

A SCIENTIST OF THE FUTURE RECORDS EXPERIMENTS WITH A TINY CAMERA FITTED WITH UNIVERSAL-FOCUS LENS. THE SMALL SQUARE IN THE EYEGLASS AT THE LEFT SIGHTS THE OBJECT

# AS WE MAY THINK

## A TOP U. S. SCIENTIST FORESEES A POSSIBLE FUTURE WORLD IN WHICH MAN-MADE MACHINES WILL START TO THINK

by VANNEVAR BUSH

DIRECTOR OF THE OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

Condensed from the *Atlantic Monthly*, July 1945

This has not been a scientists' war; it has been a war in which all have had a part. The scientists, burying their old professional competition in the demand of a common cause, have shared greatly and learned much. It has been exhilarating to work in effective partnership. What are the scientists to do next?

For the biologists, and particularly for the medical scientists, there can be little indecision, for their war work has hardly required them to leave the old paths. Many indeed have been able to carry on their war research in their familiar peacetime laboratories. Their objectives remain much the same.

It is the physicists who have been thrown most violently off stride, who have left academic pursuits for the making of strange destructive gadgets, who have had to devise new methods for their unanticipated assignments. They have done their part on the devices that made it possible to turn back the enemy. They have worked in combined effort with the physicists of our allies. They have felt within themselves the stir of achievement. They have been part of a great team. Now one asks where they will find objectives worthy of their best.

\* \* \*

There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for prog-

ress, and the effort to bridge between disciplines is correspondingly superficial.

Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call.

Mendel's concept of the laws of genetics was lost to the world for a generation because his publication did not reach the few who were capable of grasping and extending it. This sort of catastrophe is undoubtedly being repeated all about us as truly significant attainments become lost in the mass of the inconsequential.

Publication has been extended far beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships.

But there are signs of a change as new and powerful instrumentalities come into use. Photocells capable of seeing things in a physical sense, advanced photography which can record what is seen or even what is not, thermionic tubes capable of controlling potent forces under the guidance of

less power than a mosquito uses to vibrate its wings, cathode-ray tubes rendering visible an occurrence so brief that by comparison a microsecond is a long time, relay combinations which will carry out involved sequences of movement more reliably than any human operator and thousands of times as fast—there are plenty of mechanical aids with which to effect a transformation in scientific records.

Machines with interchangeable parts can now be constructed with great economy of effort. In spite of much complexity, they perform reliably. Witness the humble typewriter, or the movie camera, or the automobile. Electrical contacts have ceased to stick when thoroughly understood. Note the automatic telephone exchange, which has hundreds of thousands of such contacts, and yet is reliable. A spider web of metal, sealed in a thin glass container, a wire heated to brilliant glow—in short, the thermionic tube of radio sets is made by the hundred million, tossed about in packages, plugged into sockets—and it works! Its gossamer parts, the precise location and alignment involved in its construction, would have occupied a master craftsman of the guild for months; now it is built for 30¢. The world has arrived at an age of cheap, complex devices of great reliability, and something is bound to come of it.

A record, if it is to be useful to science, must be continuously extended, it must be stored and, above all, it must be consulted. Today we make the record conventionally by writing and photography, followed by printing; but we also record on film, on wax disks and on magnetic wires. Even if utterly new recording procedures do not appear, these present ones are certainly in the process of modification and extension.

#### NEW WAYS TO EXTEND THE RECORD— THE CYCLOPS CAMERA AND DRY PHOTOGRAPHY

Certainly progress in photography is not going to stop. Faster material and lenses, more-automatic cameras, finer-grained sensitive compounds to allow an extension of the minicamera idea are all imminent. Let us project this trend ahead to a logical, if not inevitable, outcome. The camera hound of the future wears on his forehead a lump a little larger than a walnut. It takes a picture three millimeters square, later to be projected or enlarged. The lens is of universal focus, down to any distance accommodated by the unaided eye, simply because it is of short focal length. There is a built-in photocell on the walnut such as we now have on at least one camera which automatically adjusts exposure for a wide range of illumination. There is film in the walnut for a hundred exposures and the spring for operating its shutter and shifting its film is wound once for all when the film clip is inserted. It produces its results in full color. It may well be stereoscopic and record with two spaced glass eyes, for striking improvements in stereoscopic technique are just around the corner.

