN

Apparatus Department

GAS TURBINES: For the first time in industrial history gas turbines, a new type of power plant adaptable to land, rail, or marine use, have gone into full-scale production. Orders for more than 20 of the new power plants have already been received by General Electric, for use in power generation and for gas-pipeline pumping stations.

While it is still too early to predict the full potentials of this new power plant, we foresee the increased use of direct fuel-burning power plants like the gas turbine to help meet the country's expanding needs for electric power. Two units, in particular, with ratings of 3500 and 5000 kilowatts, have unique advantages:

(1) They are comparatively small and compact, (2) they can be started quickly and require minimum attendance, (3) the smaller unit can be made portable and therefore is well suited for emergency use, (4) both types can be moved easily from the original location to meet changing power needs, (5) they need little or no water, and therefore have special potentialities, particularly in the Southwest, where low-cost gas is available and water is scarce.

Three General Electric gas turbines are already in use. Of these, the first unit to be used in this country for electric power generation has been in regular service more than a year for the Oklahoma Gas & Electric Company in Oklahoma City. A second was put into service last April by a New England power company. Another powers a developmental locomotive built at the Company's Erie Works and now undergoing tests in regular service by the Union Pacific Railroad.

Schenectady, New York
August 15, 1950

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BERNARD VONNEGUT

Research Laboratory

RAINMAKING: Legislators in the future may well face many problems connected with cloud seeding. Laws may be necessary to prohibit and police seeding operations contrary to the best interests of the public. Licensing of seeding operators and permits for seeding may be desirable in the future.

The extent to which new laws may be necessary to control cloud seeding depends largely on to what extent these groups now conducting these operations meet their responsibility to the public. Those scientists engaged in research in this field must keep the public and their legislators informed and must exercise every caution to be sure that at no time do they run the risk of aiding a few people at the expense of many.

New England Assn. of Chemistry Teachers; Storrs, Connecticut
August 25, 1950

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C. L. SCHUCK

Apparatus Department

POWER FUSES: A need exists for low-voltage fuses having much higher short-circuit interrupting capacity than that of cartridge fuses commonly used.

Cartridge fuses for circuits of 600 volts and less have been used in the United States for many years, principally in low-burden branch circuits where available fault currents were relatively low. They are produced by numerous manufacturers, and practically all makes satisfy the National Electrical Code through compliance with the "Standard for Fuses" of Underwriters' Laboratories, Inc.

In the matter of short-circuit interrupting ability, the "Standard for Fuses" includes a d-c test with 10,000 amp available, the rate of rise of the U. L. New York City testing circuit being approximately 2,000,000 amp per sec. While most applications of cartridge fuses are on a-c circuits, this d-c short-circuit test is, even today, the only criterion in use for determining the acceptability of fuses for application on either a-c or d-c circuits.

However, no direct inference is valid concerning the a-c short-circuit interrupting ability of a fuse which has passed this particular test . . . Conversely, the a-c short-circuit interrupting ability demonstrated for a fuse is not a reliable indication of its ability to interrupt a d-c short circuit . . .

The need . . . now can be satisfied with specially designed fuses of the current-limiting type. A line of such fuses has been developed, satisfying in every respect the "Standard for Fuses" of the Underwriters' Laboratories, Inc. . . .

General Electric Review
July, 1950

★

J. P. DITCHMAN

Lamp Department

PLANT LIGHT: The farmer may now control conditions favorable to the growth of plants and animals. Among the farmer's latest implements and agents are new man-made "suns" designed to produce visible radiation, ultraviolet, and infrared radiant energy. These artificial suns may be teamed up with natural daylight or may be used entirely independent of natural conditions. Thus plants may be grown successfully underground in a completely artificial environment of light, humidity, temperature, and air . . . Our world may in the future depend very much upon how well we learn to apply radiant energy to produce more and better food and to reduce the life processes which oppose our own.

Illuminating Engineering Society
Pasadena, California
August 21, 1950

You can put your confidence in—

GENERAL ELECTRIC

PARTNER OF THE GENES

An account of the experimental evidence indicating that the factors controlling heredity lie not only in the nucleus of the cell but also in the rest of it

by T. M. Sonneborn

THIRTY years ago the age-old question of how living things pass on their biological inheritance to their offspring was widely believed to have been solved. Biologists had located the material basis of heredity in the nucleus of the cell. They had shown that heredity could be traced to invisible factors in the nucleus called genes. Further, the elegant observations and experiments of the Columbia University school of biologists led by Thomas Hunt Morgan and Edmund Beecher Wilson had proved that these genes were localized in the visible chromosomes of the nucleus. Apparently all the phenomena and rules of heredity could be explained by the way these chromosomes with their genes were transmitted from parents to offspring.

In this scheme of things the cytoplasm—all the surrounding material of the cell outside the nucleus—was just a silent partner. It was viewed as a highway across which supplies from the outer world traveled to the genes in the nucleus and as a workshop in which the products of the genes' activity interacted to yield the stuff that constitutes the organism. Thus the cytoplasm was not considered to play any direct part in controlling heredity. The sole physical basis of heredity was believed to be the nucleus.

Now an accumulation of old and new evidence, particularly during the past decade, suggests that the role of the cytoplasm was greatly underestimated. Claims have been made that the cytoplasm, like the nucleus, houses genelike factors or particles that take a hand in shaping an organism's heredity. Some biologists have gone so far as to contend that the cytoplasm controls all the basic traits of the organism and the nuclear genes determine only the relatively trivial ones. Although most professional students of heredity reject this extreme view, the weight of the present evidence does indicate that the cytoplasm is an active partner with the nucleus in the control of inheritance.

A Test for Inheritance

How can one find out whether a given hereditary trait is determined by nuclear genes or by the cytoplasm? Fortunately a comparatively simple method is available. It is based on an important difference in the cytoplasmic contributions of the father and the mother to the fertilized egg from which the offspring develops. The fertilized egg represents the fusion of a mother cell and a father cell—the egg and the sperm. The nuclei of the egg and sperm are fully equivalent: each has exactly the same number and types of chromosomes (with the single exception of the sex chromosome), so the offspring receives equal contributions of nuclear material from both parents. But the egg has a good deal of cytoplasm, while the sperm has very little. Thus the new individual derives cytoplasm almost entirely from the mother. Hence if a given trait is always or almost always inherited from the mother (and is known to have no connection with the sex chromosomes), there is at least a strong suspicion that the trait is transmitted through the cytoplasm. On the other hand, if it is inherited with equal readiness from either the mother or father, it can be assumed to be transmitted by nuclear genes.

The method of testing this is reciprocal crossing, a technique first used by the Moravian monk Gregor Mendel, the founder of genetics, in his historic experiments with garden peas. Suppose we have two pure strains of peas, one bearing white flowers, the other red flowers. We mate a red-flowered female with a white-flowered male and a white-flowered female with a red-flowered male; this is a pair of reciprocal crosses. If flower color were inherited through the cytoplasm, we would expect to get different results from the two matings: the first should produce red-flowered offspring and the second white-flowered. Actually both matings yield the same result: the offspring are always red-flowered. This shows that flower color is inherited as readily from the male as from the female. Consequently the presumption is that flower color is controlled by the nucleus, and detailed analysis has proved that it is determined by a nuclear gene.

Experiments on a great variety of traits in both plants and animals, performed by thousands of investigators and students, have shown that reciprocal crosses nearly always yield identical results. Yet there are many reports to the contrary. For example, the mating of a mare to a jackass produces a hybrid called a mule, while the offspring of the reciprocal cross, between a stallion and an ass, is often claimed to have somewhat different traits from a mule; to distinguish it from that animal it is called a hinny.

Before concluding that such cases indicate cytoplasmic inheritance, however, we must rule out other possible explanations. In the first place, we must be sure that the outcome of a given experiment is a valid and regular result. In the particular case of the mule and hinny, it has not been established that they are invariably different. In the second place, even when real differences are demonstrated, it is still possible that nuclear genes, rather than the cytoplasm, may be responsible for them.

One possibility, already mentioned, is that the traits in question are controlled by genes in the sex chromosomes, which differ in the male and female. One can readily determine, however, whether a trait is controlled by genes in these chromosomes and thus exclude the interpretation of cytoplasmic inheritance. Another possibility is that a trait under the direct control of the cytoplasm of the egg is actually controlled indirectly by nuclear genes acting on the cytoplasm. But such cases, of which a number are known, also can be distinguished from true cytoplasmic inheritance by following the offspring carefully for several generations after the original genes have been eliminated. A third possibility is that the egg cytoplasm affects heredity by rejecting some or all of the chromosomes brought in by the sperm but does not itself possess genetic properties. It has long been known that such chromosome elimination occurs when certain plants and marine animals are mated with other species to produce hybrids. The fourth and most perplexing possibility that must be taken into account in reciprocal-cross experiments is that some parasitic organism in the cytoplasm, not the cytoplasm itself, may influence heredity.

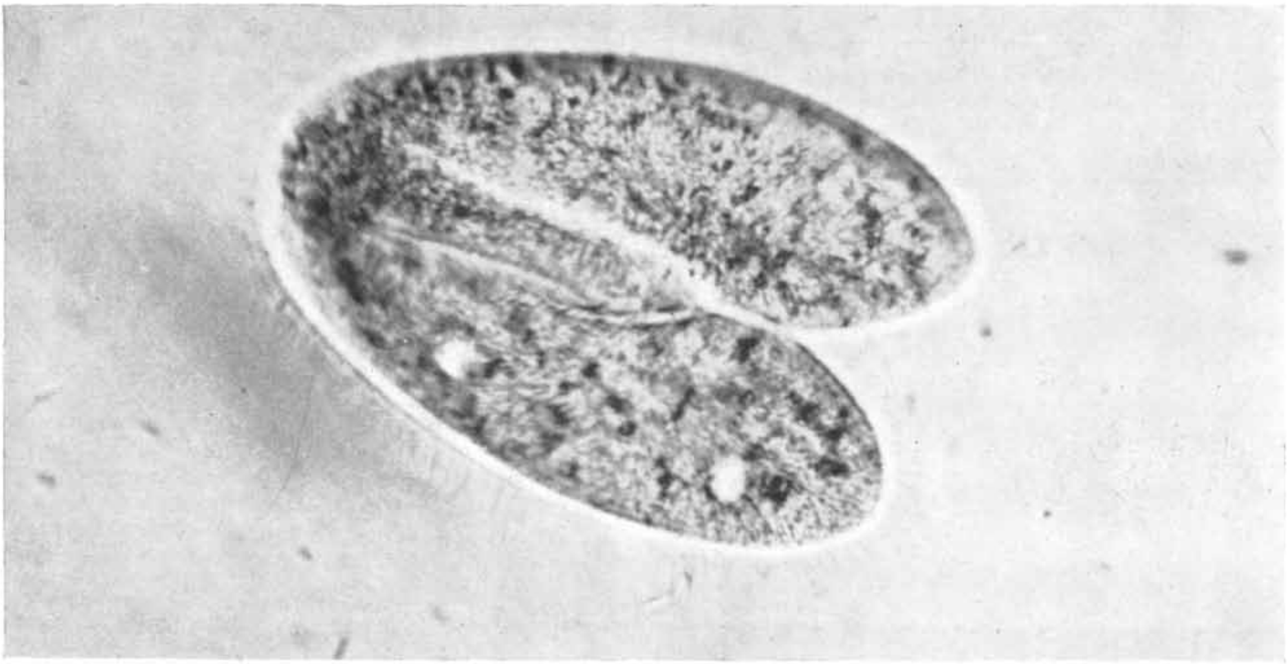
The German zoologist Paul Buchner has written a fascinating volume on parasites that dwell in cells: in a great variety of plant and animal organisms the cytoplasm has been found to be inhabited by one-celled algae, bacteria and various other tiny fungi and animals. The cytoplasm may also harbor the still tinier Rickettsiae and viruses. Now a microorganism that infects and multiplies in the cytoplasm will pass along with the cytoplasm to the descendant cells. Since the egg is well provided with cytoplasm, while the sperm is not, cytoplasmic parasites may be transmitted regularly from the mother, rarely or never from the father. If these parasites affect some traits of the organism, such traits will not be "inherited" equally in reciprocal crosses, and the result will appear to be a case of cytoplasmic inheritance. Most students of heredity maintain that if a trait is due to the presence of a virus, Rickettsia or other parasitic organism, its transmission cannot be considered an example of inheritance.

Yet here we enter a realm where the words and definitions we use may confuse our thinking. The concept of a virus, for example, is by no means sharp and clear, and it is very difficult, if not impossible, to make a satisfactory distinction between a regularly transmitted, non-pathological virus and a normal genetic particle. In the cytoplasm, as we shall see, there are genetic particles that are indistinguishable in biological properties from viruses; they are on a borderland where the study of heredity merges into parasitology and *vice versa*.

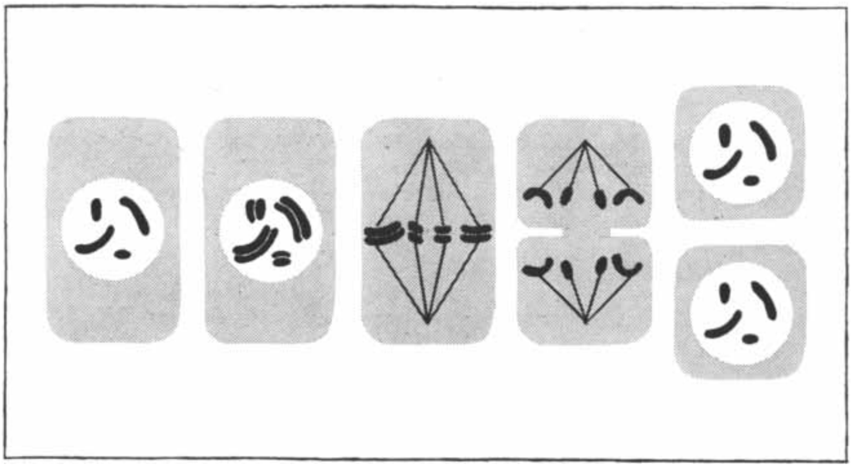
Because of these various pitfalls, and others suspected to exist, students of heredity are apt to be extremely wary of any claim of evidence for cytoplasmic inheritance. By now, however, there is a considerable number of extensively analyzed and well-substantiated cases of such inheritance.

Non-Mendelian Inheritance

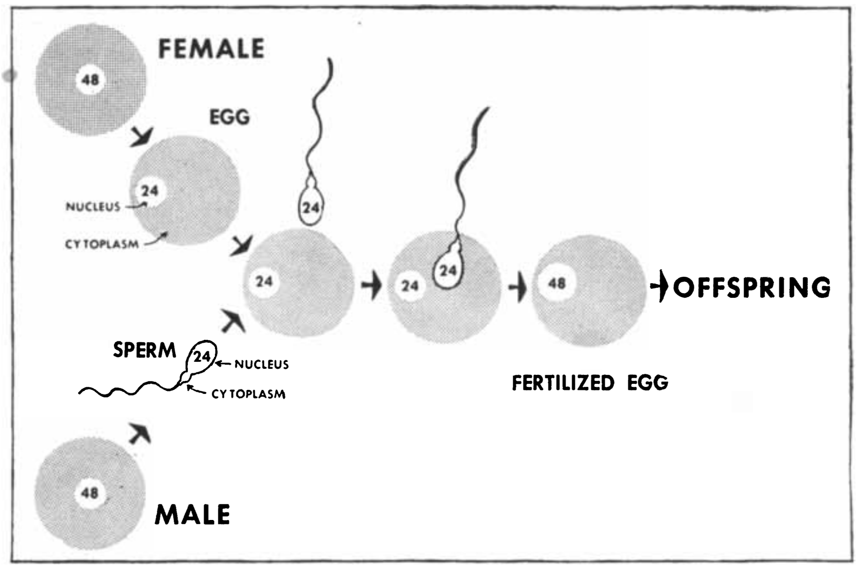
The interest in this subject is largely due to the work and influence of one man, Carl Correns of Berlin, one of the three scientists who in 1900 rediscovered Mendel's unnoticed work and confirmed the Mendelian laws of heredity. Correns was alert from the first to the possibility that not all heredity conformed to the Mendelian pattern of control by nuclear genes. For 27 years he collected apparent exceptions to Mendelian heredity, verifying many of them by his own experiments. In 1927 at the International Congress of Genetics in Berlin he presented his survey under the title of "Non-Mendelian Inheritance." Later Correns greatly expanded this survey, and it was completed after his death by his devoted pupil Fritz von Wettstein. This monumental and prophetic work was the starting point for subsequent investigations of cytoplasmic heredity. Today there is



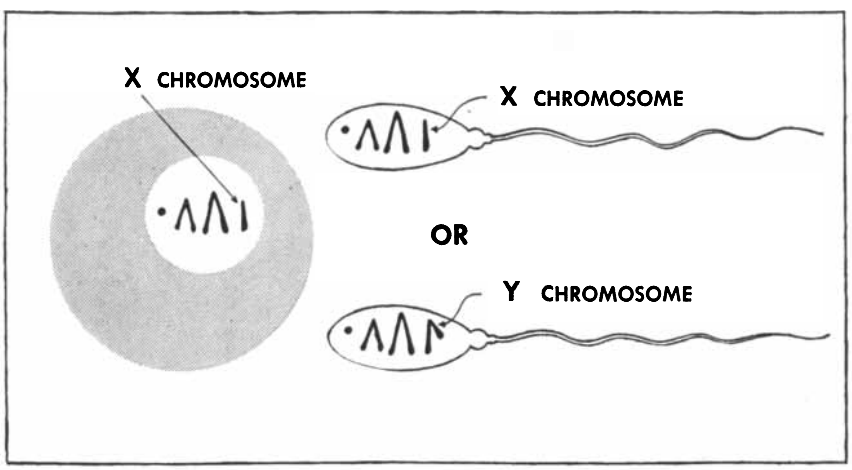
PARAMECIUM is the experimental organism of the studies undertaken by the author and his colleagues. Here two paramecia are in conjugation. Ordinarily this juncture involves exchanging nuclei but not cytoplasm.



CELL DIVISION is shown in schematic drawings of five stages. In first stage chromosomes appear in the nucleus. In second they are duplicated. In third and fourth they are separated. In fifth two entirely new cells are formed.



SEXUAL REPRODUCTION begins with cells containing characteristic number of chromosomes, here the 48 of man. In egg and sperm cells this number is halved. In the fertilized egg it is restored to original number.



SEX IS DETERMINED by X and Y chromosomes. One chromosome in egg of Drosophila is an X; one in sperm is either X or Y. If sperm fertilizing egg is X-bearing, the offspring is female; if it is Y-bearing, the offspring is male.

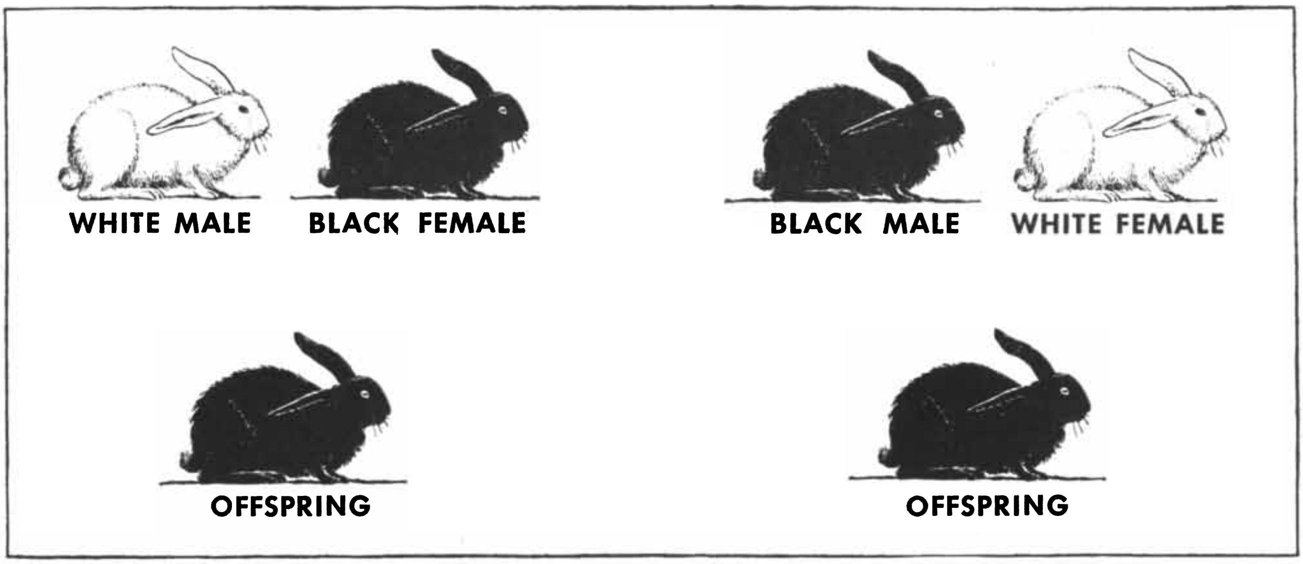
a large and impressive literature on the role of cytoplasm in inheritance. Correns' work was confined to plants; his successors have extended it to animals.

The example of cytoplasmic inheritance that was most thoroughly analyzed by Correns and other investigators concerns a familiar peculiarity of leaf coloring. Everyone has seen occasional plant leaves which are not uniformly deep green but have streaks of light green and yellow or white. This variegation is hereditary and is usually controlled by nuclear genes, but it has been shown beyond doubt that in many cases the trait is under the control of the cytoplasm. One indication of this is that often the trait appears in the offspring only if the seeds happen to be set on a variegated part of the mother plant.

Another well-documented case of cytoplasmic inheritance is male sterility in plants. Male sterility results from the degeneration of the sperm-forming pollen cells in the male structures. The botanical geneticist Marcus Rhoades, now at the University of Illinois, carried out a particularly thorough study of this condition in corn. He was able by breeding experiments to replace each chromosome of a male-sterile strain of corn with the corresponding chromosome from a male-fertile strain. Still the male sterility persisted. Strange as it may seem, reciprocal crosses can be carried out with such "sterile" plants, because pollen grains capable of fertilizing the egg are occasionally formed on the plants. Reciprocal crosses showed that the characteristic of male sterility was regularly transmitted through the egg, never through the pollen. Since control by nuclear genes was excluded, it was clear that in this case the trait must be determined by something in the cytoplasm.

The most important current study of cytoplasmic inheritance in higher plants is being carried out on the willow herb Epilobium. This investigation, led by the German botanical geneticists Ernst Lehman and Peter Michaelis, has been in progress for over 30 years and is probably the most extensive ever carried out on cytoplasmic inheritance. Reciprocal crosses between certain species of Epilobium, and even between geographical races of the plant, yield offspring with different characteristics. Very extensive further breeding experiments show that at least some of the reciprocal differences continue to be transmitted only from the mother for many generations after the chromosomes of the maternal strain have apparently been largely replaced by chromosomes of the paternal strain by breeding.

The plant studies clearly demonstrate, then, that the cytoplasm must play a part in determining inheritance. But they also reveal two limitations on its role. First, the traits in which cytoplasmic inheritance is involved are commonly con-



RECIPROCAL CROSSES are a method of testing whether a trait of an organism is controlled by nuclear genes or cytoplasm. Here a white male rabbit is crossed with a black female and *vice versa*. The offspring are black. Since there is little cytoplasm in sperm cells, this indicates that coat color is controlled by nuclear genes.

sidered to be expressions of "inhibition" or interference with normal development; they are reduction in fertility, reduced pigmentation, reduced size of leaves, flowers and the whole plant. Second, the inhibitions result only when certain cytoplasms are combined with certain nuclear genes. Sometimes the cytoplasm is decisive; sometimes the genes are. Michaelis and others have therefore concluded that normal development occurs only through the harmonious joint action of both nuclear and cytoplasmic genetic materials.

