the time necessary to read *Chemical Abstracts* in his chosen field to say nothing of the primary references pertaining thereto.

The chemist employed by industry, for the most part, enjoys the advantages of specialized library aid in calling to his attention papers of direct interest to him. The university professor can depend (in general) on graduate students to keep him abreast of the literature amidst his multitudinous distractions such as proliferating committee assignments within his own institution and increasing demands on his time invoked by service on a multitude of advisory committees. I presume these situations are unavoidable. Parkinson's Law seems to have afflicted the universities. The alternative to service on advisory committees is allocation of grants for research subsidized by the government based on recommendations from professional civil servants and bureaucrats who, with the best of intentions, may not only be incapable of proper evaluation of the merits of a particular proposal but only too frequently because of their undoubtedly very excellent capacity for administration are far removed from the current life stream of research.

We are thus on the horns of a dilemma. Time devoted to advisory panels, committees, *etc.*, is time taken from that which should be available for current contact with contemporary literature. On the other side of the argument is the problem of awarding increasing dollar amounts for research without adequate review by those most competent to evaluate research proposals in their respective areas. You just can't have your cake and eat it too.

What is the solution? In my opinion (which is most assuredly open to argument) the answer to this dilemma lies in the publication of *critical* reviews of various aspects of organic chemistry. I intentionally emphasize the term "critical." A review prepared by a company librarian encompassing all references to a given topic without critical evaluation of the relative merits of the cited references will most assuredly cause more trouble than can be compensated for the good will it generates. Similarly an uncritical compilation of data by a graduate student or a post-doctoral assistant will fall into the same pit. What is needed are *critical* (again emphasized) reviews by experts in given areas in which the relative scientific merits of all papers dealing with these topics are assessed. This applies particularly to the patent literature in which, unfortunately, too much graphite and cellulose chemistry is found. In compiling such critical reviews obviously some sensitive toes will be trodden on. It is sincerely to be hoped that, when this stage is reached, authors will not be bound by personal bias but, rather, will give the subject under discussion completely objective treatment.

This, then, is my closing plea: That either through the established mechanism of *Chemical Reviews* or some presently unestablished publication provision be made for *critical* surveys of appropriate areas not only of organic chemistry but of all areas of chemistry. I predict that the dividends will be enormous and that the burden of keeping *en courant* with current literature in general (rather than in isolated specialties) will be greatly lightened.

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The Relation of the Industrial Technical Literature to Creativity*

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In recent article, Jacques Barzun[1] made the important point that the same word—creativity—should not be applied to the chimpanzee's daub, or the four-year old's smear, and also to the Mona Lisa. Creativity should be concerned with the significant.

Definition.—The writer's definition of creativity is this: it is the ability to formulate new combinations of social worth. This definition covers the arts as well as the sciences, a symphony or a novel as well as a chemical investigation. For every creation is a new combination. Creativity formulates the absolutely new as sum from old.

A philosopher will be quick to point out that there is nothing new under the sun, to which I should reply, nay, rather, there is nothing old under the sun, nothing the same this minute as it was last. The philosopher will also have a comment to make on the term, social worth. This means, in simple terms, the creation must be given form, and the resulting formulation must be accepted as valuable by a social group. The larger this group is, and the longer the formulation holds the stage as a valuable

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unit, the more clearly stands its worth as a creation, and its author as a creator. We all construct fantasies, pleasing for the moment, comforting to the ego, but of no worth. If the fantasy is formulated into a novel, and published, and is read with pleasure, it is a creation. The years winnow the wheat from the chaff, and determine the value of the work to larger and larger successive groups. Many creations in the arts and sciences already have had value to mankind for thousands of years.

Nature of Creativity.—A chemist can use the form of a chemical equation to generalize that creativity means a new combination

$$A + B \rightarrow C$$

In this equation, A is found to be one item of the combination, and also to involve an objective, goal, quest, or unanswered question. B is the matching piece which serves two purposes, both to trigger and to complete the new combination, C. Let this be illustrated with a famous example.

Example 1—Newton

A: There is the knowledge of the deviation of the motion of the moon from a straight line, and the question, why?

+

B: There is the observation, the apple falls from the tree, and the knowledge of its rate

↓

C: The creation, the moon falls too.

For the deviation of the moon and the fall of the apple were at the same rate. From this realization came the concept of a universe knit with a single force.