The cord which trips its shutter may reach down a man's sleeve within easy reach of his fingers. A quick squeeze, and the picture is taken. On a pair of ordinary glasses is a square of fine lines near the top of one lens, where it is out of the way of ordinary vision. When an object appears in that square, it is lined up for its picture. As the scientist of the future moves about the laboratory or the field, every time he looks at something worthy of the record, he trips the shutter and it goes, without even an audible click. Is this all fantastic? The only fantastic thing about it is the idea of making as many pictures as would result from its use.

Will there be dry photography? It is already here in two forms. There have long been films impregnated with diazo dyes which form a picture without development, so that it is already there as soon as the camera has been operated. An exposure to ammonia gas destroys the unexposed dye, and the picture can then be taken out into the light and examined. The process is now slow, but someone may speed it up, and it has no grain difficulties such as now keep photographic researchers busy.

#### REDUCING THE WRITTEN RECORD TO MANAGEABLE SIZE—MICROPHOTOGRAPHY

Like dry photography, microphotography still has a long way to go. The basic scheme of reducing the size of the record, and examining it by projection rather than directly, has possibilities too great to be ignored. The combination of optical projection and photographic reduction is already producing some results in microfilm for scholarly purposes, and the potentialities are highly suggestive. Today, with microfilm, reductions by a linear factor of 20 can be employed and still produce full clarity when the material is re-enlarged for examination.

Assume a linear ratio of 100 for future use. Consider film of the same thickness as paper, although thinner film will certainly be usable. Even under these conditions there would be a total factor of 10,000 between the bulk of the ordinary record on books, and its microfilm replica. The *Encyclopaedia Britannica* could be reduced to the volume of a matchbox. A library of a million volumes could be compressed into one end of a desk. If the human race has produced since the invention of movable type a total record, in the form of magazines, newspapers, books, tracts, advertising blurbs, correspond-



Dr. Vannevar Bush is head of the Office of Scientific Research and Development, which marshaled the scientific brains of the U.S. in the service of the war. As such he has performed one of the greatest, though most secret, jobs of the war, as important in its sphere as that of the Army chief of staff. Under his direction 6,000 scientists worked on such projects as the development of radar and the atomic bomb.

In the July issue of the *Atlantic Monthly* Dr. Bush published an article in which he set a great task for men of science in the peacetime world. Man has piled up a staggering body of knowledge—so staggering, in fact, that men of learning have great difficulty in finding and using the parts they want. It is the task of science, Dr. Bush says, to make this store of knowledge more available, to aid the human memory. Says the *Atlantic*, "Like Emerson's famous address of 1837 on 'The American Scholar,' this paper by Dr. Bush calls for a new relationship between thinking man and the sum of our knowledge."

LIFE is indebted to the editors of the *Atlantic Monthly* for permission to bring a condensed version of this important article to its larger audience.

#### WHAT DR. BUSH FORESEES

##### Cyclops Camera

Worn on forehead, it would photograph anything you see and want to record. Film would be developed at once by dry photography.

##### Microfilm

It could reduce *Encyclopaedia Britannica* to volume of a matchbox. Material cost: 5¢. Thus a whole library could be kept in a desk.

##### Vocoder

A machine which could type when talked to. But you might have to talk a special phonetic language to this mechanical supersecretary.

##### Thinking machine

A development of the mathematical calculator. Give it premises and it would pass out conclusions, all in accordance with logic.

##### Memex

An aid to memory. Like the brain, Memex would file material by association. Press a key and it would run through a "trail" of facts.

## Do you believe in spanking a child?



**WHEN HE THROWS A TANTRUM...** A good walloping won't help. If the tantrum is caused by *frigid*. If your child shows signs of *tear* when you try to give him a laxative—be careful! It may be that the medicine tastes bad or that it upsets him afterwards. You'll have to admit, yourself, that

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**SUPERSECRETARY OF THE COMING AGE**, the machine contemplated here would take dictation, type it automatically and even talk back if the author wanted to review what he had just said. It is somewhat similar to the Voder seen at New York World's Fair. Like all machines suggested by the diagrams in this article, it is not yet in existence.

### AS WE MAY THINK CONTINUED

ent, having a volume corresponding to a billion books, the whole affair assembled and compressed, could be lugged off in a moving van.