Paramecium and Drosophila

The first indications of cytoplasmic inheritance in animals came almost simultaneously from separate studies on two different laboratory favorites: the one-celled Paramecium and the fruit fly Drosophila. The chief investigators of this phenomenon in Drosophila have been Philippe L'Héritier and his collaborators in Paris. They have studied the inheritance of sensitivity to carbon dioxide in a certain Drosophila strain, a strain which is unusual in that it is killed, rather than merely anesthetized, by moderate doses of this gas. They found that all the offspring from the mating of a sensitive female to a resistant male are sensitive; whereas the offspring from the reciprocal cross are usually, but not always, resistant. That the sensitive and resistant flies do not differ in any nuclear genes affecting these traits was proved by breeding experiments in which all of the chromosomes of the sensitive stock were replaced by corresponding chromosomes of the resistant stock. The difference between the two kinds of flies must therefore be due to something in the cytoplasm. The sporadic exceptions in which sensitivity is inherited from the male may be accounted for by transmission of the trait through the small quantity of cytoplasm carried by the sperm.

The work on cytoplasmic inheritance in Paramecium has been carried out mainly by my co-workers and myself. This common denizen of ponds and streams is an unusually favorable material for the study of cytoplasmic inheritance. Curiously enough, it takes only one mating to achieve a pair of reciprocal crosses! The reason is that Paramecium is hermaphroditic, each mate of a pair fertilizing the other. During mating a nucleus comparable to a sperm passes from each mate into the other and fuses there with a nucleus comparable to that of an egg. The nuclear exchange is so arranged that no matter how different the two mates' sets of genes were before mating, they become identical. On the other hand, ordinarily little or no cytoplasm is exchanged; if the mates had different cytoplasms before mating, they still differ in cytoplasm afterward. After fertilization, the two mates separate and each produces a culture of progeny by repeated cell divisions. Because the nuclear genes in the two sets of progeny are identical, any trait controlled by them should be the same in both cultures, but any traits controlled by the cytoplasm should remain different in the two cultures.

We have studied the inheritance of three kinds of traits in Paramecium. In all three respects the two mates of a pair do in fact produce unlike cultures. One of these traits is sex, or mating type. Although the two individuals that mate are functionally hermaphroditic, they differ physiologically: mating can occur only between physiologically diverse cells, that is, between different mating types. In some species of Paramecium each of the mates usually gives rise to a culture of the same mating type as itself.

The second trait investigated is the capacity of some strains of Paramecium to produce a poison, called "paramecin," that kills paramecia of certain other strains. The poison-producing strains are known as "killers," the others as "sensitives." These two kinds of strains can be mated to each other because sensitives are resistant during mating. Reciprocal crosses again give different results: the killer mate gives rise to a culture of killers, the sensitive to a culture of sensitives.

The third trait has to do with certain complex chemical substances, known as antigens, possessed by paramecia. The antigens we have studied are located on the hairlike cilia that the paramecia use for swimming. When a specific antiserum, obtained from the blood of rabbits into which part of a culture of paramecia has been injected, is applied to other paramecia of the same culture, it combines with the antigens, causes the cilia to stick together and thereby paralyzes the animals. We found that a single paramecium gave rise to eight diverse antigenic types of paramecia, readily identifiable by their reactions to different kinds of antiserum. Now when two paramecia of different antigenic types mate, each mate produces a culture of the same type as itself. The offspring remain as diverse as the parents, in agreement with the expected consequences of cytoplasmic control.

Although these three experiments are not in themselves sufficient evidence to prove cytoplasmic inheritance, two further facts clinch the matter. First, it is possible to bring about an exchange of cytoplasm between paramecia. When they exchange cytoplasm, there is no difference in their offspring; both mates produce cultures with identical traits. The second decisive fact is that it can be proved that the genes in the differing offspring of a pair of mates are actually identical. When later generations are bred from them, no hidden or delayed gene effects appear. The differences between the two lines persist, showing that their cytoplasmically controlled traits are truly hereditary.

It must not be supposed, however, that Paramecium's characteristics are mainly or exclusively controlled by the cytoplasm. Paramecium also has a genetic system like other organisms; its traits are controlled by nuclear genes as well as by cytoplasm. Its nuclear and cytoplasmic inheritance are not two mutually exclusive phenomena but go hand in hand. The studies on Paramecium support the fundamental conclusion, drawn by Michaelis from his Epilobium studies, that the nuclear genes and the cytoplasm are partners in the control of heredity.

Yeast

Work on cytoplasmic inheritance has also been done in the microorganism yeast. In 1945 Carl and Gertrude Lindegren and Sol Spiegelman, all then at Washington University in St. Louis, reported the first of a series of studies that startled students of heredity. They said they had found that a certain enzyme or enzyme precursor could be maintained and multiplied in cytoplasm *even in the absence of a nuclear gene necessary for its initial formation.* The enzyme, melibiozymase, could arise only when this particular gene was present in the yeast. Once formed, however, it could go on reproducing independently, so long as it was supplied with the sugar melibiose. Thus the enzyme or its precursor behaved, according to their report, like a gene in the cytoplasm.

The Lindegren-Spiegelman results and their interpretation of them were much publicized and widely discussed, but they have not been confirmed. The Danish geneticist O. Winge, who has also made extensive studies of the inheritance of enzymatic capacities in yeast, maintains that the observations of the Lindegrens and Spiegelman can be explained without resort to cytoplasmic inheritance. Moreover, other investigators and they themselves have failed in attempts to repeat the original experiment. Spiegelman later brought forth an independent line of supporting evidence based on the kinetics of enzyme formation in the yeast cell. Until the matter has been clarified, however, it would seem wise to refrain from speculations as to the significance of this work in relation to cytoplasmic inheritance.

Meanwhile a new and important center of research on heredity in yeast has appeared on the scene. The leader of the new group is the colorful and able geneticist Boris Ephrussi, who was born in Moscow and works at the Institute of Physico-Chemical Biology in Paris, where he now heads a remarkable laboratory.

When, a few years ago, Ephrussi turned his talents to the turbulent field of yeast heredity, he soon discovered that he could change his yeast cultures radically by exposing the cells to the action of acriflavine, a dye that has an affinity for that most important component of genetic materials, nucleic acid. At first he noticed only that the altered cells produced dwarf colonies. But further study showed that this dwarf trait was a reflection of deep-seated physiological and biochemical changes. The organisms had apparently lost some of their respiratory enzymes. In ordinary organisms this would be fatal, but not so in yeast. It has two enzymatic systems for respiration: one utilizing free oxygen, the other managing without free oxygen. Consequently it can survive and multiply when one of its respiratory systems fails to function.

Eventually Ephrussi and his collaborators demonstrated by breeding analysis that this hereditary alteration in yeast is under the control of the cytoplasm. Thus they proved that cytoplasmic inheritance can affect a very fundamental trait. Recently, however, they have also found that the very same change can be controlled by a gene! At a meeting of the Genetics Society of America in Columbus in September, celebrating the 50th anniversary of the beginning of modern genetics, Ephrussi reported that he had found a strain of yeast in which the same enzymes are apparently lost as the result of mutation of a single nuclear gene. In other words, a change in either the cytoplasm or a nuclear gene can result in the loss of the fundamental respiratory enzymes—again a case in which the nuclear genes and the cytoplasm are partners in the control of heredity.

"Genes" in the Cytoplasm?

We have now reviewed the major evidences for cytoplasmic inheritance. It unquestionably occurs with some frequency in higher plants and in microorganisms. There is still a dearth of examples in higher animals, but a few have been found even there. In general the traits controlled by the cytoplasm are comparable in kind, in magnitude and in importance to those controlled by nuclear genes. They involve differences in color, size, shape, fertility, enzymes, antigens, sex organs, mating types and so on. Thus cytoplasmic inheritance is not only a fact, but one of the capital facts of biology.

These discoveries, however, are only a beginning. They bring the study of cytoplasmic inheritance to the stage in which nuclear genetics found itself when it was known only that the nucleus was a physical basis of heredity and the genes had not yet been identified. The next step in cytoplasmic "genetics" is to investigate what materials in the cytoplasm have genetic functions and how these materials are related to the known examples of cytoplasmic inheritance. About this relatively little is yet known. One of the major theories now being investigated is that the cytoplasm contains genetic materials or particles comparable to the genes and chromosomes of the nucleus.

What must be the nature of such particles? Certain general statements can be made about them. Like the genes, they must be able to duplicate themselves, so they can transmit their properties in perpetuity. Second, they must possess the property of mutability, so they can give rise to mutations ("false copies" of themselves) which persist and produce permanent alterations of an organism's traits. Indeed, the property of mutability is the most convincing evidence of self-duplication and genetic function; in the case of the chromosomes it was the demonstration of their mutability that clinched the conclusion that they were self-duplicating and therefore true heredity-controlling structures.

Chloroplasts

Now the cytoplasm is known to contain a number of visible, self-duplicating structures. The outstanding example is the chloroplasts of plants. These structures, often as large or larger than the nucleus, contain the green pigment chlorophyll and are the centers of photosynthesis, the process which utilizes energy from the sun in the formation of carbohydrates. In the lower green plants each cell usually has a small number of chloroplasts, sometimes only one, but the cell in higher plants as a rule has large numbers of them. The chloroplasts, which divide and are distributed to the daughter cells, though not with the same regularity and precision as chromosomes, are known to control certain inherited traits in plants.

The chloroplasts arise from smaller, colorless bodies known as leucoplasts. Normally the leucoplasts turn green as they develop into chloroplasts. But under certain conditions they fail to do so. Cells that contain only such defective plastids are white or yellow instead of green. This proved to be the explanation of at least some of the cytoplasmically inherited color variegations in leaves that Correns investigated.

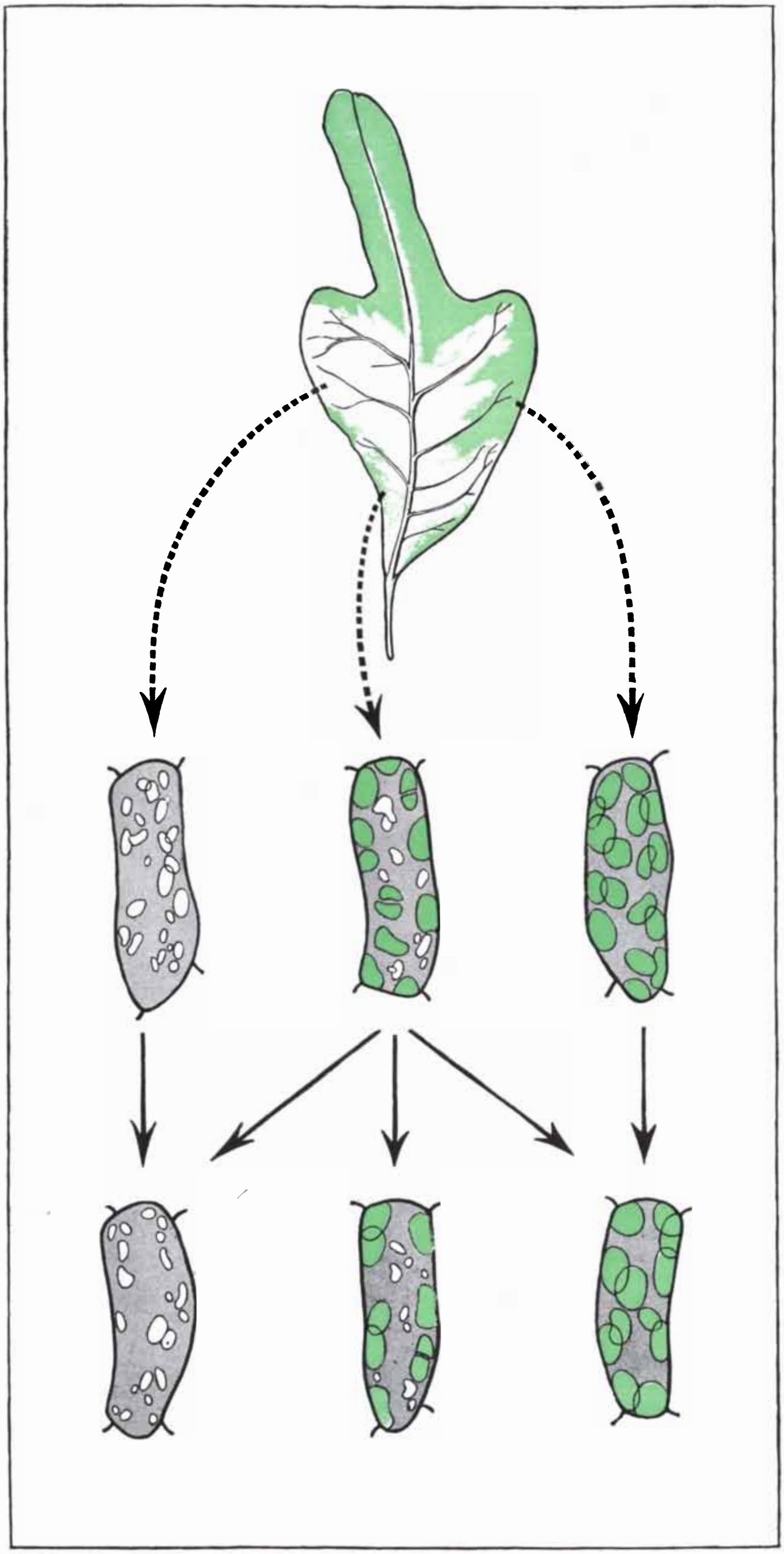
It seemed logical to suppose that the defect was due to a mutation of the chloroplasts, or plastids, but Correns rejected this interpretation. He pointed out that if plastid mutation had taken place, one would expect to find a mixture of normal and defective plastids in many cells; yet such mixed cells were rarely observed. Correns maintained that the defective development of the plastids must be caused by some deficiency or defect in the surrounding cytoplasm. Later investigators discovered a fact that supported his interpretation: a single nuclear gene mutation can result in the failure of all the plastids to develop chlorophyll. Evidently the gene controls some alteration in the cytoplasm which makes it impossible for the plastids to turn green.

Yet, as so often happens in biology, it turned out that more than one cause can produce the same effect. Other lines of evidence proved beyond doubt that plastids can mutate and that these mutations can lead to variegation. The German botanist Otto Renner demonstrated that different species of the evening primrose have genetically different plastids: in a hybrid produced by mating two different species of the plant, the plastids of one species are unable to become green in the presence of nuclear genes of the other species, and this defect continues through many generations. But these plastids regain the ability to produce green pigment when the original genes are restored by backbreeding. Since it must be assumed that the different plastids of the different species arose in the course of evolution from common ancestral plastids, the conclusion that plastid mutations have occurred seems warranted.

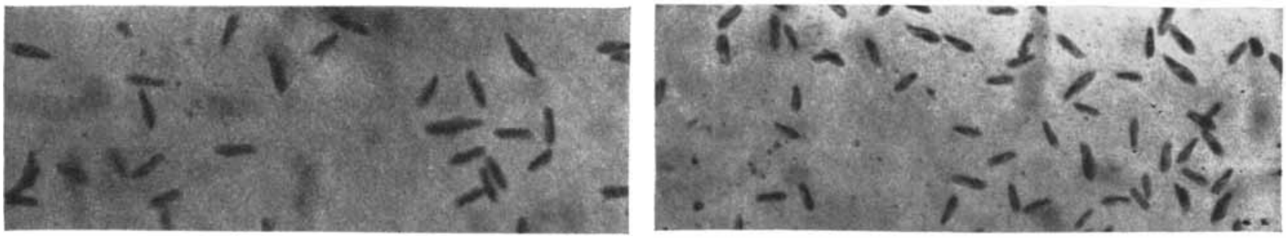
Another excellent evidence for chloroplast mutability is provided by the 1920 study of the European biologist C. van Wisselingh on the common pond bloom, Spirogyra. This plant consists of a single row of cells forming a fine filament. In a species in which each cell contains 10 chloroplasts, van Wisselingh found a filament in which each cell contained one colorless and nine normal plastids. There can be little doubt that one plastid had mutated and then reproduced true to its type.

Perhaps the clearest and most elegant example of plastid mutability has come from the studies of Marcus Rhoades on corn. He demonstrated that a particular gene, known as the iojap gene, brings about mutations of the plastids which render them unable to form chlorophyll. The plastids descended from them remain defective and reproduce true to this condition in a later generation after the iojap gene has been removed by appropriate matings. In other words, the change in the plastid is permanent and reproducible even in the absence of the nuclear gene that was responsible for its origin.

The plastid is the only visible, unquestionably normal cytoplasmic structure that has been shown beyond reasonable



VARIEGATED LEAF COLOR is due to the fact that some of the tiny green chloroplasts in the cells are colorless. Cells descended from those with mixed green and colorless chloroplasts are either green, colorless or mixed, indicating that chloroplast heredity is independent of genes.



MATING TYPE is one of the Paramecium traits observed by the author and his associates. In the first photomicrograph are paramecia of Type I; in the second are paramecia of Type II. None of the paramecia is in

doubt to be self-duplicating, mutable and the basis for cytoplasmic inheritance of a trait. There is partial and more or less suggestive evidence, however, for a number of others.

Other Particles

Foremost among these candidates are the mitochondria—the tiny bodies that are found in the cytoplasm of all sorts of cells. These structures often have the size and shape of bacteria. They have characteristic chemical properties, evidenced by their reactions to certain dyes, and they are known to be associated with complexes of enzymes. Mitochondria have often been observed to reproduce, dividing in two. The chief objection to ascribing genetic significance to them is that under certain conditions they seem to disappear from the cell or to spring up from no known source. This is not, however, a conclusive objection, for mitochondria can grow, and it is now known that they can exist in submicroscopic sizes. Hence their sudden appearance and disappearance may simply be due to changes in size that place them within the visible or the invisible range under the microscope. In this connection it is worth remembering that chromosomes seem to disappear and reappear regularly in each nuclear cycle, yet they unquestionably are genetically continuous.

H. G. DuBuy, Mark Woods and Mary D. Lackey of the National Cancer Institute have recently reported evidence that mitochondria are mutable. They claim to have found many mutations of the particles' enzymatic properties. If these findings are confirmed, the genetic function of the mitochondria will be established. The question is of surpassing importance to the whole conception of the extent and nature of cytoplasmic genetic particles.

Several other visible cytoplasmic structures are known to possess the ability to duplicate themselves. These include the centriole, the blepharoplast and the kinetosome. The centriole is a small granule near the nucleus which duplicates itself at each nuclear division, one product passing to each daughter cell. It plays a role in forming the spindle on which the chromosomes orient and move during nuclear division. The centriole is chemically and functionally related to a structure that forms a normal part of every chromosome—the centromere.

The blepharoplast is a structure that occurs at the base of the whiplike flagellum in certain cells. The blepharoplast divides when the nucleus and cell divide. There is some evidence that it contains desoxyribose nucleic acid; the presence in a normal cytoplasmic structure of this chemical, which is normally confined to the nucleus, is unique and remarkable.

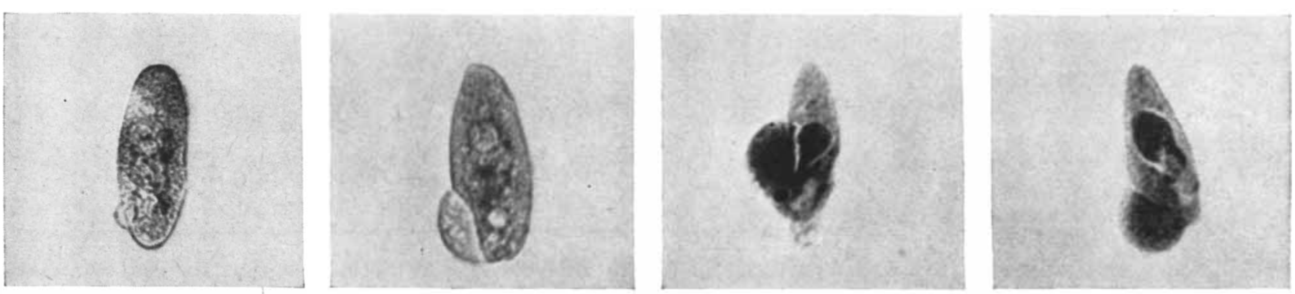
The kinetosome, a barely visible granule about a thousandth of a millimeter in diameter, is the structure from which the vibrating cilia grow in cells that bear these appendages. Kinetosomes seem always to arise from division of similar pre-existing granules. André Lwoff, microbiologist of the Pasteur Institute in Paris, has just published a stimulating little book summarizing the work of the French school on the kinetosomes of unicellular animals. His main thesis is that these structures are visible models of the basis and mechanism of cytoplasmic inheritance. It is remarkable that the kinetosomes can give rise to several other structures besides cilia; apparently other influences in the cell, not the kinetosome itself, determine what it will produce. Although there is no evidence that the centrioles, blepharoplasts or kinetosomes are mutable, their regular self-duplication marks them as genetic material.

Another type of visible self-duplicating structure is the "bacteroid," found in certain insects. As the name implies, bacteroids closely resemble bacteria. They may have evolved from organisms that were originally independent, but they now seem to be a vital part of the cell, for when they are removed the insects die. Thus they have become normal cytoplasmic materials, and therefore of genetic interest.

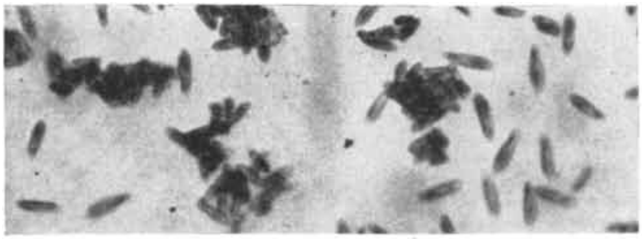
We have already noted that another tiny but visible particle sometimes occurs in the cytoplasm—namely, the Rickettsia. Rickettsiae, found in arachnids, insects and mammals, cause Rocky Mountain spotted fever, typhus and other diseases when they get into human beings. They are usually considered to be parasitic organisms. The most interesting fact about them in connection with heredity is that in the tick and certain other animals they are regularly transmitted to the progeny through the cytoplasm of the egg.

Parasites *v.* Genetic Particles

We return, then, to a question asked earlier in this article: How can one tell in such cases whether the cytoplasmic inheritance is controlled by a genetic agent in the cytoplasm or by a parasite? In other words, how distinguish between a parasite and a normal heredity-



KILLER FACTOR is another trait useful in studying the heredity of Paramecium. The first five photomicrographs show effects of placing sensitive paramecia in fluid where killer paramecia have lived. First blisters



conjugation. In the third Type I and Type II paramecia have been mixed; after one and a half minutes they have begun to form clumps. In the fourth the same two types form even larger clumps after eight minutes.

controlling structure, particularly if the agent in question is very small and reproduces only in the cytoplasm of certain cells?

One test might be the capacity of the particle to infect other cells—the obvious stamp of a parasite. But this would not be conclusive, for there are normal components of cytoplasm that seem to have the ability to infect—one example is the spread of pigments from one cell to another in spotted guinea pigs. The fact is that at present there seems to be no absolutely satisfactory criterion for deciding whether certain particles are genetic or parasitic agents in the cell.