Another example is taken from the arts.

Example 2—Impressionism

A: There is the concept, that light is the real subject of pictorial art; many things are worth painting to show a special effect of light upon nature. But how?

B: Pure colors in close juxtaposition give the effect of shadings of light

↓

C: An impressionistic work of art.

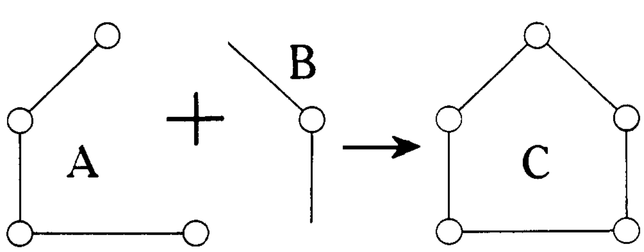

Fig. 1. Creative Closure

This instance has been used because it is also an excellent example of what Duncker[2] calls a *model of search*, that is, a formula for creation. Historically, the schools of literature, of art, and of science, have been founded by men who produced these great, generalized insights. In the example given, one has the formula for secondary creation within the scope of the primary: find an interesting light pattern, and paint the areas of different intensity with suitable pure color variations.

In the writer's own research experience in the field of the cold waving of hair, the material in a recent paper[3] can be set up in this A + B → C form (but disclaiming the scope of the other examples):

A: Thioglycolic acid for cold waving of the hair has certain drawbacks, that modifications might remedy. Which one is best?

+

B: The simplest derivative of an acid is an amide

↓

C: Try amide for waving, and find special, advantageous properties,

The amide was found by us as early as 1951 to be expecially good, being, for example, effective at lower pH values than the acid. However, it turned out to be a sensitizer, and two models of search for other related nitrogen compounds were set up to correct this. Using these models

$$HSCH_2\ CONHX \text{ and } HSC_2H_4NHY$$

appropriate groups were substituted for X and Y, and a considerable number of mercaptans were synthesized.

Notice the similarities here. Creative method and creative process (and also creative personality) are the same in all fields.

Creations of course are not usually set up in the mind in this formal way. Rather, one has a problem in mind, or a mind attuned to problems, and something triggers item C. By analysis, the creation can then be cast in the A + B → C form. Then it appears that the creative work was to arrange a pattern in the mind of such nature that C was able to be triggered. Creative men as they go about their daily work have numerous problems formulated in the mind waiting for the appropriate piece to complete each combination. This is shown by Fig. 1.

Stages.—The well-known stages of creation readily can be related to the given equation. The *preparation* stage involves the search for material; and working it over to seek relationships and to find other directions of search. This prepares the way for the fixed element A to be cast into many different forms. In the stage of *incubation*, many B elements are fitted, mostly by unconscious cerebration, until one clicks. The click is symbolized by the arrow, which leads to the *insight* C, which has been called, the arrival of the fittest. The many elements that follow from C, deductions, elaborations, devices of communication, represent the final stage, commonly termed *verification*.

Various writers have symbolized or diagrammed the creative process in different ways. Hutchinson[4] has provided a flow chart. Von Fange[5] shows the process as one of intensification, using a wave form diminishing along an axis. Pacifico[6] symbolizes the tracks of old and new ideas. Kubie[7] shows the mental scope of thoughts and emotions. To this the writer[8] has added a center of attention.

Each of the curves is a kind of interface. An idea may enter consciousness, as shown in the figure, apart from the

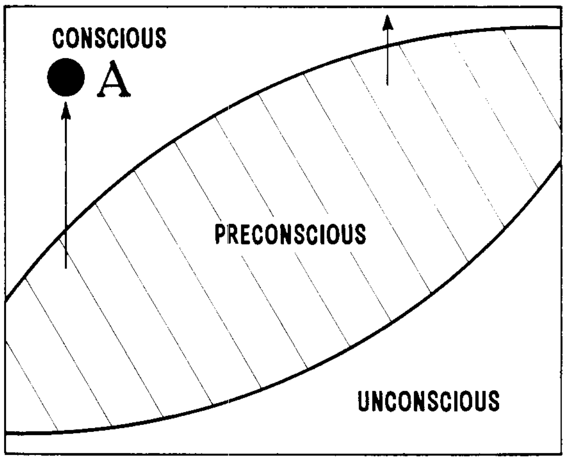

Fig. 2. Mental functions (after Kubie) with center of attention A.

center of attention, and wait for recognition. Or, it may shoot like an arrow to the center of attention. This is sudden, sharp insight. The other case, where the idea waits to be recognized, is similar to Graham Wallas'[9] *intimation*. Either of these ideas, unless note is taken of it, will sink back through the interface, maybe forever. It is always of vital importance to record insights.