The material for the microfilm *Britannica* would cost a nickel, and it could be mailed anywhere for a cent. What would it cost to print a million copies? To print a sheet of newspaper, in a large edition, costs a small fraction of a cent. The entire material of the *Britannica* in reduced microfilm form would go on a sheet 8½ by 11 inches. Once it is available, with the photographic reproduction methods of the future, duplicates in large quantities could probably be turned out for a cent apiece beyond the cost of materials. The preparation of the original copy? That introduces the next aspect of the subject.

#### THE AUTHOR NEED NOT WRITE—

##### HE COULD TALK HIS THOUGHTS TO A MACHINE

Will the author of the future cease writing by hand or typewriter and talk directly to the record? He does so indirectly, by talking to a stenographer or a wax cylinder, but the elements are all present if he wishes to have his talk directly produce a typed record. All he needs to do is to take advantage of existing mechanisms and to alter his language.

At a recent world fair a machine called a Voder was shown. A girl stroked its keys and it emitted recognizable speech. No human vocal cords entered into the procedure at any point; the keys simply combined some electrically produced vibrations and passed these on to a loudspeaker. In the Bell Laboratories there is the converse of this machine, called a Vocoder. The loudspeaker is replaced by a microphone, which picks up sound. Speak to it, and the corresponding keys move. This may be one element of the postulated system.

The other element is found in the stenotype, that somewhat disconcerting device encountered usually at public meetings. A girl strokes its keys languidly and looks about the room and sometimes at the speaker with a disquieting gaze. From it emerges a typed strip which records in a phonetically simplified language a record of what the speaker is supposed to have said. Later this strip is retyped into ordinary language, for in its nascent form it is intelligible only to the initiated. Combine these two elements, let the Vocoder run the stenotype, and the result is a machine which types when talked to.

Our present languages are not especially adapted to this sort of mechanization, it is true. It is strange that the inventors of universal languages have not seized upon the idea of producing one which better fitted the technique for transmitting and recording speech. Mechanization may yet force the issue, especially in the scientific field, whereupon scientific jargon would become still less intelligible to the layman.

One can now picture a future investigator in his laboratory. His hands are free and he is not anchored. As he moves about and observes, he photographs and comments. Time is automatically recorded to tie the two records together. If he goes into the field, he may be

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connected by radio to his recorder. As he ponders over his notes in the evening, he again talks his comments into the record. His typed record, as well as his photographs, may both be in miniature, so that he projects them for examination.

#### SIMPLE REPETITIVE THOUGHT COULD BE DONE BY MACHINE, FOLLOWING LAWS OF LOGIC

Much needs to occur, however, between the collection of data and observations, the extraction of parallel material from the existing record, and the final insertion of new material into the general body of the common record. For mature thought there is no mechanical substitute. But creative thought and essentially repetitive thought are very different things. For the latter there are, and may be, powerful mechanical aids.

Adding a column of figures is a repetitive thought process, and it was long ago properly relegated to the machine. True, the machine is sometimes controlled by a keyboard, and thought of a sort enters in reading the figures and poking the corresponding keys, but even this is avoidable. Machines have been made which will read typed figures by photocells and then depress the corresponding keys; these are combinations of photocells for scanning the type; electric circuits for sorting the consequent variations, and relay circuits for interpreting the result into the action of solenoids to pull the keys down.

All this complication is needed because of the clumsy way in which we have learned to write figures. If we recorded them positionally, simply by the configuration of a set of dots on a card, the automatic reading mechanism would become comparatively simple. In fact, if the dots are holes, we have the punched-card machine long ago produced by Hollerith for the purposes of the census, and now used throughout business. Some types of complex businesses could hardly operate without these machines.

Adding is only one operation. To perform arithmetical computation involves also subtraction, multiplication and division, and in addition some method for temporary storage of results, removal from storage for further manipulation and recording of final results by printing. Machines for these purposes are now of two types: keyboard machines for accounting and the like, manually controlled for the insertion of data, and usually automatically controlled as far as the sequence of operations is concerned; and punched-card machines in which separate operations are usually delegated to a series of machines and the cards then transferred bodily from one to another. Both forms are very useful, but as far as complex computations are concerned, both are still in embryo.

Rapid electrical counting appeared soon after the physicists found it desirable to count cosmic rays. For their own purposes the physicists promptly constructed thermionic-tube equipment capable of counting electrical impulses at the rate of 100,000 a second. The advanced arithmetical machines of the future will be electrical in nature and they will perform at 100 times present speeds or more.