This basic question is well illustrated by the case of the killer trait in Paramecium. The trait is controlled by a cytoplasmic particle to which I gave the name "kappa." This kappa has very interesting properties. They have been most ingeniously investigated by John R. Preer, Jr., and Ruth V. Dippell, students in my laboratory at Indiana University. (Preer is now at the University of Pennsylvania.)

Preer discovered several years ago that if paramecia were given an excess of food they multiplied faster than kappa. The amount of kappa per cell therefore decreased until none was left, and the paramecia irreversibly lost the killer trait. He then proceeded to determine the number of particles of kappa in a killer paramecium. First he proved in an ingenious way that if a single particle of kappa was left in a cell, the entire amount could be restored by underfeeding the paramecia so they multiplied more slowly than kappa. Using this knowledge, he was able to determine what proportion of the paramecia had lost kappa completely after various periods of heavy feeding. From this he could compute the average number of kappa particles at each step; by extrapolating back to the starting point he estimated the number of particles present in the original killer cell. This number turned out to be from a few hundred to about a thousand.

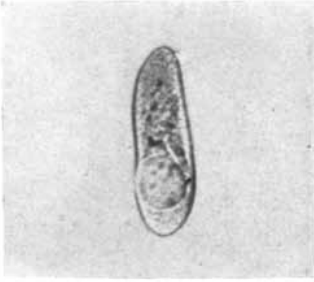
Continuing his study at the University of Pennsylvania, Preer set out to determine the size of kappa. The method he used was to bombard killer paramecia with X-rays. This radiation can inactivate kappa particles. Obviously the probability that it will "hit" and inactivate a particle depends in part on the particle's size. More "shots" of radiation are needed to inactivate a small particle than a larger one, within certain limits. Preer came out with the astonishing result that kappa, which had never been seen, probably was big enough to be visible under a microscope.

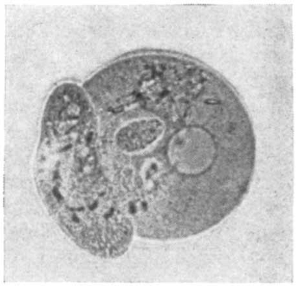
But how look for kappa? How distinguish it from other fine granules? Preer found a clue in evidence obtained by the Indiana University biochemist Willem van Wagtendonk that the poison controlled by kappa was chemically similar to chromosomal material. Using a stain suggested by this clue, Preer was able to see the kappa particles. They had the size and were present in the numbers he had indirectly inferred!

Dippell now made a thorough investigation to determine whether kappa had the property of mutability. A number of mutations of the killer trait had been observed. The original killers caused sensitives to develop a hump on one side of the body before they died. From them there had developed mutant killers that produced no hump but paralyzed the sensitives or made them swim aberrantly or swell up before they died. Other mutants produced two kinds of poison; still others produced very little. Each of the mutants was subjected to extensive breeding analysis. This brought the finding that no nuclear genes affecting kappa or the killer trait had mutated. Then Dippell showed that some of the mutants carried two kinds of kappa that could be separated from each other. As both were derived from the original kappa, it was clear that mutations of kappa had occurred. In short, kappa was indeed mutable.

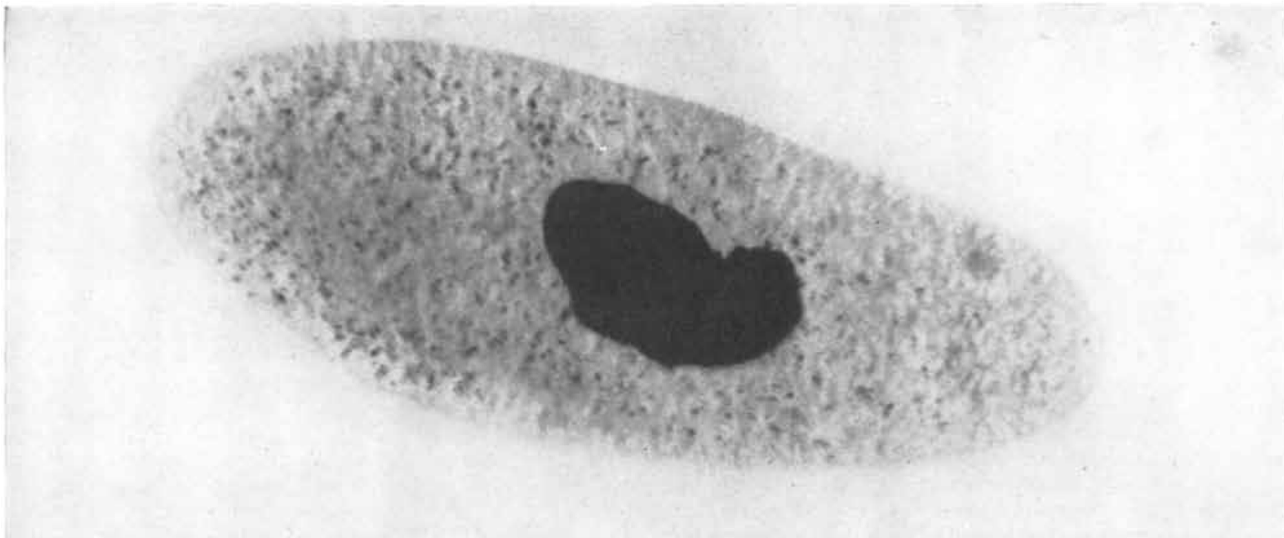
The question remains: Is kappa a parasite or a normal cytoplasmic component? Those who argue that it is a parasite cite several suggestive facts. For example, kappa does not always multiply synchronously with the nuclei and cells. But plastids, which are unquestionably normal, show the same lack of synchronism in most plants. Secondly, under certain conditions killers can be freed of kappa without killing the cell. But certain plant cells can likewise be freed of their normal chloroplasts. Thirdly, kappa contains a chemical found only in the nucleus, which suggests that kappa is an organism. But blepharoplasts, a normal component of cytoplasm, are reported to possess this same chemical. Fourthly, kappa is infectious. But I have shown that infection occurs only in the presence of concentrations of kappa far beyond any that could occur in nature, so there is as yet no evidence that kappa is normally infectious.

None of these facts, therefore, can be taken as proof that kappa is a parasite. The only strong reason for thinking that it may be, in my opinion, is that kappa is relatively uncommon; most strains of





form on its surface, then a large characteristic hump. Finally the paramecium shrinks and dies. The last three photomicrographs show the effect of another strain of paramecia which cause the formation of a huge blister.



KAPPA, the substance responsible for the effects shown at the bottom of pages 36 and 37, appears as small dark particles in the cytoplasm of a killer paramecium. The large dark body is one of the paramecium's two nuclei.

paramecia do not contain any particle of this kind.

Plasmagenes?

A close parallel to kappa is the particle which L'Héritier and his co-workers believe to be in control of the Drosophila fly's cytoplasmic inheritance of sensitivity to carbon dioxide. They call their particle "sigma" and have characterized it as a "genoid," to emphasize its gene-like properties. Sigma is self-duplicating and apparently can undergo mutation. Sigma behaves like kappa in many ways. It does not necessarily multiply at the same rate as the cells of the fly, and it may be lost completely under certain conditions. It is infectious, in the sense that it may pass from cell to cell, but there is as yet no evidence that this happens under normal conditions. Normally it is transmitted only by heredity, chiefly through the cytoplasm of the egg.

Sigma has been estimated by indirect means to be about the size of a virus. Is it a virus or a mutant form of a normal cellular component of the fly? So far as I can see, there is at present no way of getting decisive evidence, particularly in view of the fact that it is too small to be seen.

It is possible that particles comparable to kappa and sigma may be found to be the basis of other cases of cytoplasmic inheritance. Yet there remain the cases where cytoplasmic inheritance is controlled by what are unquestionably normal genetic particles; of this the best example is the chloroplasts and the plastids from which they arise. The Japanese botanist Yoshitaka Imai maintained that the basis of the genetic properties of plastids is an invisible genelike component of the plastid which he called a "plastogene." Similarly, Woods and DuBuy ascribe the mutations they think they have found in mitochondria to "chondriogenes."

Speculations about cytoplasmic genes have gone on for well over 50 years. In early years these hypothetical particles were variously called "ids," "biophores," "plastidules," "pangenes." Nowadays the name usually applied to them is "plasmagene" or "cytogene." Although all of these terms—and others—refer to particles with essentially the same properties, those who use them differ in their ideas as to where the particles originate. Some believe the particles arise in the nucleus; this is the sense in which the term "pangene" was used by Hugo De Vries and the term "plasmagene" has been used by Sewall Wright, Cyril Darlington and Spiegelman. The evidence for a nuclear origin of plasmagenes is, however, practically nil. Others hold that the cytoplasmic genetic particles are not of nuclear origin but autonomous or semi-autonomous. Kappa, sigma, kinetosomes, centrioles, blepharoplasts and plastids are well-established examples. It must not be forgotten, however, that the test of mutability has been clearly established only for chloroplasts, for kappa, for sigma and perhaps for the mitochondria.

The Delbrück Model

Could some other mechanism bring about cytoplasmic inheritance? This brings us to the second major theory now under investigation. Until recently it was generally supposed that cytoplasmic inheritance necessarily implied the existence of particles responsible for it. But the biophysicist Max Delbrück, developing an idea suggested by Wright and others, has pointed out that the persistence of a trait can be accounted for without assuming the existence of cytoplasmic genes. The essence of his idea is that the dominance of one reaction in a cell among two or more mutually exclusive ones may favor one line of development and inhibit the others, thus maintaining the favored trait. Suppose, to take a simple example, that a cell is capable of carrying out either of two reactions: a change of the substance A to B or of Y to Z. Suppose further that high concentrations of B inhibit the change of Y to Z and that high concentrations of Z inhibit the change of A to B. Then the cell will ordinarily be capable of carrying out only one of these reactions at a time, since the success of one reaction inhibits the other. Most important, the reaction that "goes" will perpetuate itself (*i.e.*, be inherited), because as long as much of the dominant material, B or Z, is present, the competitive reaction is inhibited and the favored reaction remains free to continue.

Delbrück's model was proposed as a possible explanation of cytoplasmic inheritance of antigenic types in Paramecium. It will be recalled that eight hereditary antigenic types appeared among the descendants of a single ancestral paramecium. The Delbrück model therefore suggests that there are eight alternative chains of reactions, each with a link which, in high concentration, inhibits all of the other seven.

We had found that changes in temperature or feeding or the administration of a paralyzing antiserum could transform paramecia of one hereditary antigenic type into others. Under standard conditions the induced transformations persisted and were cytoplasmically inherited. According to the Delbrück model, such changes are due to modifications of the system of mutual inhibitions. This can be brought about by reducing the concentration of the inhibitor or by altering the relative rates of formation of the different inhibitors. If the Delbrück model is correct, the transformations of antigenic type should be reversible. And experiment shows that they actually are reversible.

The Delbrück model is capable of accounting for the main features of the system of antigenic types. There is little or no evidence that it is the correct or best interpretation of the results, but it does show clearly how cytoplasmic inheritance could occur without being based on cytoplasmic genetic particles. Actually no visible particles have yet been observed to be involved in the control of the antigenic types.

The Delbrück model has reopened the whole question as to whether cytoplasmic inheritance is always controlled by genetic particles in the cytoplasm and has stimulated a search for other possible mechanisms. It therefore seems likely that the study of cytoplasmic inheritance will be greatly broadened in the near future.

A Cooperative Affair

Perhaps the most important feature of the investigation thus far is the finding that the nuclear genes and the heredity-influencing factors in the cytoplasm are definitely related to each other. The latest discoveries in the work on paramecia point this up.

As already mentioned, a single individual gave rise to progeny of eight different types. When the same experiment was made with an individual of another race of paramecia, it too produced a set of differing types, but the second group of types was not identical with the first. Now a very curious fact emerged when progeny of the second race were crossbred with those of the first. Let us call the two races I and II and focus attention on one type descended from each. Race I produces eight antigenic types, one of which we shall call type A. The difference between type A and the seven other types is cytoplasmically inherited. Similarly in race II the difference between the corresponding type A′ (not identical with A) and the seven other types it produces is also cytoplasmically inherited. But when A is mated to A′, the difference is *not* cytoplasmically inherited; it proves to be controlled by a nuclear gene! The same results are obtained when other pairs of comparable but not identical types in these two races are crossbred. And this pattern has been confirmed by similar experiments with other pairs of races.

These experiments show that the cytoplasm determines whether a cell will form antigen A or B or C, and so on, but the specific character of each type (*e.g.*, A or A′) is controlled by the nuclear genes. While the full meaning of these observations is not yet clear, they do demonstrate the important point that some close interrelation exists between nuclear genes and cytoplasmic inheritance.

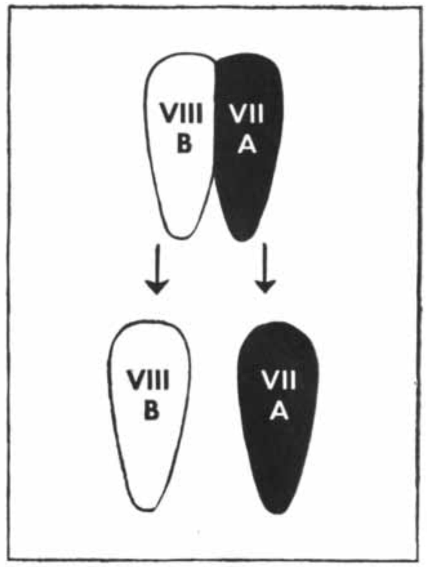
Apparently cytoplasmic inheritance of antigenic types is limited to certain mutually exclusive alternatives defined by the nuclear genes that are present. The same situation may exist in the body cells of higher organisms. These cells, all of which come from a single cell (the fertilized egg), are presumably identical in their genes but nevertheless develop into a number of different specialized types. The cells all have the same genes but they possess a set of hereditary alternatives that permit them to develop along different roads. The explanation may be that genes for all the possibilities are present and that the cytoplasm determines which of these possibilities will be realized and perpetuated. If this hypothesis is correct, the elucidation of the interaction between genes and cytoplasm would probably carry with it the beginning of a general solution of one of the greatest remaining enigmas in biology: the question of how normal and abnormal cell differences arise in the course of the development of the individual from the egg.

The Path to Explore

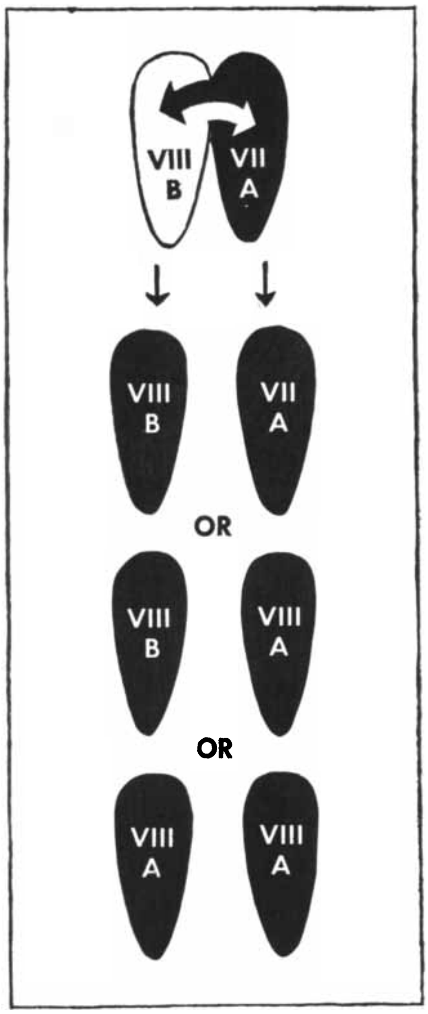
Where now does all this leave the general theory of heredity? Clearly there is more to heredity than the chromosomal genes. But it would be absurd to conclude from this, as is done in the U.S.S.R., that the whole theory of the gene must be discarded. The new discoveries about the genetic role of the cytoplasm leave untouched the vast accumulation of evidence that the nuclear genes do control nearly all of the hereditary differences thus far analyzed. They merely emphasize what has long been realized: that the gene is not in *exclusive* control of heredity. It operates not in an ivory tower but in the organic unity of the cell, and the rest of the cell has some voice in the directions that are given.

The outstanding result of the studies we have reviewed seems to be that the nuclear genes and self-perpetuating cytoplasmic mechanisms work jointly in determining heredity. When nuclear genes are the variable, they control hereditary differences; when cytoplasm is the variable, it too controls the hereditary differences, apparently even the same differences. The path for future workers to explore is the interaction between these two components of the cell in the control of cellular and organismic traits.

T. M. Sonneborn is professor of zoology at Indiana University.



EXCHANGE OF NUCLEI between paramecia causes no change in killer trait (***black***), mating (***numbers***) or antigenic type (***letters***) of offspring.



EXCHANGE OF CYTOPLASM can cause several changes in the offspring. Killer factor will be in all and other factors distributed variously.

SIMPLE SIMON

A small mechanical brain that possesses the same fundamental characteristics as its larger relatives can explain in rudimentary fashion how they work

by Edmund C. Berkeley

DURING the past eight years the designers of computing machines have announced the completion of giant mechanical " brains" of increasing size and genius. Last spring a curious mutation in this evolutionary line was exhibited at Columbia University. It was the smallest complete mechanical brain.

Compared to its larger cousins the tiny computer was almost a moron. Like Simple Simon of the familiar nursery rhyme it entertained its audience with its rudimentary intellectual processes, and it was christened Simon. Simon occupies only a little more than a cubic foot of space, and it weighs a mere 39 pounds. In contrast to Aberdeen Proving Ground's great Electronic Numerical Integrator and Computer, or Eniac, which performs 5,000 operations a second, Simon performs one operation in about two thirds of a second. In contrast to Harvard University's Mark I calculator, which can remember 144 numbers at a time, Simon can remember 16 numbers at a time. In contrast to Bell Telephone Laboratories' two General Purpose Relay Calculators, which can conceive of 351,000,002 numbers, Simon can conceive of only four numbers. Yet Simon possesses the two unique properties that define any true mechanical brain: it can transfer information automatically from any one of its "registers" to any other, and it can perform reasoning operations of indefinite length.

How did Simon come to be built? What is its purpose? Can we expect this little moron of a mechanical brain to be useful around the laboratory and earn its keep?

THE STORY of Simon is closely connected to the story of the big mechanical brains. These machines fall into two main types: the "digital" and the "analogue." Digital means handling information as characters or digits, in the way the fingers of one hand can express the numbers 0, 1, 2, 3, 4, 5. Analogue means handling information as measurements of physical quantities; the measurements are analogous to numbers. There are no easy analogues for random numbers, alphabetical information and certain other classes of information. So digital computers are generally more versatile than analogue computers.

Both digital and analogue computers possess breath-taking powers. They can manipulate numbers much faster than the human brain, often 10,000 and sometimes 100,000 times faster. They are also more reliable than the human brain. As a result many problems that would not be practical for the human brain may be submitted to the machines.

Most of the digital machines are able to make choices and decisions. They can choose between numbers and between calculation routines. They can make choices from time to time in the course of a problem according to indications in the problem itself. Many of the machines can work out more than 95 per cent of their own instructions.

Powerful though the machines may be, there are difficulties in their application. It takes time, and often a long time, to train specialists to prepare the correct instruction sequences for a mechanical brain. It also takes time to train other specialists to operate the machine correctly, to use the right controls at the right time. And in spite of the fact that the machines are more reliable than human brains, they have temperaments and moods. They do not inevitably supply the correct answer, nor are they always consistent in their mistakes. Anyone who has sought to run a problem on such a machine has learned that it is vital to have good trouble-shooting—to find what part of the machine is failing to operate as it should, and then to repair or replace it promptly. Usually trouble-shooting on a big machine requires two people: a mathematician who knows what the instructions currently require from the machine, and an electrician who can get to the failing part of the machine and repair or replace it.

Unhappily it is difficult for an inexperienced mathematician or electrician to learn this job on the machine itself. It is too advanced to give much useful instruction to students; it is also too valuable to entrust to inexperienced hands. Its time is precious: it is monopolized by what some inhabitants of computing laboratories call VIPs—very important problems.

WHAT CAN be done about the difficulty? How can we provide training and experience for the few who must work with the big machines, and for the many who wish to understand them? We can hope that as time goes on the machines will become cheaper, less complicated, more easily operated and more accessible to students. Or we can build a really cheap, simple machine designed mainly to teach the student the fundamentals.

This we can do, provided we surrender one characteristic that is usually thought to be essential in computing machines: the capacity for useful work. Obviously this capacity is not required for teaching purposes. To abandon this capacity, in fact, is to give us some necessary freedom. We become free to play with the machine, and to tinker with it.

It was such considerations that led to the birth of Simon. But what sort of operations can a small, nonutilitarian mechanical brain accomplish?

In mathematics there exist not only systems that are very large, containing millions of numbers or elements, but also systems that are very small, containing only a few numbers or elements. In daily life we use some number systems that are very small. Take the days of the week: Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday. This is exactly equivalent to a system of seven numbers: 0, 1, 2 ,3, 4, 5, 6. A smaller mathematical system in common use is right, left, up, down, back, front. This has six elements. A smaller one still is North, East, South, West. This has four elements. Perhaps the commonest and most useful of all mathematical systems has just two elements: yes and no. Mathematically we can use 1 and 0.

Which of these small mathematical systems shall we choose for Simon? Let us choose a mathematical system of four elements. Then we can see at least a little of the numerical side of mathematics and still handle the logical side of yes and no.

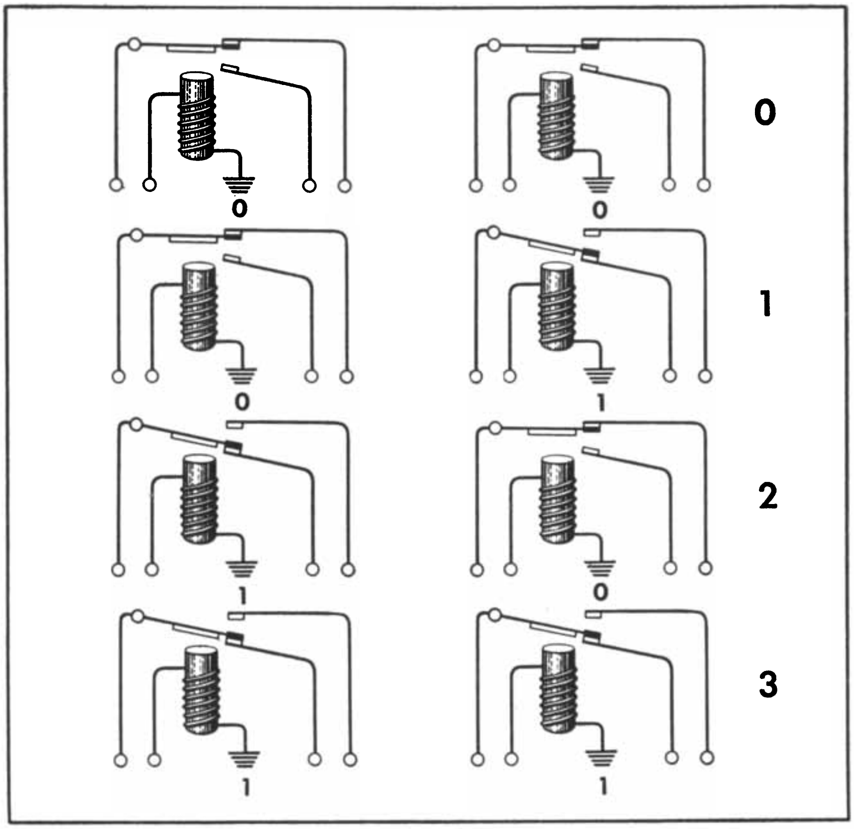
We can think of these four elements or numbers as four compass directions, North, East, South, West. Or we can think of them as four numbers, 0, 1, 2, 3. Or we can think of them in the notation of the scale of two—binary notation—in which they are written 00, 01, 10, 11. Here the left-hand digit counts not the number of tens but the number of twos, and the right-hand digit counts the number of ones. For example, 11 in binary notation means one two plus one one, and this in decimal notation is 3. Or we can think of these four numbers as right-angle turns: 0 for no turn, 1 for one right-angle turn; 2 for two right-angle turns in the same direction, and 3 for three right-angle turns in the same direction. With this kind of interpretation of 0, 1, 2, 3, we can see that 4 is interchangeable with 0, 5 with 1 and so on. If we turn through four right angles we face in just the same direction as before.