Literature Functions.—A pencil and notebook have been defined as an idea trap, to write ideas down before they are lost. Lewis Carroll even designed a "nyctograph," so that he could legibly record his ideas in bed at night.

By the same imagery, a chemical journal can be called an idea mine, to be worked for fruitful suggestions of all kinds.

In industrial chemistry, there are several ways in which the literature aids creative activity. It serves: (1) to provide information about a problem so that it can be restructured; (2) to provide the pieces which fulfill already structured problems. The mental approach in using the literature is different in the two cases. In the first, the approach is the deliberate literature search. In the second, there is the sudden notice of the key item to complete a new combination.

Information.—The usual prelude to a research problem is a literature search. This provides, principally: new knowledge, ideas, methods, indicated other directions of search. Suppose the employer is a rubber company, and the young researcher gets the assignment to develop a longer-lasting, longer-wearing tire. If the researcher knows little or nothing of the subject when he starts, he is in a fortunate position. Ideas of things that are pertinent and things to try with them will come as he proceeds. There are the rubber, the carbon black, the sulfur, the zinc, the acid, the accelerator, the antioxidant to play with, as well as the conditions of processing and the tread pattern.

Then he will read of methods to use to carry out his new ideas, and laboratory tests to prove their success.

As he studies, new directions to explore, some tangential and some of which he was completely unaware at the start, suggest themselves and these he follows, too. Soon, the researcher learns that synthetic rubber polymerized at low temperature ("cold rubber") shows sharp improvement in abrasion resistance. The problem solution is to make the tire tread from rubber polymerized at a temperature many degrees lower than now used. But, in so lowering the temperature, it is found that an antifreeze must be added to the mix. Then, in the cold, the rate of conversion becomes impractically slow. Eventually, the problem of a longer wearing tire reduces to this: find a catalyst system to polymerize rubber in a nonfreezing mix at the present rate of conversion but at significantly lower temperature. This is a concrete thing on which to go to work. Then begins the process of spot check experiments, consultations, discussions, and keeping abreast of newly published technical papers which discuss the latest information on polymerization and catalysts. These methods of search are directed not only to the problem but also to surrounding or halo material, such as, high speed formulas used at present; general methods of speeding up reactions; method for present lowest-temperature polymerizations; general theory of polymerizations; general theory of kinetics.

When the researcher has found his ideas and methods, that is the time to quit, and forget his exhaustive study. Rather, let energy be expended in exploring the new, unforeseen, remote, creative bypaths. All that exhaustive study can do is to teach a hatful of reasons for not doing the right thing. The time for the exhaustive review is when the *purpose* is to write an exhaustive review. The argument is the same as the one that the expert cannot achieve a major breakthrough because he knows so many reasons why it won't work.

To read creatively, one should not read critically. Again, if the purpose is to write a critical review, by all means read critically. But the person who is uncreative is often in a state of continual polemics with the author as he reads. Being engaged in pitting what he now knows against the author's frozen record (unexpandable in the reader situation), he has little room for creative activity. The creative person is not so. He seeks ideas which, as Poincare has described, will "collide" in his mind to produce the new combination, C. He says to the author, "you can be wrong, you can commit errors of logic, even record inconsistencies, but I won't care, if you can help me to useful new combinations."

These are, naturally, the black and white of the reading process, not the shades of grey. Criticism is necessary. But note that it is precisely when he has a critical assignment that the creative person is conscious of shifting gears mentally. He is as uncomfortable reading for criticism as is the habitual critic in attempting to read without his usual mental polemics with the author. Reading to further the preparative work of creative thinking is an opening of the gates, as Schiller describes, to admit all the candidate-ideas before any selection is made. But criticism *is* selection.

So the first function of the literature is to implement the investigation with ideas, methods, and new directions of search. This work serves to structure the question in different ways and may be termed *poly-preparation*.