Moreover, they will be far more versatile than present commercial machines, so that they may readily be adapted for a wide variety of operations. They will be controlled by a control card or film, they will select their own data and manipulate it in accordance with the instructions thus inserted, they will perform complex arithmetical computations at exceedingly high speeds and they will record results in such form as to be readily available for distribution or for later further manipulation. Such machines will have enormous appetites. One of them will take instructions and data from a whole roomful of girls armed with simple keyboard punches and will deliver sheets of computed results every few minutes. There will always be plenty of things to compute in the detailed affairs of millions of people doing complicated things.

It is a far cry from the abacus, with its beads strung on parallel wires, to the modern keyboard accounting machine. It will be an equal step to the arithmetical machine of the future. But even this new machine will not take the scientist where he needs to go. Relief must be secured from laborious detailed manipulation of higher mathematics as well, if the users of it are to free their brains for something more than repetitive detailed transformations in accordance with established rules. A mathematician is not a man who can readily manipulate figures; often he cannot. He is not even a man who can readily perform the transformations of equations by the use of calculus. He is primarily an individual who is skilled in the use of symbolic logic on a high plane, and especially he is a man of intuitive judgment in the choice of the manipulative processes he employs.

All else he should be able to turn over to his mechanism, just as confidently as he turns over the propping of his car to the intricate mechanism under the hood. Only then will mathematics be prac-



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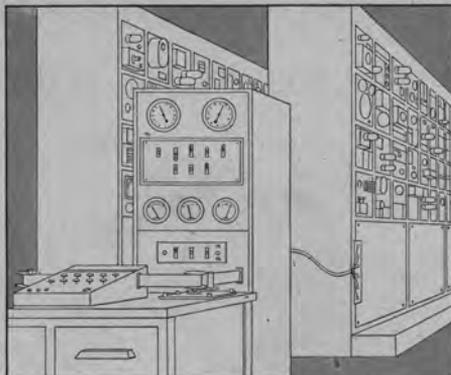
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**THINKING MACHINES** would solve not only the most difficult mathematical problems but even problems of logical thought. Mathematical problems would be fed by punched tape to the electronic device in the racks at rear. Results, accomplished in a fraction of the time it takes man, would be recorded on dials at top and bottom of control board.

## AS WE MAY THINK CONTINUED

tically effective in bringing the growing knowledge of atomistics to the useful solution of the advanced problems of chemistry, metallurgy and biology. For this reason there will come more machines to handle advanced mathematics for the scientist. Some of them will be sufficiently bizarre to suit the most fastidious connoisseur of the present artifacts of civilization.

The scientist, however, is not the only person who manipulates data and examines the world about him by the use of logical processes, although he sometimes preserves this appearance by adopting into the fold anyone who becomes logical, much in the manner in which a British labor leader is elevated to knighthood. Whenever logical processes of thought are employed—that is, whenever thoughts for a time runs along an agreed groove—there is an opportunity for the machine. Formal logic used to be a keen instrument in the hands of the teacher in his trying of students' souls. It is readily possible to construct a machine which will manipulate premises in accordance with formal logic simply by the clever use of relay circuits. Put a set of premises into such a device and turn the crank and it will readily pass out conclusion after conclusion, all in accordance with logical law. We may some day click off arguments with the same assurance that we now enter sales on a cash register. But the machine of logic will not look like a cash register, even of the streamlined model.

## HOW TO CONSULT THE RECORD—MACHINES EXAMINE THE FILES AND SELECT RELATED ITEMS

So much for the manipulation of ideas and their insertion into the record. Thus far we seem to be worse off than before—for we can enormously extend the record; yet even in its present bulk we can hardly consult it. This is a much larger matter than merely the extraction of data for the purposes of scientific research; it involves the entire process by which man profits by his inheritance of acquired knowledge. The prime action of use is selection, and here we are halting indeed. There may be millions of fine thoughts, and the account of the experience on which they are based, all encased within stone walls of acceptable architectural form; but if the scholar can get at only one a week by diligent search, his syntheses are not likely to keep up with the current scene.

In a narrow sense something has already been done mechanically on selection. The personnel officer of a factory drops a stack of a few thousand employe cards into a selecting machine, sets a code in accordance with an established convention and produces in a short time a list of all the employes who live in Trenton and know Spanish. Even such devices are much too slow when it comes, for example, to matching a set of fingerprints with one of five million on file. Selection devices of this sort will soon be speeded up from their present rate of reviewing data at a few hundred a minute. By the use of photocells and microfilm they will survey items at the rate of a thousand a second and will print our duplicates of those selected.