Now in order to make a computing machine, we must consider computing operations utilizing our numbers 0, 1, 2, 3. In the case of Simon it was decided to choose at least two computing operations belonging to logic. The two logical operations were "greater than" and "selection." These can be put in the following form. Greater than: Is the number *a* greater than the number *b*? Yes (1) or no (0). Selection: Choose the number *a* if there is an indication that *p* and *p* is 1, and choose the number *b* if there is an indication that *p* and *p* is 0.

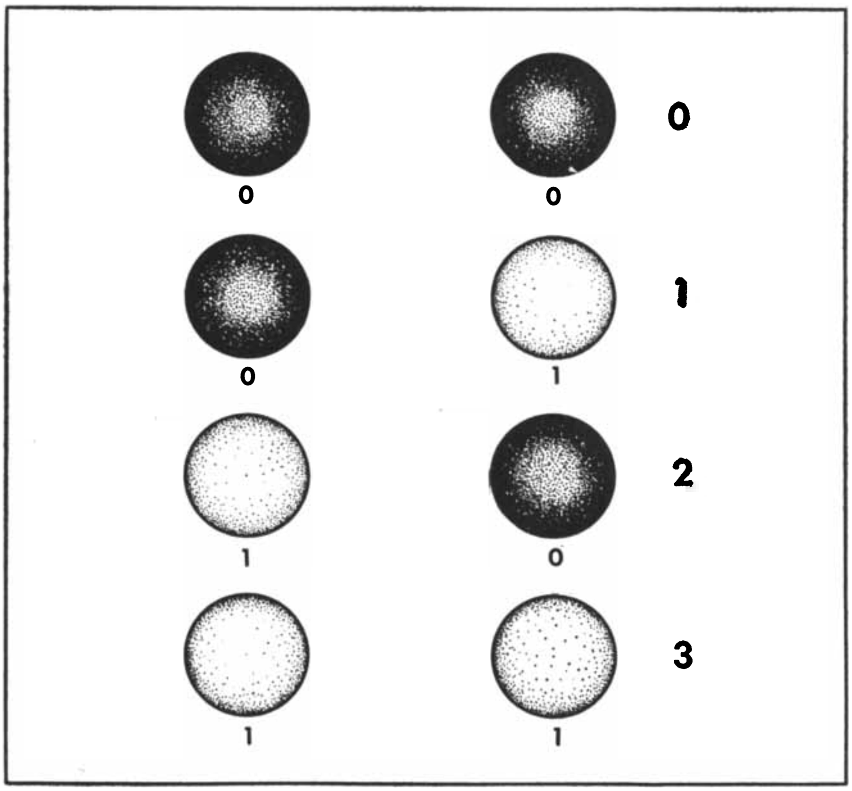
It was also decided to equip Simon with two arithmetical operations. The two operations which at once suggested themselves were addition and "negation." A mechanical adding system can be illustrated by the operation of an automobile speedometer. Each adding wheel in the speedometer proceeds 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 1, 2 and so on. Simon, using only four symbols, adds units in this progression: 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0 and so on. A man can add 1 and 2 and get 3; so can Simon. A man can add 2 and 2 and get 4, but when Simon adds 2 and 2 it gets 0; its limited mentality cannot distinguish 4 from 0.

Negation may be defined as "finding the negative of." In Simon we find the negative of a number by subtracting it from 0 or from 4, which is interchangeable with 0. Thus 0 is the negative of 0, 2 is the negative of 2, 1 is the negative of 3, and 3 is the negative of 1.

All these features of Simon were worked out some two years before Simon was actually built. Published as a chapter in the author's recent book *Giant*



RELAYS of Simon express numbers 0, 1, 2, 3. Each relay can express 1 or 0, and pairs of them can express numbers in binary notation. In this notation relays at left express number of twos; those at right, number of ones.



LIGHTS flash the answers of problems submitted to Simon. One pair of lights is sufficient to express Simon's four numbers in the binary notation. Simon has three other lights, however, for additional purposes (*see page 43*).

Brains, they served as an introduction to bigger computers. Even in the first hypothetical designs for Simon it was decided that its principal elements should be relays rather than electronic tubes. Circuits involving relays are considerably easier to understand than those involving tubes. In fact, they can be understood in terms of yes and no, *i.e.*, of current flowing and no current flowing.

A survey of war-surplus stores suggested that we use relays of 24 volts and 3,000 ohms, which were available at 60 cents each. A second-hand stepping switch was acquired and modified with coils that would energize at 24 volts. For feeding Simon its instructions, via a punched-paper tape, we chose the simplest available tape feed—a regular Western Union tape transmitter costing $50. A front panel with switches and lights, some rectifiers and condensers and a frame for mounting all the parts made Simon complete.

The machine is mounted on a chassis 24 inches long and 15 inches wide. Its front panel is 24 inches long and 6 inches high. The switches there enable the machine to be operated either automatically from tape or manually by pushing buttons. Simon shines its answers on the five lights that are mounted on the panel. Just behind the panel is the tape-feeding mechanism and the stepping switch. The rest of the machine consists mainly of 120-odd relays (of which about 10 per cent are spares, available for increasing Simon's capacity).

Simon was built by William A. Porter, a skilled technician who had a considerable responsibility in the construction of the Harvard Mark II and Mark III calculators, and two Columbia University graduate students of electrical engineering, Robert A. Jensen and Andrew Vall. Like any computer, Simon required three kinds of workers for its creation: a mathematician to design its circuits, an electrical engineer to make sure that all its elements would work, and a skillful technician to put it together. The final cost of Simon was about $270 for materials and another $270 for the labor of wiring. This figure does not include the cost of the designing and a good half of the labor, which was contributed.

THE OPERATIONS that Simon can perform with numbers are such as to make anyone present at the performance feel distinctly superior. Consider a typical problem, the first given to the machine, which embraces all the numbers and operations that Simon knows and demonstrates its capacities. The problem: Add 2 and 1; find the negative of 3; find whether the first result is greater than the second; if so, select 2; if not, select 3.

Simon, or for that matter any other mechanical brain, is analogous to a long series of sidings on a railroad. Freight cars may be switched onto the sidings and left there until they are brought out again. In a computing machine the freight cars are numbers or other items of information, and the sidings are called registers. Each register is fundamentally made up of two relays, although for practical reasons it may be made up of more (*see diagram at top of preceding page*).

Simon's 16 registers may store the numbers 00, 01, 10, 11, or the operations 00, 01, 10, 11. The first two registers (called Input Registers) take in from the punched tape either numbers or operations. The next six registers (called Storage Registers 1 to 6) store information unchanged until it is called for. The next five registers (called Computer Registers 1 to 5) have had mathematical and logical capacity wired into them in such a way that together they can compute. Computer Register 5 always holds the result of an operation, specified in Computer Register 4, on certain numbers specified in Computer Registers 1, 2 and 3. The last three registers of Simon (called Output Registers) are connected to five lights on the front panel, and whatever information they hold is spelled out by the lights.

As in any other mechanical brain, calculation in Simon proceeds as a series of commands. Each command to Simon takes the same form: "Take the number out of register____; put it into register____." The blanks may be filled with the numbers of registers in many ways. In fact, about 200 different commands of this kind can be given to Simon.

Let us now convert the first sentence of Simon's demonstration problem into a series of commands.

Operation: Take 2.

Command: Read from Input Register 1 (which has been filled from a line of punched tape holding the binary number 10) into Computer Register 1.

Operation: Take 1.

Command: Read from Input Register 1 (which has now been filled from another line of punched tape holding the binary number 01) into Computer Register 2.

Operation: Add.

Command: Read from Input Register 1 (now filled from another line of punched tape and holding the binary number 00, the symbol for addition) into Computer Register 4 (the register that holds the operation instruction).

Operation: Take the result and store it.

Command: Read from Computer Register 5 (now holding 11, the result of adding 10 and 01) into Storage Register 1.

This is the way Simon carries out a problem. The process may seem so simple as to lack meaning. Yet the machine is required to remember results from the earlier stages of the problem, to refer to these results and to combine them. Simon actually has a slightly better memory than many human beings. Its memory capacity is the equivalent of a sheet of paper where 16 numbers can be put down and referred to later.

WE have now described how Simon came to be conceived, how Simon was built and what sort of problems Simon can do. But this is not the end of Simon's story. The little machine has some interesting future possibilities.

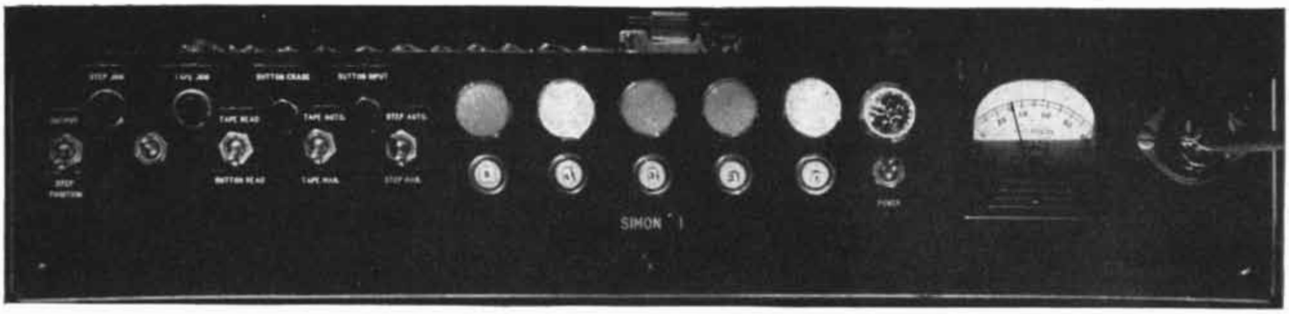
The first is that Simon itself can grow. It possesses all the essentials of a mechanical brain, but other circuits can be added to it. One that can easily be added is a "carry" circuit. There is no basic reason why Simon should be restricted to numbers less than 4. A carry circuit will enable Simon to deal with numbers of two digits. Another possible extension of Simon would be to add a mechanism capable of punching paper tape. Then impulses delivered by Simon could be used to punch the tape, and Simon could prepare some of its own tapes. It would not be surprising if in another six or eight months Simon was able to handle decimal digits, and to do a moderate amount of real computing.

Simon has a second future: It is likely to stimulate the building of other small mechanical brains. Perhaps the simplicity and relatively low cost of such machines may make them as attractive to amateurs as the radio set and the small telescope.

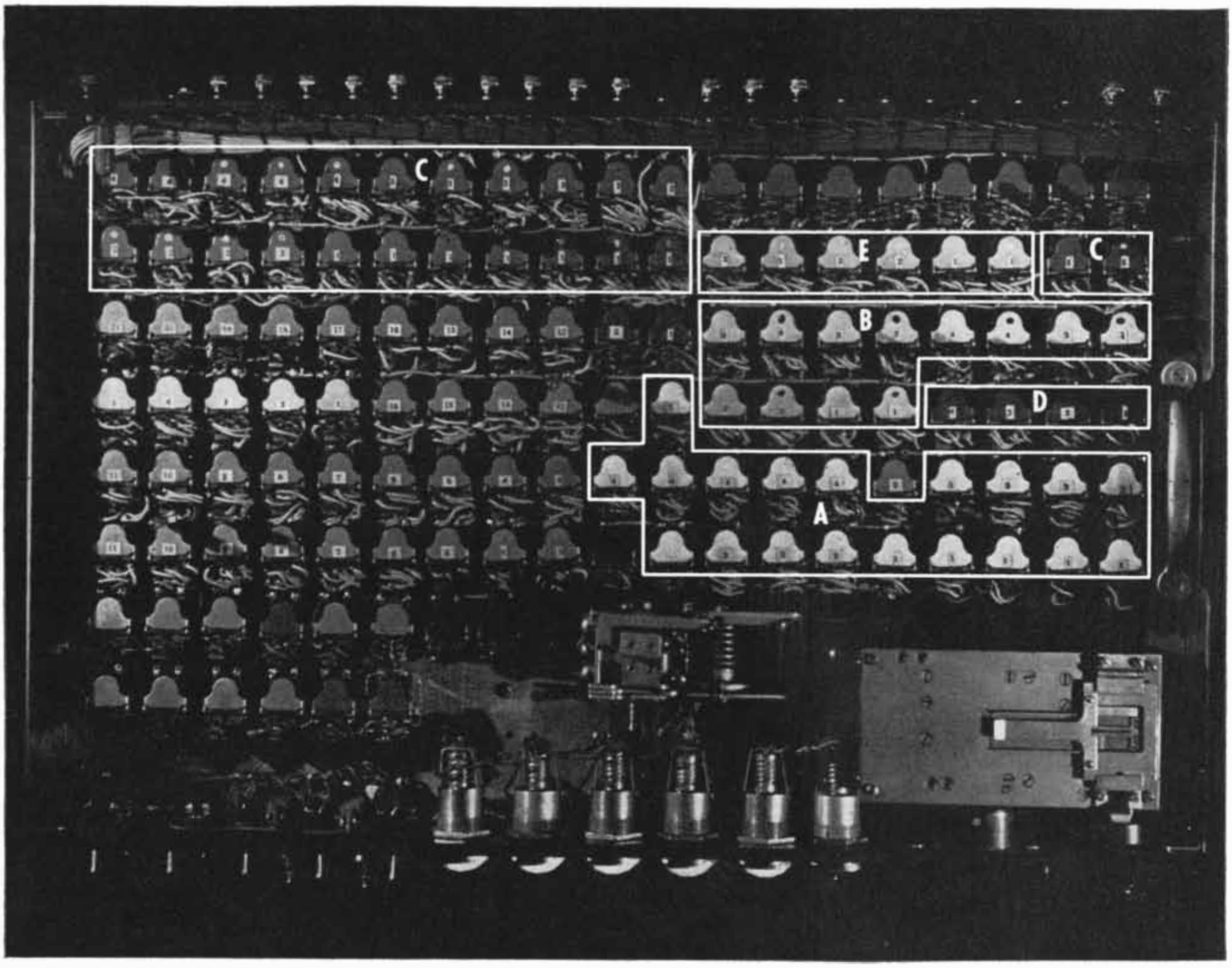
Simon has a third future: It may stimulate thought and discussion on the philosophical and social implications of machines that handle information. An essential point about these machines is that they are endowed with the spark of automatic activity. In a machine this is basically the capacity to pay attention to and respond to a series of stimuli. The more experience human beings have with this unique faculty, the better they will be able to develop and utilize it.

SOME DAY we may even have small computers in our homes, drawing their energy from electric-power lines like refrigerators or radios. These little robots may be slow, but they will think and act tirelessly. They may recall facts for us that we would have trouble remembering. They may calculate accounts and income taxes. Schoolboys with homework may seek their help. They may even run through and list combinations of possibilities that we need to consider in making important decisions. We may find the future full of small mechanical brains working about us.

Edmund C. Berkeley is the author of the recent book Giant Brains.



FRONT VIEW of Simon shows its controls and lights. Here the lights show not the answer to a problem but the stage of its solution. Light at right indicates power is on. Other two lights show that problem is at stage 9.



TOP VIEW of Simon shows its relays. Their basic functions are programming (A), storage (B), computation (C), input (D) and output (E). At the lower right is the tape feed. To the left of it is the stepping switch.

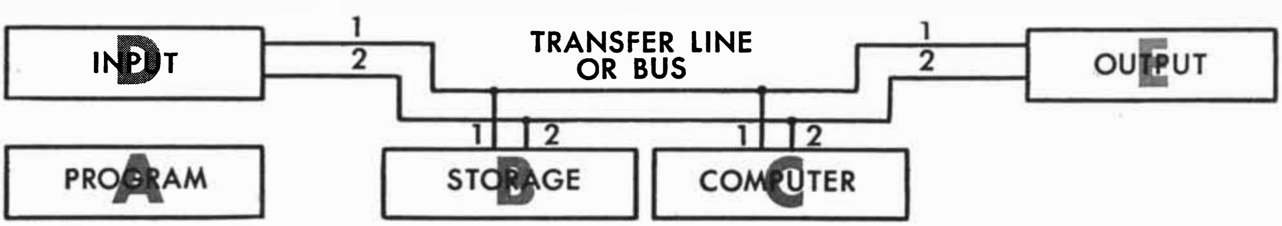
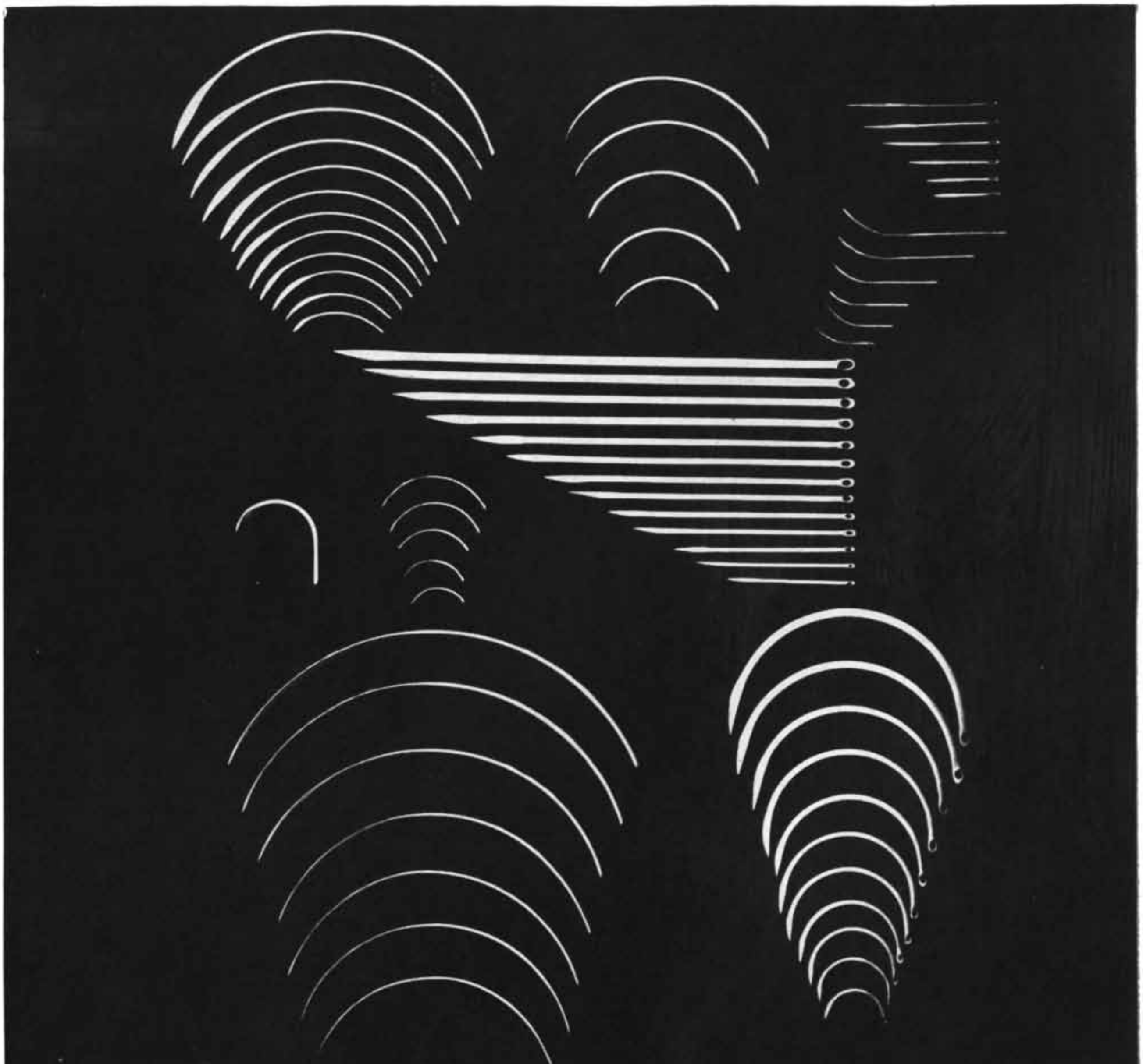


DIAGRAM shows relationship of relays noted on photograph above. The remaining relays are for auxiliary purposes or for expanding the capacity of Simon. By adding a "carry" circuit, Simon will be able to count higher.

Surgical Stitching

The surgeon's needlework is in many ways similar to that of the housewife, but it requires special skills because of the properties of the material

by Sir Heneage Ogilvie



SURGEON'S NEEDLES come in a great variety of sizes and shapes. They are divided into two classes: the cutting and the round-pointed. The straight needles are best for sewing on the surface; the curved needles, for penetrating beneath the surface. The diameter of the needle is determined by the diameter of the thread.

THE SURGEON'S stitching is very like that of the housewife, but the garment he is sewing is made of living tissues and the seams he makes will be there for a lifetime.

If we were to put our housewife into a sterile gown, cap and mask, and lead her into a modern operating theatre, she would probably be struck first of all by the resemblance of all she saw to a religious ceremony—the bright lights, the men and women in white moving swiftly about their allotted tasks, the soundless progress of a ritual made perfect by repeated rehearsal. When she came to the side of the table and looked over the surgeon's shoulder, she might find the performance much less impressive. She might think the surgeon was using needles too large and of too many different shapes. She might think his threads were coarse and his stitches unnecessarily far apart. She might sum up that he wasn't very good at the job.

We should have to explain to her that the surgeon was stitching material a good deal tougher than she worked with, and that he could not take it on his lap but must stitch it where it lay, often in an awkward place. We should tell her that the thread was not meant to join the two edges of a cut, but merely to hold them together while they joined themselves. As for the surgeon, we should have to excuse him by saying that he had first used a needle at the age of 24, while she had started at four, and that he was practicing a method quite new in the long history of the craft of surgery.

The pattern of any occupation depends on the quality of the material with which it is conducted, and on the nature of the manipulations which are carried out on that material. If the material is coarse and heavy, and its handling needs nothing but the application of force in a simple manner, the worker is a laborer, skilled or unskilled. If the material is small in size or fine in texture, so that it must be worked with delicacy and precision, he is a craftsman. If the task to be done differs on each occasion and the worker is called on to use his judgment to produce something of his own choice rather than one of a series, he becomes an artist.

The raw material of surgery is the human body, a material differing from that on which other crafts are conducted in two respects: 1) it contains many tissues with widely different properties, and 2) it is alive, meaning that it can grow and rejoin itself and can also decay and die. Man is the lord of creation, but he is safe in his castle only while the protective rampart of skin that keeps out his microscopic enemies is intact. The prick of a needle may open the door to the bacterial hordes that can within a day lay his hopes, ambitions and imaginings in the grave.

Before Pasteur's discoveries and Lister's application of them to surgery, any breach of this rampart, even in a surgical operation, was followed by infection, often by serious infection of the bloodstream. The simplest operations had a death rate of nearly 50 per cent, and childbirth in a hospital, where the bacteria of puerperal fever spread from ward to ward, was almost as dangerous. Surgeons therefore confined their operations to draining abscesses, amputating limbs and removing tumors from the surface of the body and stones from the bladder. They knew that safety lay in leaving the wounds open, thus allowing the defenses of the body complete freedom to evacuate the litter of the battlefield as pus. They never opened the abdomen. They never stitched a wound.

The conquest of infection has saved more lives in the past 70 years than were lost in all the wars of history. It has also transformed surgery from a brutal trade to a delicate art, has transferred its interests from drainage and removal to repair and reconstruction, and has elevated the surgeon from the itinerant peddler of the Middle Ages and the rough battle-follower of a hundred years ago to the scientific healer of today.

THE BODY, looked on merely as the material of a craft, may be said to have five basic structures: the covering membranes, fat, muscle, fibrous tissue and bone. Fibrous tissue is the lowliest, yet the most universal of all the tissues, for it is the binding and sheathing element that gives strength to all the others. The covering membranes owe their strength to the tough fibrous sheet on which they lie. The nerves and arteries run in fibrous tunnels. The muscles work in fibrous jackets and exert their pull through fibrous tendons. The bones are fibrous tissue, solidified by the deposition of calcium salts.

Surgical stitching is the stitching of fibrous tissue. A stitch will include other tissues, but unless it takes a firm bite of fibrous tissue in some part of its course, it will pull out.

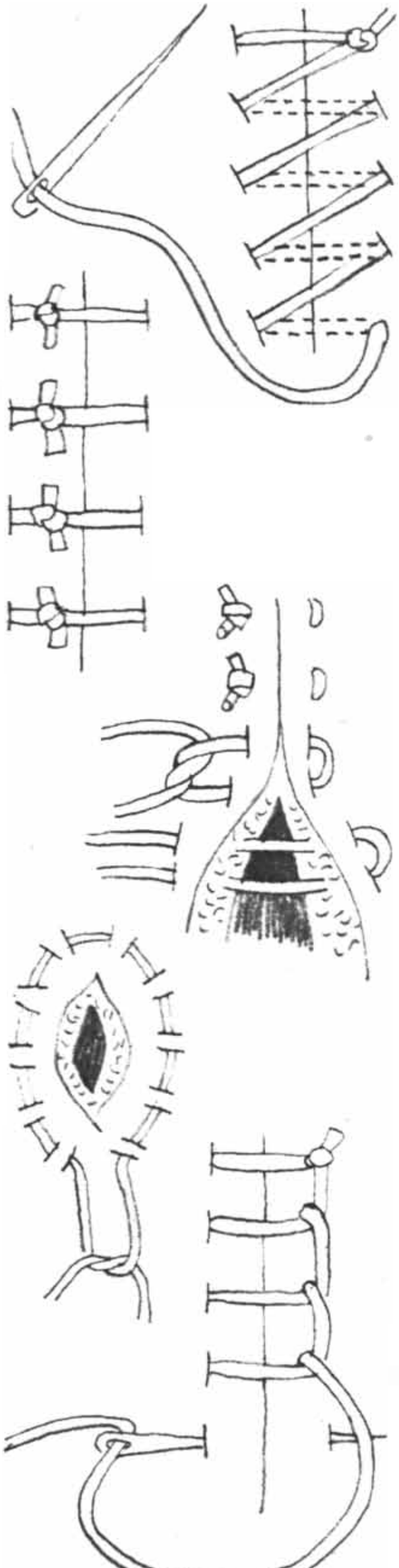
Since surgical stitches are to be inserted into the living body, the material to be used as thread, or suture, cannot be chosen for its strength and diameter alone. It must be considered in relation to the properties, movements and power of repair of the tissues it is required to hold together. The suture materials used in surgery fall into three groups, each with its advantages and disadvantages: the absorbable, the fibrous and the monofilaments.

The only absorbable suture material in common use is catgut. It is made from the intestines of the sheep, not the cat; it gets its name from the fact that it was first made for the Kat, or Kit, a musical instrument like a small fiddle. Catgut is used where it is essential that the stitch shall disappear entirely when it has done its work, as in operations on the stomach. The time it takes to absorb is determined by the method of its preparation. Apart from its absorbability, it has no advantages. It must be used in strands much thicker than those of any other substance to give comparable strength. It is hard to sterilize. The strands break and the knots slip more readily than will other material. Worst of all, it produces a considerable reaction in the tissues that are absorbing it. Manufacturers are seeking to produce a strong, nonirritating, absorbable thread of plastic to replace catgut, but so far without success.

The fibrous materials in common use are silk, linen thread and cotton. They have many advantages over catgut: they can be sterilized by boiling; their strength is uniform and from six to 10 times that of a catgut strand of equal diameter; knots tied with them will not slip. Their price is from a thousandth to a twentieth that of catgut. They are more pliable, and, owing to their strength, are used in finer threads with finer needles that make smaller holes. They produce very little irritation of the tissues in which they lie. Yet they also have a serious disadvantage. Because they are woven from fine fibers, they have a mesh structure into which body fluids and body cells can penetrate. In sterile conditions this property is innocuous, but where there are bacteria the meshes may give them shelter.

Monofilament materials are those made from a single strand, or from fibrous materials whose meshes have been obliterated by a filling agent. The common materials in this group are silkworm gut, nylon and noncorrosive wire, either of stainless steel or tantalum. These materials can be sterilized by boiling and have no interstices in which body fluids can seep and bacteria can lodge. But they are all unabsorbable and less pliable than the fibrous materials, and on the whole less strong. For work where complete reliability combined with extreme fineness is essential, as in operations on the arteries and the eyes, many surgeons use fine silk impregnated with wax or plastic. Silkworm gut is stronger than nylon of equal diameter and knots better, but it is stiffer and cannot be obtained in lengths much over a foot. Wire is stronger than either silkworm gut or nylon, but stiffer, liable to kink, snarl and snap. It can be used only by a patient surgeon served by an instrument nurse with the qualities of an angel. Wire usually breaks down into fragments after a few months, tears the fingers of any surgeon who opens the wound again, and plays strange tricks with radiotherapy should that be required. Surgeons are either "wirophiles" or "wirophobes." I am one of the latter.

The needles used in surgery are of infinite variety. Four considerations gov-



SURGEON'S STITCHES, from the top, are continuous suture, interrupted suture, buried mattress suture, purse-string suture and lock suture.

ern the choice of the needle for any particular job: the tissue through which the stitch has to be passed, the suture material the needle must carry, the accessibility of the structures to be sewn and the fad of the surgeon. Surgical needles are divisible into two classes: the cutting and the round-pointed. The choice of the type of point depends on the toughness of the tissue it has to pierce. For sewing skin or tough fibrous sheets a bayonet or triangular point like that of a saddlemaker's needle is wanted; for the intestine a round-bodied needle is usually chosen. The diameter of a needle is governed by the suture material it must carry; catgut will need a coarser caliber than thread. The length and shape of a needle will depend on the way it is to be held, and the thickness of the tissue it must pierce. For easy sewing on the surface a straight needle is best, because the site of its point is always known and the direction of its travel is always under control. For sewing at a depth a curved needle is necessary; the greater the depth and the smaller the bite to be taken, the sharper must be the curve.

From another point of view needles may be divided into those to be held with the fingers and those to be used with needle holders. The former need to be longer than the latter, for the fingers require four centimeters of length for their grip, while the needle holder needs only one centimeter. In intestinal work and in fine plastic operations "atraumatic" needles are used; the suture material is gripped in a little tube at the end of the needle, instead of being threaded through an eye, to avoid drag when it enters the tissue.

The choice of suture methods and suture materials will depend upon the demands of the particular task, on whether the part to be sutured is infected or sterile, on whether it is moving or stationary. It will also depend on whether the strength or the appearance of the scar are the final consideration, and on whether the stitches will be removed or will remain in the body.

Surfaces are always infected or potentially infected, and any stitch provides a track that may carry infection to the deeper layers. Skin stitches are always removed to prevent persisting sepsis, but even a small amount of infection around a stitch hole may leave a permanent stitch scar. The mesh materials—silk, linen, cotton and catgut—provide a wick soaked in tissue fluids along which bacteria can grow from the surface or from the deep glands in which they reside to the deeper layers, and therefore they are never used to stitch skin. The monofilament materials have no such action, and if the stitches are removed early they leave no scar.

In the intestinal surfaces, where the appearance of the scar is immaterial and infection, provided it is transient and limited to the stitch hole, is unimportant, the preferred materials are catgut, silk or linen; the monofilament materials are too rigid for use in this situation. In the case of silk or linen, interrupted stitches are used; continuous sutures of unabsorbable material are not permissible in infected sites where they cannot be removed. A single-thread stitch will drop out when it has done its work if there is any infection, but a continuous one may remain for years, giving trouble all the time.

When a moving structure is to be stitched, it may be advisable to use catgut, so that no foreign material remains at the site of suture when repair is complete. In many places, however, particularly in the closing of abdominal incisions, catgut is hardly reliable enough. Many surgeons prefer interrupted stitches of silk, linen or stainless-steel wire in such situations. In the repair of hernia, stitches are often used as a reinforcement for a weak layer of tissue; they are therefore woven into the tissues and must remain there. This means that the suture material must be of a kind that can yield to the normal movements of the lower abdominal wall. Wire, which is used by many, seems unsuitable, for while wire can bend it will not do so forever without fragmenting. Here, where sepsis should not occur and incorporation in the tissues is desirable, silk, linen or cotton is preferable to silkworm gut or nylon. In all operations on the stomach or intestines, the site of repair must be free to expand and contract with the movements of the part. A continuous stitch of unabsorbable material would fix it in one position. Free from this drawback is a continuous catgut stitch or a series of interrupted thread stitches that do not hinder expansion.

THE MOST delicate operations in surgery today are those on the brain, the heart and the great blood vessels. The brain is unstitchable, since it contains no fibrous tissue. For the same reason ligatures cannot be used there; hemorrhage from cut surfaces of the brain must be controlled by some special means such as electric coagulation or little patches of gelatin or fibrin sponge soaked in thrombin, the agent responsible for clotting of the blood. The arteries and heart, having abundant fibrous tissue in their walls, can be stitched, but it is a most difficult form of needlework. The surgeon not only has the great problem of joining surfaces that pulsate with every heartbeat; his stitching must be done with the finest of needles and suture materials to an incredibly high standard of accuracy. The join must be so exact that no breach on which clots could form appears in the lining membrane, and so strong that blood cannot force its way between the stitches.

Further, the needle must be no larger than the suture that follows it, or blood will force its way out along the stitch hole. This last need, which is peculiar to blood-vessel surgery, is met by the use of a very fine round-pointed needle molded onto very fine black silk of identical diameter, the whole suture being kept in sterile liquid paraffin.

A woman's skin is her shopwindow, and more and more of it is exposed to public gaze every year. It is also the surface on which the surgeon writes his signature, and by the beauty of the scars he produces, rather than by the excellence of the job he has done underneath them, will he be judged. A surgical scar can be invisible only if it is placed out of sight or where there was a scar before, but it need never be ugly. Happily the surgeon's scar can often be concealed by nature's scars—the skin creases. The scar of a thyroid operation, if accurately placed in one of the normal transverse creases of the neck, well sutured and well healed, will be quite invisible when the color has left it. The scar of an appendectomy operation placed in the outer end of the lower abdominal crease can escape the eye even of the examiner for an insurance company.

These devices are not always possible, but to make a scar that shows no more than a thin white line like a piece of paper on edge should always be possible if certain principles are borne in mind. First, incisions made across the line of elastic tension in the skin heal better than those made along it. Second, complete apposition of the edges of the cut layers of skin, not merely on the surface but throughout its depth, is necessary to secure smooth healing. Third, infection in either wound or stitch holes means unsightly scars—and stitch scars are uglier than wound scars.

The stitches are used to bring the wound together but not to hold it together, except in the early stages of repair. The holding is soon taken over by living tissues. The more accurately the cut edges are brought together, like to like, without gaps yet without pressure, the more rapidly will living cells grow across and render the stitches superfluous. The earlier, too, will epithelial growth close the breach in the ramparts made by the knife and shut out infection. In neck wounds the stitches normally can be removed in 48 hours. In other wounds those that merely bring the skin edges together can come out in four days if they have been accurately placed, and the wider ones which bring the fat into apposition can be removed in another three or four days.

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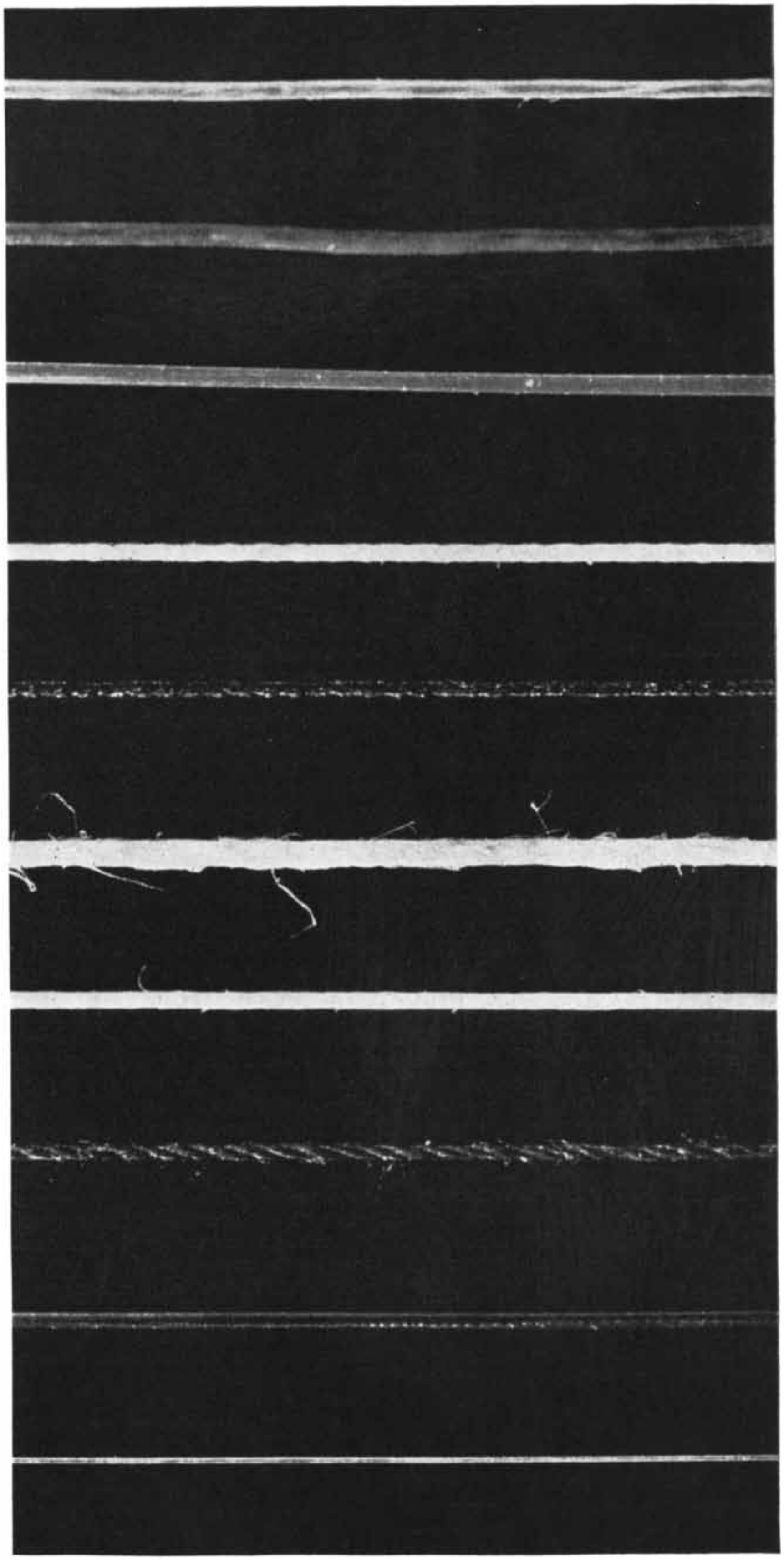


SURGEON'S SUTURES, like his needles, come in a wide variety for various purposes. These sutures, from top to bottom, are catgut, chromic catgut, silkworm gut, white silk, black silk, linen, white cotton, black cotton, nylon and wire. Only sutures that are made of catgut are absorbed by the body.

ION EXCHANGE

The technique of replacing electrically charged atoms or groups of atoms with others of the same charge has become increasingly useful to science and technology

by Harold F. Walton

IONS are electrically charged atoms or groups of atoms. Most inorganic substances are made up of ions. A classic example is common salt. When this is formed by the combination of its elements, sodium and chlorine, a very vigorous reaction occurs in which each sodium atom loses an electron, becoming a positively-charged sodium ion, and each chlorine atom gains an electron, becoming a negatively-charged chloride ion.

The properties of the ions are, of course, very different from those of the neutral atoms whence they came. There is a tremendous attractive force between the positive and negative ions. Suppose one could somehow separate the sodium and chloride ions in an ounce of common salt and then take the pile of sodium ions to the North Pole and the chloride ions to the South Pole. The two tiny piles of ions, though 8,000 miles apart, would attract each other with a force of several tons!

Needless to say, the separation of positive from negative ions in any weighable amount is quite impossible. Wherever we have a positive ion, there must be a negative ion in its immediate neighborhood. Yet, though positive and negative charges may not be separated, there is nothing to stop us from substituting one kind of positive ion for another, or one kind of negative ion for another. This substitution is known as "ion exchange." More specifically: ion exchange is the reversible interchange of ions of similar charge between a solution and a solid insoluble body in contact with it. The solid body is called an ion exchanger. Being insoluble in water, it does not contaminate the solution in any way; its sole effect is to trade ions.

Suppose we have potassium chloride in a solution and want sodium chloride; or, taking a more practical case, we have the potassium salt of penicillin and want the sodium salt. We place the solution in contact with an ion exchanger containing sodium ions. This solid gives up some of its sodium ions to the solution and takes potassium ions in exchange. The exchange is reversible, so it is really a sharing of potassium and sodium ions between the solution and the exchanger. We can, however, completely replace the potassium ions in the solution with sodium ions by packing a column with granules of the exchanger and letting the solution flow through it.

A SOLID ion exchanger must have three characteristics. First, it must contain ions of its own. Second, it must be insoluble in water under all conditions; this means that its molecules must be very large. Third, there must be enough space between its molecules so that small ions such as the sodium ion can move freely in and out of the solid.

The chemical structure of two typical ion exchangers is shown in the diagrams on the opposite page. An exchanger molecule contains many thousands of atoms, most of them linked together in a long chain or network. This main part of the molecule is really one big, multiply charged ion; it may have either a negative or a positive charge. To neutralize this charge, smaller ions of opposite charge are present. It is these small ions, which are not held by bonds to the rest of the molecule, that change places with ions in a solution. When the small ions are positive, the molecule is a cation exchanger; when they are negative, it is an anion exchanger.

In one of the exchangers illustrated here the free ions are negative chloride ions; in the second they are positive sodium ions. The second, a modern resinous cation exchanger, demonstrates the way in which the structure of the molecule permits free ions to move in and out. Here the chains of atoms carrying negative charges are kept a certain distance apart by bridges of benzene nuclei. The spaces between the main molecular chains are now large enough so that metallic ions, and even relatively large ions like those of vitamin B or nicotine, can diffuse in and out easily.

A granule of ion exchanger may be likened to a submicroscopic sponge. In the channels of the sponge are many tiny fish (ions). There is a law, corresponding to the law of electrical neutrality, which says that the number of these fish must always be constant. If the sponge is surrounded by nothing but water, therefore, the fish cannot escape but must stay inside the sponge. But if we put the sponge into a tank containing other tiny fish, some of these will swim into the sponge, and an equal number of its original population can now swim out. The mingling is not entirely promiscuous. If we start with 50 red fish in the sponge and 100 blue fish outside, we may wind up with an equilibrium in which there are always 30 red and 20 blue fish in the sponge and 20 red and 80 blue outside. The red fish evidently like the environment of the sponge more than do the blue fish. So it is in ion exchange; cation exchangers hold potassium ions more firmly than sodium ions, and sodium ions more firmly than lithium ions.

Our fish analogy can be carried further: just as big fish cannot enter a small sponge, so ions cannot enter an exchanger granule if they are too large, though they may be held on the outside of the granule to some extent. The fish analogy breaks down, however, in one respect: it is actually the number of charges, not the number of ions, that must stay constant in or on an exchanger granule. One calcium ion, for instance, displaces two sodium ions, because its electrical charge is double that of the sodium ion.

THE MOST important ion exchanger in nature is the soil. It was in soil that ion exchange was first discovered, exactly 100 years ago, by J. T. Way, a consulting chemist to the Royal Agricultural Society of England. He was curious to know how soil could hold a water-soluble fertilizer, such as potash (potassium chloride) or sulfate of ammonia, so strongly that rain could not wash it out. He made an experiment in which he allowed a solution of potash to percolate through soil in a jar with a hole in the bottom and analyzed the water that dripped out of the bottom. The experiment revealed that the potash released from the soil a chemically equivalent quantity of chloride of lime or soda. We would say that the potassium ions displaced calcium and sodium ions from the soil. Once the potassium ions are inside the soil, no amount of rain water will wash them out, because it is impossible to separate positively-charged ions from the negatively-charged "sponge" of the soil. But the potassium ions can be washed out by irrigation water containing sodium ions, for the latter displace them.

It is certain minerals, notably clays, and acids formed from decaying vegetation that are responsible for the soil's ion-exchanging ability. In 1858 a chemist in Germany named H. Eichhorn used this knowledge to create the first synthetic exchanger. He mixed sodium silicate and sodium aluminate solutions and produced a white jelly which, when dried and crushed into small pieces, made an excellent exchanger. This material is still one of the most important commercial exchangers today; it is used on an immense scale for softening water.

A new era in ion exchange opened in 1935, when the British chemists B. A. Adams and E. Leighton Holmes announced they had prepared synthetic resins which had ion-exchanging properties. Their resins were chemically analogous to bakelite, but more strongly ionized and more permeable. (Bakelite itself is an ion exchanger, though a very poor one.) All synthetic resins consist of long chainlike or weblike molecules, so they can be made into exchangers simply by building ionic groupings onto them and arranging for suitable permeability. Today many different types of ion-exchanging resins are commercially available. It is becoming possible to produce "tailor-made" resins suited to the particular needs of the process in which they are to be used. This is accomplished by varying such factors as the degree of ionization, permeability, capacity (number of ions per unit volume) and selectivity (ability to hold one ion more strongly than another). Another advantage of the resin exchangers is that they are not broken down by acid or alkaline solutions.