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## AS WE MAY THINK CONTINUED

This process is simple selection: it proceeds by examining in turn every one of a large set of items and by picking out those which have certain specified characteristics. There is another form of selection best illustrated by the automatic telephone exchange. You dial a number and the machine selects and connects just one of a million possible stations. It does not run over them all. It pays attention only to a class given by a first digit, then only to a subclass of this given by the second digit, and so on; and thus proceeds rapidly and almost unerringly to the selected station. It requires a few seconds to make the selection, although the process could be speeded up if increased speed were economically warranted.

### THE HUMAN BRAIN FILES BY ASSOCIATION—THE MEMEX COULD DO THIS MECHANICALLY

The real heart of the matter of selection, however, goes deeper than a lag in the adoption of mechanisms by libraries, or a lack of development of devices for their use. Our ineptitude in getting at the record is largely caused by the artificiality of the systems of indexing. When data of any sort are placed in storage, they are filed alphabetically or numerically and information is found (when it is) by tracing it down from subclass to subclass. It can be in only one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. Having found one item, moreover, one has to emerge from the system and re-enter on a new path.

The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics, of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature.

Man cannot hope fully to duplicate this mental process artificially, but he certainly ought to be able to learn from it. In minor ways he may even improve, for his records have relative permanency. The first idea, however, to be drawn from the analogy concerns selection. Selection by association, rather than by indexing, may yet be mechanized. One cannot hope thus to equal the speed and flexibility with which the mind follows an associative trail, but it should be possible to beat the mind decisively in regard to the permanence and clarity of the items resurrected from storage.

Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and to coin one at random, "memex" will do. A memex is a device in which an individual stores all his books, records and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

It consists of a desk, and while it can presumably be operated from a distance, it is primarily the piece of furniture at which he works. On the top are slanting translucent screens on which material can be projected for convenient reading. There is a keyboard and sets of buttons and levers. Otherwise it looks like an ordinary desk.

In one end is the stored material. The matter of bulk is well taken care of by improved microfilm. Only a small part of the interior of the memex is devoted to storage, the rest to mechanism. Yet if the user inserted 5,000 pages of material a day it would take him hundreds of years to fill the repository, so he can be profligate and enter material freely.

Most of the memex contents are purchased on microfilm ready for insertion. Books of all sorts, pictures, current periodicals, newspapers are thus obtained and dropped into place. Business correspondence takes the same path. And there is provision for direct entry. On the top of the memex is a transparent platen. On this are placed longhand notes, photographs, memoranda, all sorts of things. When one is in place, the depression of a lever causes it to be photographed onto the next blank space in a section of the memex film, dry photography being employed.

There is, of course, provision for consultation of the record by the usual scheme of indexing. If the user wishes to consult a certain book, he taps its code on the keyboard and the title page of the book promptly appears before him projected onto one of his viewing positions. Moreover, he has supplemental levers. On deflecting one of these levers to the right he runs through the book before him, each page in turn being projected at a speed which just allows a recognizing glance at each. If he deflects it further to the right, he steps through the book ten pages at a time; still further, 100 pages at a time. Deflection to the left gives him the same control backwards.

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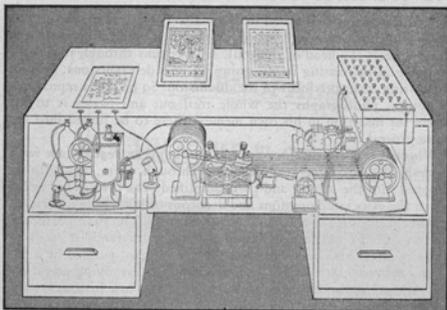
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MEMEX in the form of a desk would instantly bring files and material on any subject to the operator's fingertips. Slanting translucent viewing screens magnify supermicrofilm filed by code numbers. At left is a mechanism which automatically photographs longhand notes, pictures and letters, then files them in the desk for future reference.

## AS WE MAY THINK CONTINUED

index. Any given book of his library can thus be called up and consulted with far greater facility than if it were taken from a shelf. As he has several projection positions, he can leave one item in position while he calls up another. He can add marginal notes and comments, taking advantage of one possible type of dry photography, and it could even be arranged so that he can do this by a stylus scheme, such as is now employed in the telautograph seen in railroad waiting rooms, just as though he had the physical page before him.