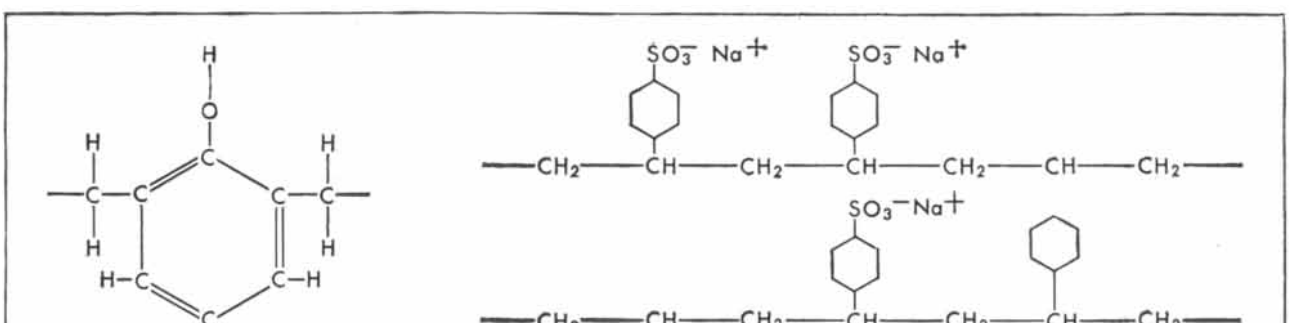
Meanwhile Dutch and German industrial chemists have found that a good cation exchanger can be made by treating bituminous coal with concentrated sulfuric acid. Chemically this material is related to the humic acids of soil. It does not have the capacity of the newer resins, and it is inferior to them in certain other respects, but it is far cheaper and has a very wide industrial use in the U. S.

THE MOST important commercial application of ion exchange, as has already been suggested, is the softening of water. As we obtain it from rivers, lake or wells, water always has some impurities. Usually it contains ions of calcium and magnesium, which make it "hard." When such water is boiled, it leaves hard, scaly deposits of carbonates and sulfates; when its ions combine with soap, they form a curd. It can be "softened" by exchanging the calcium and magnesium ions for sodium ions, which do not form a curd with soap or produce boiler scale. The water is passed through a bed of ion-exchanger granules, which take up the water's calcium ions and substitute sodium ions for them. Fresh hard water is constantly poured on to the top of the bed, so its top layers lose virtually all their sodium ions and become saturated with calcium. The layers at the bottom, however, hold their sodium ions for quite a while, because the water reaching them has already been softened. The result is a very efficient use of the exchanger; for a long time the water that emerges from the bed contains no detectable trace of calcium. This in spite of the fact that ion exchanges are reversible! The ion-exchange column offers a fine example of a reversible chemical reaction which can be driven virtually to completion by always keeping one of the reactants in excess, in this case the sodium-saturated exchanger at the bottom of the bed.

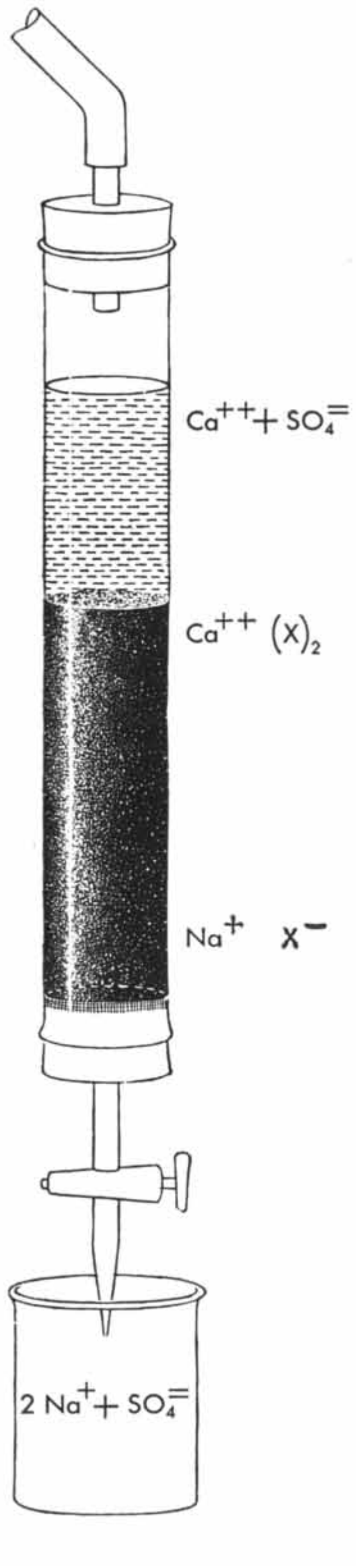
When the whole bed has finally become so loaded with calcium that calcium ions begin to appear in the water flowing out at the bottom, it is an easy matter to rid it of calcium and restore its sodium ions. The flow of hard water is stopped and a concentrated sodium chloride brine is allowed to run slowly through the bed. The excess of sodium ions reverses the exchange process; now the calcium ions are washed out and replaced by sodium ions. This is called regeneration of the exchanger. It makes it possible to use the same charge of exchanger over and over again for many years.

The largest ion-exchange softening plant in the world belongs to the Metropolitan Water District of Southern California. Each day it softens 400 million gallons of water, using 400 tons of salt for regeneration.

The process just described does not purify the water; it merely exchanges one impurity for another. For some purposes, such as manufacturing pharmaceuticals, washing photographic film, or filling high-pressure boilers, any impurity in the water is harmful. The purity of distilled water is needed. But distillation is expensive. Thanks to the organic ion exchangers, it is possible to get "distilled" water without distilling, and at a small fraction of the cost. The "raw" water, containing, let us say, calcium sulfate and calcium bicarbonate, passes first through a bed of organic cation exchanger which has been regenerated with acid and therefore contains exchangeable hydrogen ions. When the bed takes calcium ions from the water,



MOLECULAR DIAGRAMS of two resinous ion exchangers show only segments of their repeating structures. In these two exchangers chloride (Cl^-) and sodium (Na^+) ions are exchanged for other ions of the same charge.



ION-EXCHANGER BED exchanges calcium (Ca^{++}) for sodium ions. X^- stands for the negatively-charged segment of cation exchanger molecule. Na^+X^- is the exchanger itself.

it releases these hydrogen ions in their place. The water leaving the bed also contains negative bicarbonate (HCO_3^-) and sulfate ($SO_4^{=}$) ions. Some hydrogen and the atoms in HCO_3^- recombine to form carbon dioxide. (The water is passed through a degasifier where the carbon dioxide is removed.) Now the water contains only H^+ and $SO_4^{=}$, the ions of sulfuric acid. It passes next through a bed of anion exchange resin which contains negative hydroxyl (OH^-) ions. This exchanger absorbs the sulfate ions and gives up the hydroxyl ions in exchange. The latter then combine with the hydrogen ions in the water and form more water. Thus the water that finally flows from this bed contains no ions in solution at all. The whole process is known as "deionization" or "demineralization." If only ionic impurities were present originally, the process will deliver a water as pure as distilled water.

If the water has a large salt content, however, purification by ion exchange costs more than by distillation. This is true, for example, of sea water, which is about 3.05 per cent salt. Consequently we cannot at present expect ion exchange to provide a practical method of producing potable water from the sea. But it is an economically feasible method for brackish waters which contain .2 to .3 per cent of solids. Such water supplies exist in many desert regions. To purify them for irrigation purposes at a price a farmer can afford demands that the chemicals for regeneration be used very efficiently, but it has been done. A plant now operating in the Negeb Desert in Israel is producing irrigation water at 20 cents per thousand gallons—less than a third the cost of distillation.

During the war compact little ion exchangers were used in life-raft emergency kits for making drinking water from sea water. Each kit had a plastic bag and six tablets the size of candy bars, consisting of a special high-capacity cation exchanger, with silver ion as its replaceable cation. One tablet was put in the bag with a pint of sea water, and the bag was kneaded to speed up the circulation of the ions. The exchanger took the sodium and magnesium ions from the sea water. The silver ions that were thereby driven from the exchanger combined with the chloride ions remaining in the water to form insoluble silver chloride. The water, after straining through a canvas filter, was then fit to drink.

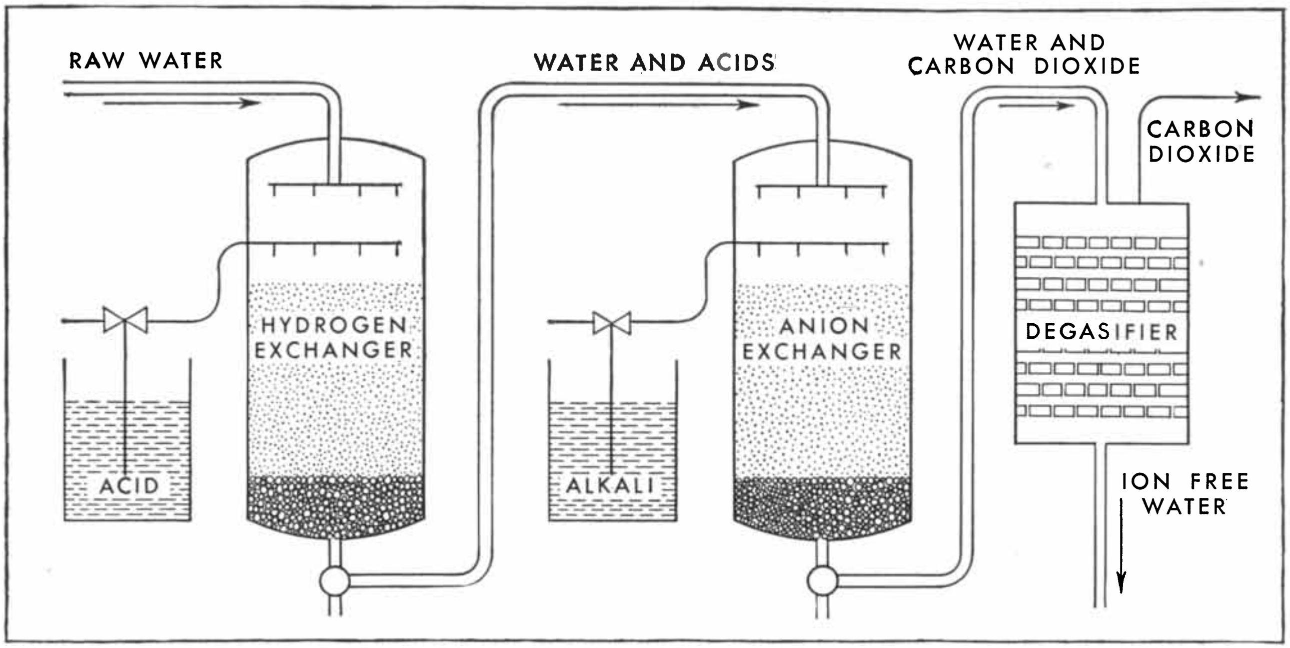
ION EXCHANGE can remove ionic or saltlike impurities from other fluids besides water; indeed, from any substance that is not itself ionized. Next to water treatment the most important commercial use of ion exchange today is the removal of salts from beet juice in the making of sugar. The salts present in the raw juice interfere with the crystallization of the sugar, and an increased yield of better quality sugar can be obtained if they are removed. They are separated out in a two-step process by exchanger beds that allow the non-ionized sugar to pass on. Similar processes are used to recover sugar from pineapple cannery waste, pectin from citrus wastes and lactose from cheese whey.

Ion exchange is also used to "soften" cow's milk for infants. Cow's milk normally contains some 25 per cent more calcium than human milk does, and it forms a hard, leathery curd in the stomach which a baby cannot digest easily. Replacement of some of the calcium by sodium by treatment with a cation exchanger yields a more digestible product known as "soft-curd milk."

Ion exchange has recently found two applications in medicine. One is a treatment for gastric ulcers. Ulcers are associated with high acidity, *i.e.*, a high concentration of hydrogen ions in the stomach. The patient is fed an anion exchange resin containing replaceable hydroxyl ions. When displaced from the exchanger, the hydroxyl ions combine with the hydrogen ions to neutralize the acidity. This resin tastes no worse than dry cereal and is completely nontoxic. The other medical use of ion exchange is the relief of edema (swelling of the tissues) resulting from high blood pressure. The swelling is caused by an excess of water in the tissues, and it can be reduced by removing sodium ions, which attract water, from the body. This can be done by feeding cation exchange resins.

When ions that have entered an exchanger from a solution are released again by regeneration of the exchanger, they usually come out in more concentrated form than in the original solution. This provides a means for recovering valuable materials from dilute solutions from which their extraction by other methods would be unprofitable. For example, the electroplating and viscose-rayon industries each year throw away vast quantities of copper and other metals, in the form of dilute solutions of their salts. This not only wastes metal but pollutes the rivers into which the solutions are discharged. A start toward recovery of these metals by ion exchange has been made. The waste solutions are passed through cation exchanger beds. A heavy metal cation such as the copper ion generally is strongly held by an exchanger, so the recovery is fairly effective. When the exchanger can hold no more metal ions, it is regenerated with a relatively concentrated acid or salt solution. The metal salt solution that comes out is concentrated enough to be used again for the original purpose.

Similarly alkaloids can be recovered from dilute plant extracts, nicotine from tobacco wastes, quinine from cinchona bark, the vitamin thiamin and the antibiotic streptomycin from dilute concen-



ION-FREE WATER is produced by a two-stage ion-exchange process. In hydrogen exchanger positive metallic ions are exchanged with hydrogen ions, *i.e.*, salts are converted into their corresponding acids. In anion exchanger negative ions are exchanged. The ions displaced by those in the raw water pass off as water and carbon dioxide. The hydrogen exchanger is "regenerated" with acid; the anion exchanger is regenerated with alkali.

trations of them, tartaric acid from grape wastes in wine-making, citric and ascorbic acids from citrus juice. Some of the monosodium glutamate sold today for food flavoring is recovered from the ion exchangers used in beet-sugar refining. The number of such applications is legion and increases almost daily.

ONE of the great uses of ion exchange has been in biological research, particularly the investigation of proteins. When the structure of a protein is broken down by hydrolysis, the wreckage is a tangled mixture of amino acids, the protein's building blocks. The amino acids are very difficult to separate and purify. Ion exchange is by far the best means that has yet been found for doing so.

Amino acids have the interesting property that they are at the same time acids and bases. They can therefore form negative ions, positive ions or neutral molecules, depending on the acidity of their solution and on the amino acid concerned. A cation exchanger will take up the positive ions and an anion exchanger the negative ions, while the neutral molecules are absorbed by neither. So the amino acids can be neatly separated into three groups.

Ion exchange can go further: it can even separate individual amino acids, provided they have the same charge. Their separation depends on the fact that all ions are not held with equal strength by an exchanger. In the case of inorganic ions, the larger the ion, other things being equal, the more strongly it is held; this is true for anions as well as cations. In the case of the amino acids the relations are more complicated, but there are still differences in the strength of attachment which make separations of some of them possible. A small amount of a solution containing the mixture of amino acids is poured on to the top of a tall column of exchanger. The top of the column takes up all the ions, *i.e.*, the amino acids. Then a regenerating solution is run slowly through the column. The ions of the regenerant displace the amino acids from the top of the exchanger and force them farther down the column. The amino acid that is least strongly bound by the exchanger is displaced first and moves farthest down the column. It is therefore the first to emerge from the bottom of the column. The taller the column, the greater the ultimate difference in the movement of the various ions. If the column is long enough, all of the first constituent of the mixture will emerge before any of the second appears. Thus each amino acid successively comes out of the column completely separated from the others.

This technique, called "chromatography," is also used to separate the fission products from uranium, particularly the rare-earth elements. As every chemist knows, the rare-earth elements are so nearly alike in their properties that separation is extremely tedious. Indeed, before the ion-exchange method was developed, only one or two of them had ever been obtained in much better than 95 per cent purity. Now they can be got 99.99 per cent pure and better. Similar separations have been made between the metals zirconium and hafnium, the "identical twins" of the periodic table.

In the biochemical field ion exchange has provided a tool for fascinating studies of the constituents of cell nuclei—nucleic acids and nucleotides—which are so similar to one another that they are nearly impossible to separate by conventional means.

THE applications of ion exchange are now so numerous that I have been able to mention only a small part of them; there are many more in catalysis, in the manufacture of colloidal suspensions, in analytical chemistry and so on. Yet the great diversity of applications must not lead us to undue optimism about their industrial possibilities. We must remember that separation processes which work beautifully with a few milligrams, or even a few grams, of rare-earth mixtures will not necessarily work with tons. Ion exchange is in its nature not a highly selective process. If we could make ion-exchanging materials that were really selective, each holding a particular cation or anion much more strongly than all others, the prospects would be vastly more exciting. We could then dream of the extraction of gold or uranium from sea water by ion exchange, or of a new kind of metal mining in which solvent solutions would go underground instead of men and ion exchangers would do the rest.

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Is Man Here To Stay?

Throughout evolutionary history all dominant forms of life except man have been supplanted. Thus far the new dominant forms have sprung from unobtrusive, unspecialized creatures

by Loren C. Eiseley

THE THOUGHT that the human race may one day disappear from the earth is somehow intolerable, even though in most epochs men have not considered the danger immediate or personal. Man has never been finicky about speculating on the possible end of the planet; the event lies so far off in the indeterminable future that it is scarcely real to finite brains. But the end of a dominant species, particularly if it be one's own, is not so easy to dismiss with a shrug. Even scientists seem loath to deal with the subject. The idea clashes with our submerged yearnings for a goal, for a purpose related to ourselves. The notion of human extinction troubles our wish to participate, even though vicariously, in the triumphs of our descendants, and to see their line perpetuated through the unbounded eras of the future.

I have before me a scientific work in which the author writes optimistically: "The earth may last for ten thousand million years yet before it and all its life are dead, so man has more time at his disposal than ever the dinosaurs had." Pierre Lecomte du Noüy in *Human Destiny* goes even further. He says that from now on man's "path separates from that of the rest of living beings, which he will always dominate. Evolution will continue through him alone." The appeal of such reassuring expressions is obvious. They link with Tennyson's hopeful dream of "that far-off divine event toward which the whole creation moves."

Yet the archaeologist who has wandered among the fallen columns of dead civilizations, and the paleontologist who has delved into wastes of time in which whole orders of life have vanished, may well bring a certain austere perspective to the consideration of this happy fantasy. In this dread hour of prospective atomic warfare, it will do us no harm to measure man and the substance of his dreams with realism. If he is to find his freedom and his length of years, it can be only through an adequate knowledge of life and not of dreams.

There is a widespread tendency to conceive of the course of evolution as an undeviating upward march from the level of very simple organisms to much more complex ones. We are inclined to think of man as the crown and culmination of this movement and the natural point of origin for any further progress. The syllogism runs something like this: Evolution is an upward movement. Man is the most intelligent form of life on the planet. Therefore he will continue to dominate the earth throughout future time, or he will himself give rise to some more perfect and intellectual species as far superior to us as we are superior to our heavy-browed, lumbering forerunners of the Pleistocene.

This last statement is very significant. In it lies the major source of the confusion we manifest about human destiny. We know that man has moved along a particular line that has led to greater and greater intellectual triumphs. We know his brain has grown and his body has altered. We call this process evolution, and we tend not to understand why it cannot go on through an indefinite future. The confusion lies in the fact that we fail to distinguish adequately between progressive evolution in a single family line and those greater movements which adjust life to the rise and fall of continents or the chill winds of geological climate.

There is a pulse in the earth to which life in the long sense adjusts, but it is a rhythm so slow that it is imperceptible in short-line evolution. We can grasp its significance and its indifference to the aspirations of individual life forms only when we call the roll of the ages and note the number of the vanished. Even if we concentrate only upon the Age of Mammals, ignoring the strange departed amphibians of the Paleozoic or the stalking giants of the Age of Reptiles—even then we discover that whole orders and families have passed out of existence. Many of these creatures were highly successful in their day. Yet as one compares the durability of the simpler creatures with that of the more efficient, one may be led to comment cynically that to evolve is to perish. In general it is slow-moving, inconspicuous creatures such as the common opossum that have come down the long range of time unmodified and "immortal." It has been observed by students of fossil life that in a surprising number of instances the danger of extinction can be shown to be proportional to the rapidity of evolutionary change.

The subject is a very complex one, of course, because obviously the completely inadaptive organism cannot master a shifting environment. Life must evolve to live. Why, then, are we confronted with the paradox that he who evolves perishes? Are we not the highest animal? And what, among all things that fly or creep or crawl, is more apt to inherit the future than we are?

THE one great biological principle that seems to deny man's hopes for continued dominance of the planet is known as the "law of the unspecialized." It is one of the curious ironies of scientific history that the discoverer, or at least the formalizer, of this law was a devout Quaker scientist who put forth his views during the full flush of 19th-century enthusiasm for evolutionary progress. He was Edward Drinker Cope, undoubtedly one of the greatest naturalists America has ever produced. It is hardly necessary here to enter into a sterile debate as to what constitutes a biological "law" or whether such laws exist. Let us call Cope's "law of the unspecialized" merely a brilliant generalization, based on his extensive knowledge of the vertebrate faunal successions throughout past time.

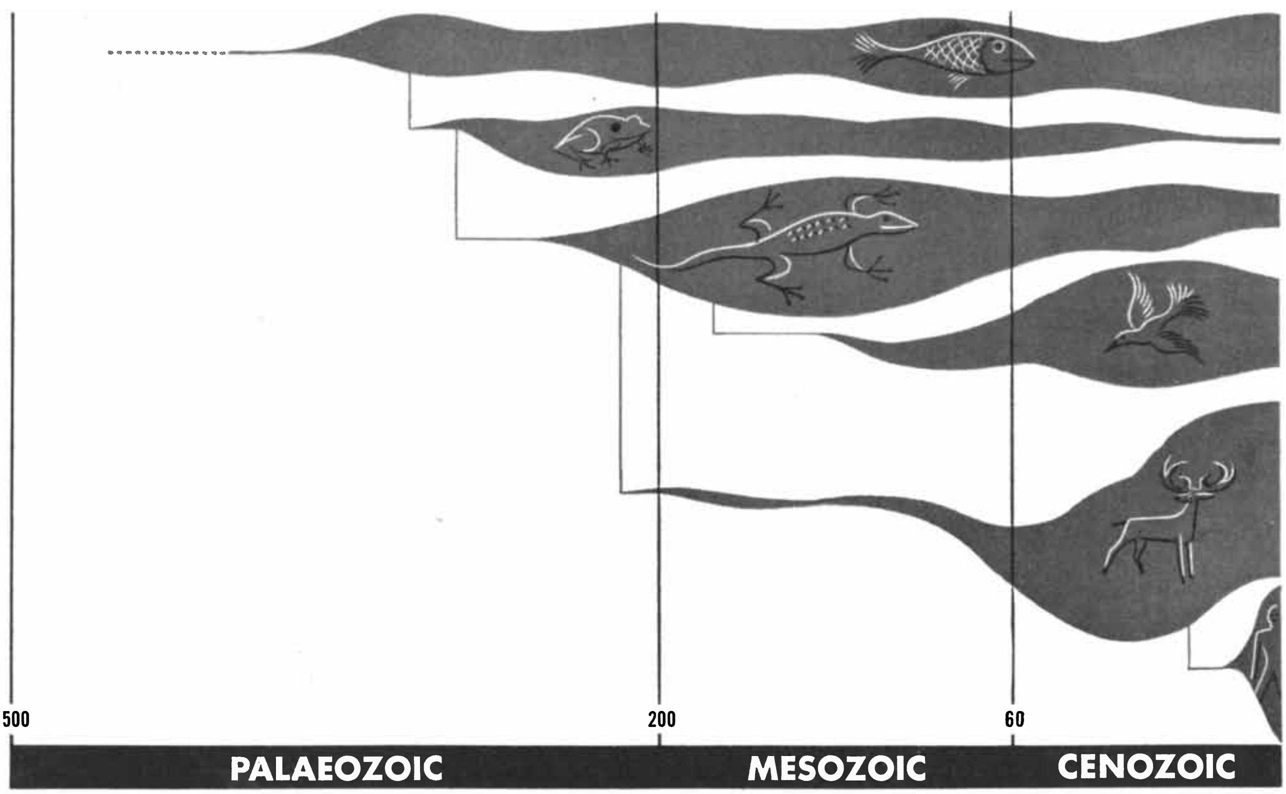
The gist of this generalization is that the leaps ahead in evolution generally take off from comparatively unspecialized forms of life, rather than from the most highly developed. In Cope's words: "The highly developed, or specialized types of one geological period have not been the parents of the types of succeeding periods but . . . the descent has been derived from the less specialized of preceding ages." It is the more adaptable and generally the smaller forms that are best able to meet the onset of new conditions which destroy the already dominant and successful types. The first amphibians arose not from a highly successful fish but from a slow-swimming, foul-water form which had to be peculiarly adaptable. Similarly, the first mammals came not from one of the specialized dragon reptiles but from a smaller and much less specialized reptile which was learning to control its blood temperature. Another climbing, jumping reptile became a bird. All were small, all were the fortunate possessors of traits that offered the potentialities of successful adaptation to new climates or new media.

Each of these insignificant, stumbling but remarkably endowed creatures founded explosive dynasties. Climbing out of the seas and marshes to the uninhabited air or land, entering into some still region whose previous occupants were dead, they radiated with amazing rapidity into a diversity of forms. The new forms grew ever more specialized as they adapted to the particular niches in the environment that they came to occupy. Many of these specializations are of quite remarkable character. Yet in the long course of evolution they threaten to reduce the adaptability of the form in case it should ever find its particular evolutionary corridor blocked or destroyed. The problem is a little like that presented to an elderly glass-blower, let us say, when glass-blowing becomes mechanized. His environmental zone has changed, yet he is old; he is no longer able to master a new field. He is through —and so it may be, in even more brutal ways, in the world of animal life.

IT is true that the history of evolution shows some instances in which a specialized form continues successfully for a long period, vanishes and then millions of years later is reincarnated in the form of similar adaptations in the same environment. Such oddities are not always easy to explain. Probably in some cases the death of a dominant form destroys its enemies along with it, so that the particular corridor is left open for renewed exploitation by a later creature which begins to evolve down the same pathway. A typical instance has been described by Edwin H. Colbert of the American Museum of Natural History. The crocodile-like Phytosaurs of Triassic times became extinct, yet the same environmental zone was entered by the true crocodilians in the Jurassic, and they have continued to be a highly successful organism ever since. Though unrelated, both reptiles assumed remarkably similar shapes. This is progressive evolution in a limited sense, but it is a very confining type of movement.

The kind of evolution that produces great advances or changes must be more versatile. Thus the small arboreal animals of the Age of Reptiles, having achieved a stable body temperature, survived the passing of the dinosaurs. Venturing on to the world of dry land, they underwent an explosive radiation which carried some of them back to the sea, some of them into the night world of the mole, some into the armor of the slow-moving Glyptodons. Some reached elephantine proportions, some inserted themselves into tiny environmental crevices where they survived as rare oddities. Each, in a sense, sacrificed something for a narrower proficiency; the armored his speed and wit, the great carnivore his ability to live if his prey became extinct.

Thus the evolutionary paradox becomes plain: The highly and narrowly adapted flourish, but they move in a path which becomes ever more difficult to retrace or break away from as their adaptation becomes perfected. Their proficiency may increase, their numbers may grow. But their perfect adaptation, so necessary for survival, can become a euphemism for death. Climates change, vegetation changes, enemies perfect their weapons, continental ice-fields advance, indirect competitors may smother the corridor. Sooner or later an impasse develops, an impasse which a small, omnivorous creature that has "specialized" in generalized adaptability and inconspicuousness may escape, but which the perfected evolutionary instrument



EVOLUTION OF VERTEBRATES is roughly plotted on the basis of time and the relative dominance of each group. From top to bottom are fishes, amphibians, reptiles, birds, mammals and man. The horizontal coordinate is numbered in millions of years. New groups sprang from early unspecialized forms of older groups.

never can. Consider, for example, the disaster that would overtake an animal like the tubular-mouthed toothless anteater if extinction overtook the social insects. The anteater could never readjust. He would starve in the midst of food everywhere available to the less specialized. He will last only as long as his strange environmental niche remains undisturbed.

The question we are mainly interested in is: Is man a specialized or a generalized creature? Are we the refined end-product of an evolutionary line whose genetic plasticity has about reached its limit, or are we the departure point for an undreamed of future? An answer of sorts can be given, but it has to be given with great care and with much attention to precise definition. We will want to ask, first of all, whether there really is such a thing as an "unspecialized" animal. My answer is that there is, and that, furthermore, it robbed our kitty's food dish last night. It is no mere intellectual abstraction.

PROBABLY the major confusion that has developed about Cope's principle of the unspecialized animal is the tendency to imagine it as some kind of inchoate "archetype" creature capable of galloping off in several evolutionary directions at once. No such animal ever existed, and Cope never intended to suggest that it had. The term "unspecialized" is used only in a comparative sense, and in this sense we need not look far, even today, to find examples. The opossum that stole up our back stairway last night and turned the cat's tail into a frightened bush has marched unchanged through 80 million years of geological upheaval. As George Gaylord Simpson observes in his widely read recent book, *The Meaning of Evolution*: "It has been suggested that all animals are now specialized and that the generalized forms on which major evolutionary developments depend are absent. In fact all animals have been more or less specialized, and a really generalized living form is merely a myth or an abstraction. It happens that there are still in existence some of the less specialized—that is, less narrowly adapted and more adaptable—forms from which radiations have occurred and could, as far as we can see, occur again. Opossums are not notably more specialized now than in the Cretaceous and could almost certainly radiate again markedly if available space were to occur again." Nature, in other words, seems to keep available creatures whose life zones are broad enough for renewed experimentation if the need arises.

It is evident, then, that there are two currents in the evolutionary flow, although neither is completely separate from the other. There are times when only a person gifted with foreknowledge of the future could indicate which of these streams means progress. But in general one of the streams is not really progressive. It is simply the perfection of specialization: the creation of the ideally adjusted parasite, of the glowing monster of the abyssal seas, the saber-toothed tiger, the fish with batteries in its belly. All of this is remarkable beyond words, but beneath these superficial diversions a deeper flow has carried life up from the waters, perfected its chemical adjustments, conquered the land, stabilized bodily temperature, developed nervous systems of growing complexity and brought into being the mind, whereby the universe examines itself.

So far this broad upward movement has never retraced its steps. Not that it has not wandered or specialized, or lost itself in peculiar and constricted niches, but once a new level of organization has been attained, it has not been lost, and the old has dwindled in importance. The Crossoptyrigian fishes gave rise to the amphibians and vanished almost totally. The amphibians, making further lung and limb adjustments, then gave rise to the reptiles. The latter then contributed the two great living groups—the mammals and birds. In all these cases it was not the largest or most highly specialized of the new classes that produced the succeeding forms. It was instead the smaller, less spectacular and more adaptable types. Man, who derives from a comparatively generalized and ancient order of mammals, has opened a strange new corridor of existence—the cultural corridor. With the appearance of culture the biologist is confronted with a true innovation.

THERE exist in various obscure parts of the globe certain ancient and remarkable forms of life. They are, one might say, the immovable immortals. Is that quick-witted, volatile and short-lived parvenu, man, destined to join their company? Has his mastery over environment, the greatest yet achieved by any animal, created the first highly specialized but truly adaptable organism? Does his one great specialization—his brain—mean escape at last from the disasters that have stalked all other forms?

There is a creature something like man that may provide a hint, though it crawls in another shape. Like man, it is an agriculturist and a city builder. It numbers, like man, in the millions, and like man it has mastered the problem of food storage and distribution. In its dark cities it knows something of the common warmth and security, the thrusting back of the harsh natural environment, that man has so recently achieved. This creature is the ant.

You will object at once that ants are physically and mentally remote from men. So they are, but in their tremendous, if minute, activities they have achieved a remarkably humanlike adaptability. The tropical Attas ant, for example, has solved the food problem by controlled culture of domesticated fungi. We need not linger over the details or over the even more ancient kingdoms of the termites. The important point is that the ants have led their present lives for more than 80 million years, while man's civilization is scarcely more than 7,000 years old. They are the oldest cosmopolites; they have sheltered longest, grown food, escaped many of the violences of the mammalian world. We shall want to ask just one question: "Have they changed?" It would seem they have changed very little, if at all. They are one of the small "immortals." They attained their present relatively high biological specialization very long ago and have since been marking time or evolving so slowly that the modifications are extremely minor.

The reason for this long life without noticeable change would seem to lie in a perfect environmental balance. Even the creatures' parasites are old. The remarkable instinct-built cities, playing a part roughly equivalent to our own metropolises, have provided shelter, food and protection. The stability of perfect adjustment has set in.

It can justifiably be contended, of course, that man, by reason of his cultural malleability, his ability to invent, to progress, to introduce changes into his environment, is in a much more dynamic and unstable relationship with nature than the social insects. But it is also true that man's cultural proclivities are directed toward making life easier for himself. He prepares food which makes an elaborate dentition superfluous, and which actually encourages its disappearance. His machines transport him with little effort on his own part. His clothing, his air-conditioned houses, his medical devices all protect him from the harsh natural environment that controls the survival and directs the evolution of other animals. As a living organism man is still susceptible in some degree to environmental influences and genetic drift, but natural selection has ceased to operate intensively upon him. To be sure, competition in implements and methods of warfare may well determine the increase or relative decline in significance of particular racial types in given moments of human history. There is nothing in the present life of man, however, to suggest the likelihood of striking increases in brain development or other remarkable innovations in human structure. We may expect at most a few mild changes toward a reduced dentition and other small adjustments if civilization and its luxuries continue.

Man, in other words, gives every sign of having reached, by a different road from that of the social insects, an equivalent environmental mastery. It would take a formidable and unforeseen world cataclysm to thrust him once more naked into the wilderness out of which he emerged. It is conceivable that his propensities for destruction may bring about his self-extinction, but because of his worldwide distribution and enormous expansion in numbers this is extremely unlikely.

The 19th century drew from the century before it a concept of human progress which the evidence of the earth's history does not entirely justify. Evolutionists do not see at work any inner perfecting principle that would automatically improve a given organism after it has achieved a certain stability of relationship with its environment. Rather the pace of evolution steadily becomes slower, until the vicissitudes of time demand new adjustments or force the now-specialized organism toward extinction. "No fixed law," wrote Charles Darwin, "seems to determine the length of time during which any single species or any single genus endures."

Darwin, like his 18th-century forerunners, believed in progressive change and predicted that "we may look with some confidence to a future of great length . . . all corporeal and mental endowments will tend to progress towards perfection." Yet curiously this quotation lies at the close of a paragraph in which he said: "Of the species now living very few will transmit progeny of any kind to a far distant futurity."

THE primate order is old. Man is a comparatively young branch of that order, but his great brain marks him as specialized in a way peculiarly apt to bring an end very soon to his physical modifications and advancement. Indeed, there is evidence that *Homo sapiens* has not altered markedly for hundreds of thousands of years. Yet man's strange specialization has introduced a new kind of life into the universe—one capable within limits of ordering its own environment and transmitting that order through social rather than biological heredity.

If man can master quickly his individualistic propensities for destruction, he may be able to become another of the small immortals. Even to this, however, judging by the records of the geological past, there will come an end some day. Sooner or later Cope's law of the unspecialized will have its chance once more. When it does, we can only hope that the beings who will replace our dominance upon earth may be, if not wiser and gentler, at least less diabolically inventive than ourselves.

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BOOKS

An approach to mathematics through some diverting mathematical pictures

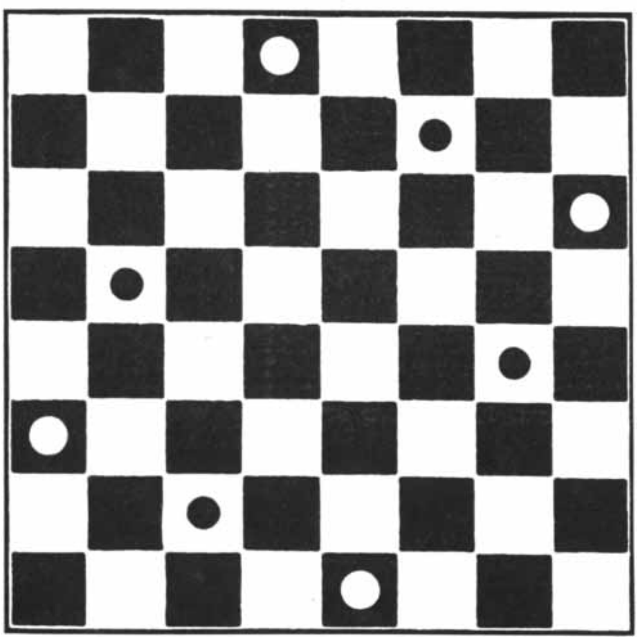
by James R. Newman

MATHEMATICAL SNAPSHOTS, by Hugo Steinhaus. Oxford University Press ($4.50).

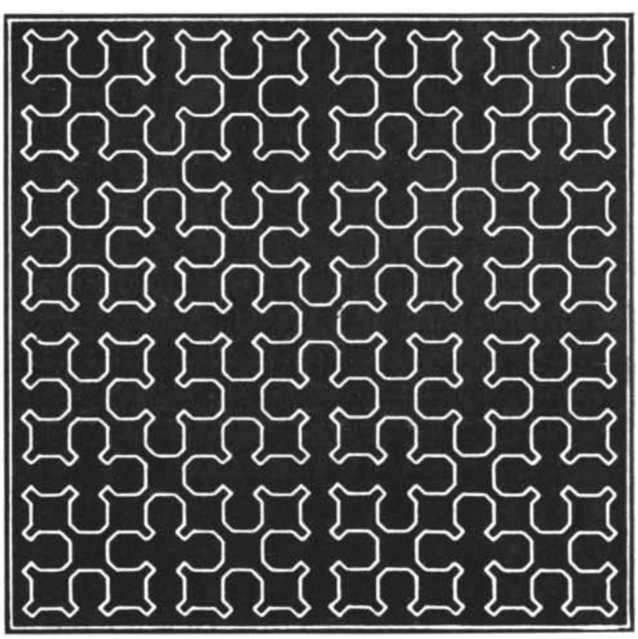
MATHEMATICS presents certain difficulties because, as Sir Bernard Darwin has said about golf, you must learn it first and think about it afterwards. There are many of us who would like to understand the subject better, to get the hang of it beyond the mere ability to arrive at the same sum when adding a column from bottom up and top down. But the preparations required for this increase of knowledge often prove too arduous. One evinces good intentions by buying the latest popular book on mathematics and, if resolve holds, even makes an attempt to read it. The ensuing disillusionment is swift and drastic; it is soon discovered that the mystique of square roots and fractions is as disagreeably elusive as ever, that if these elementary matters are not mastered, further progress in the art is impossible, that the publisher's blurb to the effect that here at least is a way to glide painlessly to the summit is a monstrous deception. It is disconcerting to learn that a ready grasp of the intricacies of world affairs does not enable one to answer such questions as: If it takes three men seven hours to build a hen house and a half, how many hen houses can five men build in an hour and a quarter? And it is particularly humiliating to find that your 12-year-old son, who knows nothing about the designs of Mao Tse-tung or the Schuman Plan, regards the hen-house problem as tiresomely simple. There is of course no law of nature that a man's mind gets sharper as he grows older.

This book by Hugo Steinhaus offers consolation for these melancholy truths. In its seemingly haphazard way it affords, in exchange for a relatively small expenditure of reader effort, a remarkably spacious view of the subject. It is a book to stretch the imagination without unduly straining the mind; but this is not to say that if you enjoy grappling with difficult ideas you will be disappointed, for they are to be found here in abundance.

The first edition of *Mathematical Snapshots* was published in Poland in 1939 and has been out of print for some years. It was a delightful little volume. Besides its many handsome diagrams and striking photographs, it possessed a side pocket containing a collapsible, multicolored dodecahedron (held together by rubber bands which made it self-erecting when removed from its hiding place), a set of motion-picture cards which when rapidly riffled displayed certain geometrical laws, a pair of red and green Cagliostro spectacles which conferred three dimensions on the book's several anaglyphs, and a few other equally ingenious gadgets. Dr. Steinhaus' introduction was so modest and amiable as to disarm all criticism. "You are right," he said, "there is no system in this book; important things are omitted and trifles are emphasized. Many things do not deserve the name of mathematics, and the author himself does not seem to know what his aim really was in publishing his 'mathematical snapshots.' They are too scientific for a child and too childish for a mathematician." Still, this was excessively modest. For Steinhaus succeeded not only in serving up a repast of mathematical objects "as peculiar as the most exotic beast or bird," but his book, for all its grab-bag disorder and despite the fact that his morsels rarely more than tickled the appetite for the strange and wonderful, afforded an



CHESSBOARD PROBLEM involves eight queens, each of which can move in any direction. The queens are arranged in such a way that none can attack any other. The same result can be achieved with 91 other arrangements.



THEORETICAL PROBLEM is to draw a curve through every point in the interior and on the boundary of a square. One mathematician solves the problem with this curve, which is impossible to draw in its final form.

amazing display of the richness, the variety and especially the interrelatedness of mathematical thought. His snapshots had a dual role. They were often beautiful and fascinating in themselves and from that standpoint it was unnecessary to ask what they meant. Yet they were also pictorial representations of purely abstract relations possessing universal validity. Thus they could illumine for the thoughtful reader something of the nature of intellectual process—how we are able to interpret the physical world and make coherent and useful systems describing its behavior. The very mishmash quality of the book serves to carry out this purpose.

The new edition of *Mathematical Snapshots*, alas, omits the spectacles, the dodecahedron and the other props. Steinhaus' earlier apologia is replaced by a more formal and less informative preface. Moreover, the illustrations, though many new ones have been added, are somewhat smaller and therefore not as strikingly handsome as those in the volume printed by Ksiaznica-Atlas in Lwow. But the principal substance of the book has been preserved, and the text has been considerably expanded and improved.

Many of the old favorites among recreations are included. The secrets of the esoteric games of ticktacktoe and three-in-a-row are here exposed to vulgar view. The standard analysis is presented of the "Fifteen" or "Boss" Puzzle invented by Sam Lloyd, an oddment which for a number of years was the rage in France and Germany. (At one time it was found necessary to post a notice in the Reichstag forbidding the legislators to move the little squares in the Fifteen Puzzle while more serious matters were being considered.) Steinhaus says that the Fifteen Puzzle went out of fashion when in 1879 a mathematical explanation of it was published in the *American Journal of Mathematics*. Evidently he has not recently inspected the novelty counters of drugstores in American cities: it is my impression that more plastic Fifteen Puzzles than prescriptions are dispensed in some of these emporia. Anyone who is intrigued by chessboard puzzles (as distinguished from chess problems) and other recreations involving the so-called Graeco-Latin squares will find fresh, diverting material in Steinhaus. The great Euler, who was not merely mathematically omnipotent but omnivorous as well, is represented in these pages for his solution of the famous Seven Bridges Problem and the Problem of the Thirty-Six Officers. How is a delegation of six regiments, each of which sends a colonel, a lieutenant colonel, a major, a captain, a lieutenant and a "sub-lieutenant," to be placed so that neither in any row nor in any file will regiment or officer's rank be repeated? It is dispiriting to learn that this cannot be done, although it is possible to place 25 officers in the desired order. I do not mean to be unduly irreverent about the importance of this mathematical discovery: the solution undoubtedly represents some contribution to mathematical knowledge and, indeed, it turns out to have practical value in horticultural and genetic experiments. As Santayana wrote: "It is a pleasant surprise to [the pure mathematician] and an added problem if he finds that the arts can use his calculations, or that the senses can verify them, much as if a composer found that the sailors could heave better when singing his songs."

Without straining matters and with considerable imagination and skill Steinhaus shows the relations between rectangles, irrational numbers, falling dominoes and tunes; between tessellations, the drying mud of a river bed, the mixing of liquids, nomograms, slide rules, Lake Michigan, musical scales and the measuring of irregular areas and lengths; between soap bubbles, geodesy, the earth and moon, maps and dates; between squirrels, screws, candles, conic sections, acoustics, billiard tables, the nervous system, electrocardiograms and shadows; between the Platonic solids, crystals, bees' heads, detergents, billiard balls, a rhombic triacontahedron and the method of proportional polling where three political parties are contesting an election; between polyhedra, the city of Königsberg, haystacks, knots, dovecotes, the Möbius band, doughnuts, the coloring of maps and the combing of hair; between Boyle's law, Pascal's triangle, frogs, college freshmen, bacteria, digitalis, the height of sunflowers and the total length of American railways. I cannot elucidate any further the links connecting the members of these assemblages except to assure that Steinhaus makes the most unlikely cousinships appear quite plausible.

For those who feel a book on popular science fails unless it makes the reader goggle, there is a fine sprinkling of goggle-making revelations. The highest known prime number, $2^{127}-1=170141183460469231731687303715884105727$, can be got by putting two chessboards side by side, placing one grain (of something or other) on the first square, two on the second, four on the third—doubling through all 128 squares and then removing one grain from the last square of the second board. The number of grains remaining on that square will then be the large number written above. Although a curve is a one-dimensional figure and cannot fill space, it is nevertheless possible, as was shown by the Polish mathematician Sierpinski, to give the formula for constructing a space-filling curve that will fill a square. If you have 13 coins, one differing in weight from the others, three weighings will suffice to identify the counterfeit. (I should warn that this is not easy; in fact I remember the current rumor, when the puzzle was first talked about a few years ago, that Albert Einstein had been unable to solve it.) If three dogs are chasing one another, they are likely to be wasting their time unless they have heard of the circles of Apollonius or at least realize that the most efficient path of pursuit for all of them is along a logarithmic spiral. It takes a highly complicated machine to draw a straight line (no point in using a straightedge since you have no way of telling whether or not it is straight until you have drawn a straight line), but it is always possible to cut a sandwich with a plane stroke so as to halve the bread, the butter and the ham. (The latter problem has been most carefully considered in an article by A. H. Stone and J. W. Tukey on "generalized 'sandwich' theorems," in the *Duke Mathematical Journal.*)

This, I hope, gives the flavor of a book both entertaining and of intellectual merit. I hope it will have many readers. I can promise even those who regard all mathematics as a basilisk an agreeable surprise.

BLINDNESS: MODERN APPROACHES TO THE UNSEEN ENVIRONMENT, edited by Paul A. Zahl. Princeton University Press ($7.50). The seeing person is often uncomfortable in the presence of a blind person, and to him the blind and blindness are apt to be almost mysterious. This anthology should provide correction for the blind spots of the sighted with respect to blindness. It was prepared under the auspices of the Committee on Sensory Devices of the National Research Council, and its authors are competent research workers or teachers of the blind. The coverage is extensive, including such topics as the history of the treatment of blind people, vocational and educational problems of blindness and the fascinating search for new devices which will assist blind people "to see."

PSYCHOSOMATIC MEDICINE: ITS PRINCIPLES AND APPLICATIONS, by Franz Alexander. W. W. Norton & Co. ($4.00). People no longer have pains; they have "psychosomatic pains." Indeed, the recent emphasis on the mental and emotional causes of disease leads one to wonder how long it will be before a counter-revolution begins, under the slogan "There Is a Body." Dr. Alexander, director of the Chicago Institute for Psychoanalysis, has written a readable book in which the principal psychosomatic aspects of several diseases are described. He does not forget, however, that there are anatomical and physiological factors important in the complex disease processes of the human being. Much of his material is familiar, but of great interest are his presentations of the psychodynamics of psychosomatic illnesses in psychoanalytic terms. As an introduction to a relatively new, complex and rapidly developing branch of medicine, the book will be valuable to the reader who has some knowledge of medical and psychoanalytic terminology and theory.