### BUILDING "TRAILS" OF THOUGHT ON THE MEMEX— UNLIKE MEMORY, THEY WOULD NEVER FADE

All this is conventional, except for the projection forward of present-day mechanisms and gadgetry. It affords an immediate step, however, to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select another immediately and automatically. This is the essential feature of the memex. The process of tying two items together is the important thing.

When the user is building a trail, he names it, inserts the name in his code book and taps it out on his keyboard. Before him are the two items to be joined, projected onto adjacent viewing positions. At the bottom of each there are a number of blank code spaces and a pointer is set to indicate one of these on each item. The user taps a single key and the items are permanently joined. In each code space appears the code word. Out of view, but also in the code space, is inserted a set of dots for photocell viewing; and on each item these dots by their positions designate the index number of the other item.

Thereafter, at any time, when one of these items is in view, the other can be instantly recalled merely by tapping a button below the corresponding code space. Moreover, when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book. It is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book. It is more than this, for any item can be joined into numerous trails.

The owner of the memex, let us say, is interested in the origin and properties of the bow and arrow. Specifically he is studying why the short Turkish bow was apparently superior to the English long bow in the skirmishes of the Crusades. He has dozens of possibly pertinent books and articles in his memex. First he runs through an encyclopedia, finds an interesting but sketchy article, leaves it projected. Next, in a history, he finds another pertinent item and ties the two together. Thus he goes, building a trail of many items. Occasionally he inserts a comment of his own, either linking it into the main trail or joining it by a side trail to a particular item. When it becomes evident that the elastic properties of available materials had a great deal to do with the bow, he branches off on a side trail which takes him through textbooks on elasticity and tables of physical constants. He inserts a page of longhand analysis of his own. Thus he builds a trail of his interest through the maze of materials available to him.

And his trails do not fade. Several years later, his talk with a friend turns to the queer ways in which a people resist innovations, even of vital interest. He has an example in the fact that the out-



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# PARIS GARTERS

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CONTINUED ON NEXT PAGE

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ranged Europeans still failed to adopt the Turkish bow. In fact, he has a trail on it. A touch brings up the code book. Tapping a few keys projects the head of the trail. A lever runs through it at will, stopping at interesting items, going off on side excursions. It is an interesting trail, pertinent to the discussion. So he sets a reproducer in action, photographs the whole trail out and passes it to his friend for insertion in his own memex, there to be linked into the more general trail.

Wholly new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified. The lawyer has at his touch the associated opinions and decisions of his whole experience and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case, and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds, and side trails to their physical and chemical behavior.

The historian, with a vast chronological account of a people, parallels it with a skip trail which stops only on the salient items, and can follow at any time contemporary trails which lead him all over civilization at a particular epoch. There is a new profession of trail blazers, those who find delight in the task of establishing useful trails through the enormous mass of the common record. The inheritance from the master becomes not only his additions to the world's record but, for his disciples, the entire scaffolding by which they were created.

Thus science may implement the ways in which man produces, stores and consults the record of the race. It might be striking to outline the instrumentalities of the future more spectacularly, rather than to stick closely to methods and elements now known and undergoing rapid development, as has been done here. Technical difficulties of all sorts have been ignored, certainly, but also ignored are means as yet unknown which may come any day to accelerate technical progress as violently as did the advent of the thermionic tube.

Man has built a civilization so complex that he needs to mechanize his records more fully if he is to push his experiment to its logical conclusion and not merely become bogged down part way there by overtaxing his limited memory. The applications of science have built him a well-supplied house and are teaching him to live healthily therein. They have enabled him to throw masses of people against one another with cruel weapons. They may yet allow him truly to encompass the great record and to grow in the wisdom of race experience. He may perish in conflict before he learns to wield that record for his true good. Yet, in the application of science to the needs and desires of man, it would seem to be a singularly unfortunate stage at which to terminate the process or to lose hope as to the outcome.



**MEMEX IN USE** is shown here. On one transparent screen the operator of the future writes notes and commentary dealing with reference material which is projected on the screen at left. Insertion of the proper code symbols at the bottom of right-hand screen will tie the new item to the earlier one after notes are photographed on supermicrofilm.

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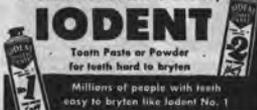
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