SEX IN SOCIAL LIFE, edited by Sybil Neville-Rolfe. W. W. Norton & Co. ($5.00). SEX QUESTIONS AND ANSWERS: A GUIDE TO HAPPY MARRIAGE, by Fred Brown and Rudolf T. Kempton. Whittlesey House ($2.95). Sex knowledge seems still to be one of the least well-distributed commodities in Western societies, and since direct laboratory investigation of this subject by the student is discouraged, books are the principal formal medium for the dissemination of information. One can highly recommend either of these two excellent books. For the intelligent, well-educated reader, the Norton anthology will be the more satisfactory. It is well written, scholarly and covers a wide range of topics in a thorough, urbane and pleasantly philosophical manner. *Sex Questions and Answers* is for less erudite readers. Its topical range is almost as wide as that of the anthology, but its presentations are not as elaborate and its language is simple. Its authors have lectured widely on sex topics, and their book considers selected questions asked them by American soldiers and by other audiences.

C. A. C.

THE AUTOBIOGRAPHY OF ROBERT A. MILLIKAN. Prentice-Hall ($4.50). Dr. Millikan has had a long and successful career as a physicist, teacher, scientific discoverer, organizer and administrator. He has traveled widely, met and worked with the outstanding men in his field in the last 60 years, conducted important researches, been rewarded with the Nobel prize and many other honors, been blessed with unbroken good health and a happy marriage, and enjoyed thoroughly the people, the ideas, the work, the challenges that have filled his existence. All this is told in his autobiography, a book of many tedious interludes and trivial details, also somewhat overladen with sermons and ingenuous social diagnoses, yet giving withal an interesting account of a busy scientist's career and absorbing descriptions of major advances in 20th-century physics to which Millikan made essential contributions. A rare history of a civilized, happy man.

OUT OF MY LATER YEARS, by Albert Einstein. Philosophical Library ($4.75). A collection of scattered essays, statements and addresses, covering a variety of topics from Max Planck and $E=mc^2$ to socialism, militarism, Zionism and the menace of atomic destruction. The selections are, as might be expected of occasional pieces, of uneven quality and importance; yet not a few bear the characteristic stamp of Einstein's originality and insight, just as others are animated by his moral courage and humanity. A book worth reading not only for much of its content but for the mirror it holds up to the mind and temper of a profoundly simple and great man.

BRING OUT YOUR DEAD, by J. H. Powell. University of Pennsylvania Press ($3.75). An overlong but well-written dramatic account of the great plague of yellow fever that decimated Philadelphia in 1793, the most frightful collective disaster to have overtaken an American city thus far. In re-creating the events of this extraordinary calamity from a mass of documents and other sources hitherto neglected, Powell has rounded out the portrait of Benjamin Rush and has memorialized the heroic labors during the plague of a handful of men and women, including a number of former Negro slaves who gave courage and leadership to the white community which had despised them. The remarkable Dr. Rush, for all his self-sacrifice and devotion, was, by his fanatical insistence on bleeding and purging, perhaps responsible for more deaths than all the other physicians put together.

HISTORY OF PHYSICS, by Max Von Laue. Academic Press, Inc. ($2.30). A lucid survey of the entire field of physics, treated topically rather than with primary emphasis on chronology, with the result that the reader is afforded an unusual opportunity to trace the evolution of the basic concepts and theories without having to shuttle continuously, as in the more conventional histories, between the diverse major developments of each successive epoch. Von Laue writes occasionally dogmatically, often brilliantly and with a wonderfully sure mastery of subject, especially when dealing with the modern period. One may, however, question the accuracy of some of his judgments in the earlier history of physics. It is also a drawback that his terse, tightly woven exposition presupposes a broad knowledge of physics and mathematics, thus rendering the book largely inaccessible to the general reader.

PRINCIPIA MATHEMATICA (second edition), by Alfred North Whitehead and Bertrand Russell. Cambridge University Press (three volumes, $30.00). It is gratifying to be able to report that a reprint of this work, one of the great intellectual achievements of the 20th century, is again available. The *Principia* has been out of print for a number of years, and second-hand copies have been scarce as well as expensive. The text is unaltered; the paper and binding are up to the usual standard of the Cambridge University Press, which is to say, excellent; the price, all things considered, is moderate. Libraries and scholars should be very well pleased.

J. R. N.

THE AMATEUR

Conducted by Albert G. Ingalls

IN A Newtonian telescope either a right-angle prism or a diagonal mirror of plane-parallel glass serves to turn the light focused by the concave mirror at right angles into the eyepiece. If a mirror is used, its front surface must be aluminized or only about four per cent of the light will reach the eye, the remainder passing through the diagonal glass to be wasted. When observing the sun, however, the large mirror of the telescope collects far more light than the eye can accept with comfort. Then an unaluminized diagonal that wastes light in this manner actually becomes desirable. The difficulty in using such a diagonal is that a fraction of the light is reflected back from the inside of the rear surface and reappears at the front to form a second image of the sun nearly as bright as the primary one beside it.

"Obviously," writes John M. Holeman of Richland, Wash., "what is needed is a piece of glass having only one side. A more attainable alternative is to use a piece of glass having its second side tilted with respect to the first, or front, side at an angle large enough to throw the secondary image out of the field of view of the lowest-powered eyepiece to be used. Since the field of view of most telescopes is narrow, an angle of 10 degrees between the faces of the prism is adequate for most conditions. This prism is known as the Herschel wedge or solar diagonal. The following notes describe how one was made.

"The optical requirements of this prism are of the simplest. The first surface should be flat to a quarter-wavelength and well polished. The figure of the second surface is not important, since the image formed here is not to be used. The other surfaces may be left ground. This is one of the easiest prisms to make, and a good first project for the beginner in prism making.

"The prism can be made from a rectangle of plate glass if a piece with one side flat enough can be found. If optical glass is desired a tank prism can be bought and cut down. Salvage companies furnish 90-degree prisms that have entrance and exit faces 1½ inches wide and 6 inches long. The figure usually found on tank prisms is turned-down edge and ends. The faces are usually convex, one nearly flat, and the third may be anything. The flatness of the faces can be tested with interference fringes, and the best one chosen for the first surface of the solar diagonal.

"After the best surface has been marked off with a wax pencil, it is covered with painter's tape or beeswax and the prism is cut crosswise to leave a rectangular face of the desired dimensions, as shown in the upper left-hand part of the drawing at the bottom of the opposite page. [The drawing was made to illustrate this article by Russell W. Porter shortly before his death.] This may be done by hand with a hacksaw blade and coarse Carborundum grains.

"Next the prism is cut through at an angle to make a second face at about 10 degrees to the first. The rough sides are trued up and ground smooth, the first surface remaining protected by tape or wax. A stove lid or a piece of glass may be used as the tool, and the prism hand-ground on it with Carbo and water. A high-grade prism may, if preferred, be made by the special method described by Fred Ferson in *Amateur Telescope Making—Advanced* (printings since mid-1944) and then polishing as he suggests in a glass surround. This will produce a beautiful prism with truly flat sides, which is really unnecessary for the purpose. The surfaces and ends may also be ground and polished by the same means if one is quixotic enough to put in an additional 42 hours, as I did.

"There is so much opportunity for originality in making the metal parts of the accessory, and so much depends upon the equipment available to the individual, that a detailed description of a method would be useless except to a few.

"The mounting needs a tubular extension in the end that fits into the telescope where the eyepiece normally goes (the left-hand end in the illustration) and a holder at right angles to it to take the eyepiece. Between these, and at the vertex of the right angle, should be the first face of the solar wedge. This should be tilted at 45 degrees, with the thick base toward the eyepiece holder. The rear of the housing should be left open to allow the direct light and heat of the sun to escape. The simplest means of supporting the wedge is to put it behind a cut-out plate of metal slanted at the proper angle and held in place by a retainer of wood, as shown in the drawing. The completed assembly is shown at the upper right.

"Besides the prism, a dark filter is needed at the eyepiece. For the sun a war-surplus dark neutral filter (No. 605) may be had from a salvage company. For the moon, where there is also an excess of light, the light neutral filter No. 604 is excellent. It is desirable to mount the dark filter as close as possible to the eye lens of the eyepiece, so that the eye can reach the necessary eyepoint, which is pretty close in most telescope eyepieces. This is usually done by burnishing the filter into a thin circular cell like the left-hand one of the two in the lower right-hand quarter of the drawing. This cell is substituted for the screw cap of the eyepiece. A setscrew in the edge will keep it from falling off. The technique of burnishing or crimping in the filter is the same as for a lens, and is described by Porter in *Amateur Telescope Making*, page 70: a thin edge is turned up and rolled over against the glass with a small roller while the lathe is running at its fastest speed. In *Lens Work for Amateurs* Henry Orford very briefly describes this process and shows two lathe tools for burnishing, one a cutting tool with profile that excavates a hollow near the edge, the other a little roller. However, the job may be done with a round-ended tool having no roller.

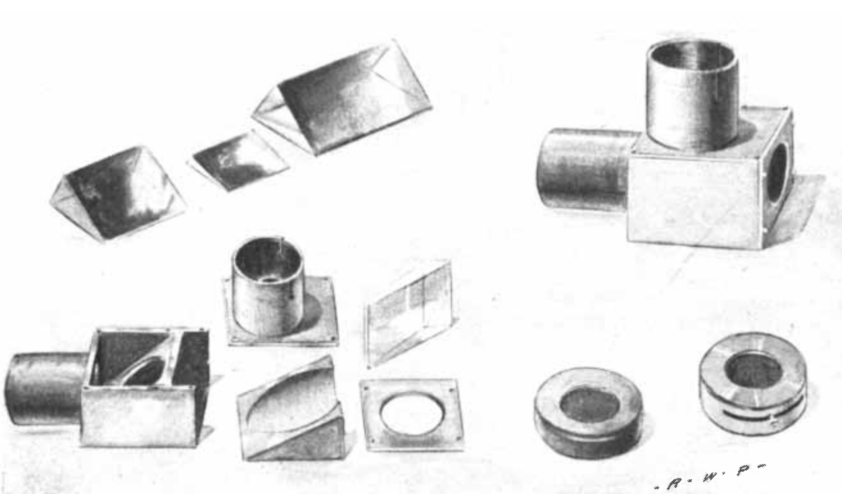
"If the variable filter shown in the lower right-hand corner of the drawing is preferred, it can be made from two small Polaroid filters No. 633. If one of these remains stationary and the other is rotated on top of it, the light will diminish gradually from about 35 per cent to practically zero. One way to mount this is to burnish one Polaroid into a rimmed cell, as with the simple filter, and to burnish the second Polaroid into a thin disk fitting into the cavity in the first cell. A retainer sprung or screwed in place keeps the whole assembly together. Rotation of the inside filter is obtained by a screw moving in a slot in the rim of the outer cell and threaded into the inner disk. The protruding head of the screw serves to rotate the filters."

After Holeman wrote the preceding article and Porter illustrated it, a question arose whose largely negative answer may nevertheless have positive value. This concerns possible injury to the eye of the observer from continued use of the second of the two types of filters described: the variable density filter.

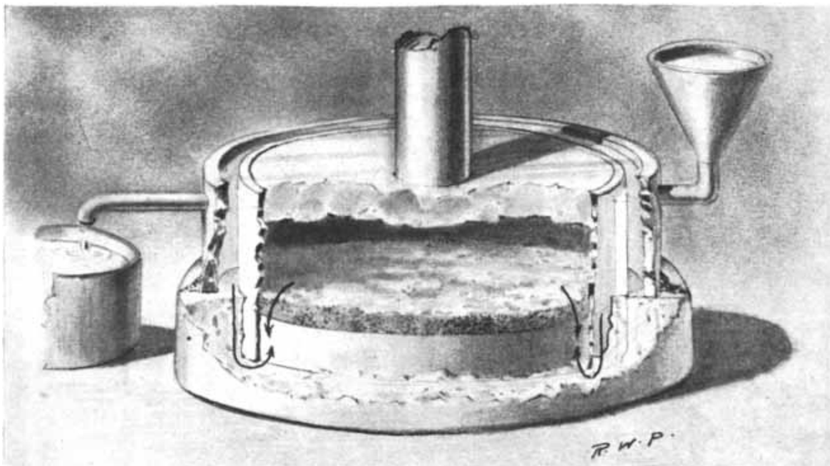
During the war the Polaroid Corporation developed its crossed Polaroid variable filter attachment that was and still is used in large numbers of military binoculars. These have virtually complete absorption for infrared and ultraviolet radiation, and may be used with safety on telescopes of any aperture—for the observation for which they were designed. They were not, however, designed for direct observation of the solar disk, and they should not be required to protect the observer under such conditions.

Preceding the filter in the optical train, with the telescope aimed squarely at the sun, is an objective lens or mirror of 6-inch or larger aperture. This gathers as much radiation as would a burning glass of the same diameter. Next is a Herschel wedge that throws 95 per cent of this radiation out of the train. But the 5 per cent that remains and passes to the filter is still far more than a filter is called upon to absorb in other kinds of observation. It is doubtful whether the variable density filter has enough absorption in the infrared to safeguard the observer while he examines the solar image, as he might, for several minutes at a time, day after day, year after year. Yet the fact that the visible light is cut down can make him think he is safe, while the invisible infrared radiation may be cooking his eye.

This in no way bears upon the use of binoculars equipped with variable density filters even in prolonged terrestrial use, nor does it bear upon Polaroid sunglasses. These absorb the ultraviolet,



Details of the Herschel wedge prism and mounting



Broadhead's device for cutting glass disks

while in normal daylight the infrared is insignificant—except when gazing directly at the sun, which our senses automatically forbid anyway. The consideration applies only to variable density filters (1) when used directly on the sun's disk (2) for prolonged observation (3) with a large light-collector.

In *Sky and Telescope,* May, 1950, Leo J. Scanlon described valuable experience with the solar-filter problem. After many experiments he found most satisfactory a telescope equipped with a Herschel wedge and, over the objective, an opaque diaphragm cut out to permit insertion of welder's filter lenses 2 inches by 4 and in several available densities.

If instead of the preceding arrangements the objective is itself reduced to small aperture, the resolving power is correspondingly reduced, while the alternative of a narrow circular opening at the edge conduces to diffraction effects.

DAVE BROADHEAD of Wellsville, N. Y., has devised a greatly improved "cookie cutter" for the purpose of cutting disks from larger pieces of glass with abrasive grains. It is shown in the illustration on this page, another drawing made by Porter shortly before his death. Its principal feature is an up-and-down pumping motion that continually flushes the broken-down abrasive and glass away from the edge of the cutter, where it would otherwise clog the groove and greatly impede the rolling of abrasive grains that do the cutting. This improvement was inspired by recollection of the "Easy" washing machine. By its use cutting was so greatly increased in speed that Broadhead was able to cut 10½-inch disks out of 12½-inch Pyrex telescope blanks 2¼ inches thick in only 2½ hours.

The drawing shows a 12½-inch Pyrex blank, on top of which is a ring of iron pipe sealed to the blank with wax. The ring might equally well be made of any kind of material. Inside it, with a narrow space between the two, is the cookie-cutter of thin metal rotated by a central shaft.

"I made this cookie-cutter airtight," Broadhead writes, "carefully sealing all its cracks with wax. Then I poured enough coarse abrasive grains on the center of the glass to spread out to a depth of perhaps ⅜-inch, lowered the cutter on the glass and filled the annular space with water. As the shaft was raised and lowered a fraction of an inch, at the rate of about once a second, water was forced in and out around the cutting edge. This kept the pasty gunk of broken-down glass and abrasive constantly flushed out of the work, and carried new abrasive to it. The gunk particles suspended in the water flow with it to the overflow pipe as water is poured at intervals into the funnel.

"On disks of 10½-inch diameter no small amount of force was needed for lifting the cookie-cutter and the column of air above it. This was applied by a 4-foot lever consisting of a 2-by-6 plank having a deep notch, or prongs, at one end. The plank was inserted over a fulcrum and under the drive pulley at the top of the vertical shaft and pumped up and down through a short amplitude. Obviously the force necessary to lift the cookie-cutter against the weight of the atmosphere would lift the Pyrex blank and all from the bench, if it were not firmly attached by clamps or otherwise.

"A part of the secret of success," Broadhead writes, "is the narrowness of the space between the cutter and the ring. Otherwise much of the unused abrasive that finds its way to this outer space will lodge there and not be used." Enough heat is generated after a time to melt the wax if the work is pushed too eagerly.

Since there is no clogging of the cutter there would be no gain in serrating its edge, as is often done in an effort to cope with clinging, pasty gunk. The vertical shaft may consist of a length of ordinary pipe running in wooden bearings in a rough temporary framework, but, unless it is held rigidly, there may be a tendency for the cutter to drift sidewise.

An attempt to drive a cookie-cutter of larger diameter than about 3 inches by means of a sensitive drill press, which the up-and-down motion of the Broadhead cutter suggests, is not likely to prove satisfactory. The too-rapid rotation would throw the water and abrasive in all directions. For large work a small drill press is also not sufficiently rigid.

Porter's drawing on this page, the last of his work that remains for posthumous presentation in this department, adequately describes an adjustable cookie-cutter, biscuit-cutter or trepan, as the instrument is designated in Britain, devised by N. C. C. Barrell of Guildford, Surrey, England. Whenever the length of the radius is readjusted the blades are removed and concaved to fit a compass-drawn circle by tapping them against the open jaws of a vise.

THERE IS NO essential difference between cookie-cutting the circumference of a disk and perforating it centrally for a Cassegrainian. In fact, the perforation in one big disk is sometimes as large as the outside diameter of another. To supplement the preceding notes on cookie-cutters, A. H. Johns of Larchmont, N. Y., who was known to be making two 16-inch Cassegrainian mirrors for others as a part of his avocation, was invited to describe his methods of trepanning, using a length of tubing as the trepan. He writes:

"I had previously drilled 1-inch and 2-inch perforations in mirrors, and had no trouble when I came to perforate the two 16-inch disks 3 inches thick with holes 4 inches in diameter. These disks weigh about 50 pounds, which permitted dispensing with holding devices other than several thicknesses of wet newspaper between the disks and the bench on which they rested. These gave an excellent grip.

"The steel drilling tube had walls ⅛-inch thick. It must be checked to assure that the walls are true, since a bulge or a taper will spell disaster.

"I did not pitch or wax a cover glass to the face of the disk, as is sometimes done to avoid splintering the glass at the entrance point. If the drill is held sufficiently rigid and the whole system is properly squared up, there will be little likelihood of such splintering. This rigidity also safeguards against the drill running down at an angle.

"Because my disks were only rough-ground at the perforating stage, and also because the hole to be cut was fairly large, I used No. 80 Carbo. This left a few pits around the edge of the perforation, but these were later eliminated in grinding the mirror curve.

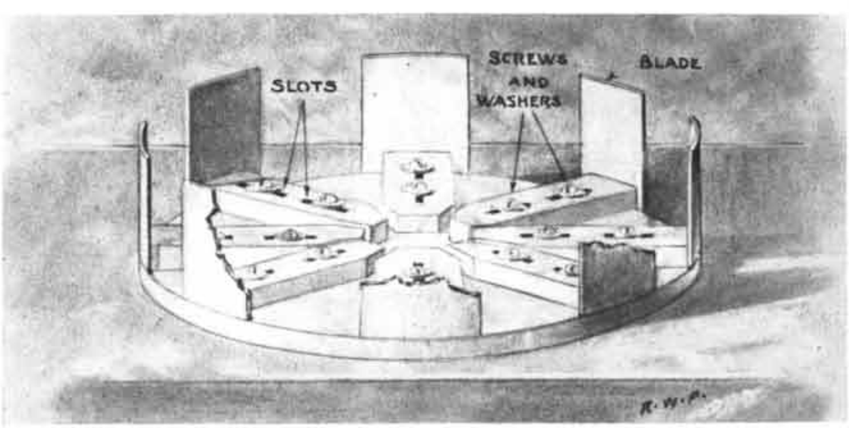
"To prevent gunk from splashing, a fence of heavy paper was wrapped around the edge of the disk. The drill was run at about 200 revolutions per minute, but there is nothing compulsory about this. For a 2-inch hole I once ran at 540 revolutions per minute, according to my log records. Plenty of Carbo and water were worked into the crevice and the grinding noise was maintained at maximum. The drill was lifted frequently, while running, to bring up the gunk and permit clean fresh Carbo to reach the bottom of the cut. When it began to pile up, this gunk was sponged away. It is not necessary to flood the surface with water.

"I ran the drill to within ¼-inch of the back, filled the cut with wax (to be left while the mirror is processed) and inverted the disk to complete it by drilling from the back. If at this point the planes of the inverted disk-faces are not made parallel with their original planes, there will be difficulty in making the cuts meet.

"Splintering occurs only where the drill emerges and not at the entrance face. Were I planning to drill straight through the disk in a single operation, and were the splintered back-face objectionable, I would first pitch or wax a cover glass over the exit area.

"If strains are already present in the glass, drilling after polishing will warp the figure.

"If a start is made with a given size of grains and a switch is later made to another size, the drill will wedge and cussing won't repair that shattered glass."



Barrell's adjustable trepan for cutting glass disks

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BUSINESS IN MOTION

To our Colleagues in American Business . . .

Temper or hardness is one of the important physical characteristics of a metal, because it affects both manufacturing processes, and the service given by the finished product. Manufacturers are generally aware of this fact, and the more complicated the piece and the fabrication methods, the more attention is paid to temper and annealing. However, it is often the case that an apparently simple part may require equally thorough consideration. Such was the case with an electric soldering "gun," which uses a 3/8-inch copper rod as the secondary of the transformer and a smaller rod for the tip. It is necessary for the rod to be sufficiently rigid, yet at the same time it must be soft enough so that during fabrication, involving shearing, coining and bending, the metal will not break, split or crack. A certain temper of rod was tried, and became twisted during fabrication, which made it difficult to assemble and interfered in other ways with the manufacture and use of the device. The cure turned out to be a slightly harder temper, hard enough to prevent the twist, but not hard enough to result in fractures during fabrication. Proper temper was the key to a perfect job, not only for the transformer secondary, but also for the soldering tip itself, which likewise has to be coined, punched, and formed into the necessary shape.

Says the manufacturer: "In addition to being extremely helpful in arriving at the proper tempers, Revere also recommended that we specify our rod in multiple lengths, and thus save considerable on scrap. They were also helpful in solving the problem of attaching the brass sleeve to the secondary rod."

The users of the soldering gun of course have no idea of the amount of testing and investigation that was necessary in order to make the device practical and advantageous for them. This is true of practically every product, whether it be a super-accurate laboratory balance for which Revere may supply metals, this soldering gun, or an automobile which may contain many pounds of Revere Copper, Brass and Bronze to assure satisfactory operation.

The point of this story is that Revere's interest in your problems by no means ends with the receipt of an order. It may well precede the order, and be maintained through very practical cooperation until you, as well as we, are convinced that the requirements of manufacture and use have been met to the maximum degree. This practice of cooperation between suppliers and manufacturers is rather common throughout industry. The paper mill and package maker will gladly work out with you the best material for your packages, for example. If you buy chemicals, the chemists may come up with something better or cheaper for your purposes, or suggest an advantageous shift in processing. There are many different types of rubber and rubber-like substances, and of glass, wood, plastics. You cannot be expected to know all about everything you buy, nor is it necessary. Simply permit your suppliers to work out with you, in full knowledge of your problems, the specification and fabrication of the material best suited for your needs. No matter what you make nor from whom you buy, the opportunity to benefit by the knowledge of your suppliers is always open to you.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

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