Direct Stimulation.—The other way the literature serves is to provide a missing piece of the $A + B \rightarrow C$ puzzle that results in invention. There are some different ways in which this can happen. Let examples be considered in relation to the cost of a product.

There might be a clear need to manufacture the product cheaper. Then visualize the researcher turning the pages of the *News Edition*, and seeing advertised as commercially available a new material to accomplish this purpose. The sequence here is, first the clearly explicated need, then the new element.

The same result easily can come about otherwise. Let the researcher see the advertisement and say to himself, "I never thought we could economize our process that way." The sequence here is, first the new element, then the need.

A third, related possibility is to read in the Journal a definitive statement of a need, such as: if a cheaper way to make this were found, it would be used much more widely, and in different ways. The researcher would say, "I never realized a cheaper way offered such large possibilities. We don't make it now, but if we used that compound I saw advertised yesterday, we could make that product lots cheaper than anyone." The sequence here is, be given the need, then formulate the answer.

The patterns of have a need, or see a need, or be told a need, can be illustrated with other examples not concerned with cost.

An established need often is answered by a suggestion from the literature. In laboratory work on the synthesis of mercaptans for testing as cold-wave agents, we encountered considerable difficulty in synthesizing and then isolating such compounds as $HSCH_2CONHCH_2$-$COOH$ and $HSCH_2CONHCHRCOOH$, where X in the model of search described earlier was carboxymethyl or substituted carboxymethyl. Then our synthesist came upon an abstract in the Abstracts volume released for the fall 1954 ACS meeting in New York, which discussed the S-acetyl compounds. Immediately, the light lit. Subsequently, the desired compounds were prepared as the S-acetyl derivatives, from which the liberation of the mercaptan was the final step. For our evaluation, we required only solutions, and often it was not even needful to isolate the mercaptan for testing; the S-acetyl compound was simply dissolved in the correct amounts of water and ammonia, and the solution used.

A creative man is especially able to see needs when others don't. Often, it is explication of the need that is the real invention, because when it is explicated, the means to answer it become obvious. The inventor, Henry Wise Wood, illustrated this with a chance observation. He said,[10] "I chanced to notice that in machines for smoothing the interior of printing plates the resulting chips would continue to lie in the machine and injure the following plate unless carefully removed by hand. I turned the machine upside down so that the chips would drop out of their own accord, thus inventing a means of overcoming a persistent cause of trouble."

An example of a stated need is as if an Eastman chemist had read, "It is too bad that there are not available for purchase large numbers of pure organic intermediates suitable for reactions of all kinds." Then he develops this sequence:

A: There is a need for these chemicals.

+

B: We make many, and can buy many more.

↓

C: Set up an organic intermediates business.

So the literature serves:

1. To implement investigations
2. To set up and/or complete patterns.

Library Service.—The industrial chemist is less concerned with the literature of pure science than some others, but he *is* concerned to a degree, and he is concerned with more types of literature than other chemists, such as these:

Types of Literature for Industrial Chemists

Weekly News Periodicals (*Chemical Engineering News*)
Abstracts journals (*Chemical Abstracts*)
General specific journals (*Journal of the American Chemical Society*)
Special journals (*Textile Research Journal*)
Trade journals (*American Perfumer*)
Reviews (*Chemical Reviews; Annual Reviews*)
Patents
Trade literature (Tech. bulletins)
Meeting abstracts
Correspondence
Company Reports

Because of this diversity, it is especially in industrial chemistry that efficient library service can multiply the ways in which literature helps creativity. The system now in use by the Technical Information Service of the Procter and Gamble Company is especially well-planned. The literature is divided into three classifications, of which lists are made and distributed at suitable intervals.

Class	Circulation Frequency
Patents	Weekly
Current Periodical Literature	Semi-monthly
Books, Pamphlets, Trade Catalogs	Monthly

For each classification, brief abstracts of the new pertinent literature are circulated to staff members. The abstracts are conveniently sub-classified by subject. Each abstract is numbered. The list is accompanied by an order sheet, on which the numbers of articles one may want to see can be circled. The order sheet is returned to the library, and in due course the literature arrives at each desk. But first, all is held in the library for two weeks. During this time, one can consult it there with assurance that it will be available. A separate list of Company Technical Reports is circulated monthly, for which requests are handled in the same way. This list includes all technical departments of the Company, including those from the overseas companies.

This system serves several purposes. It ensures that one knows about the important literature in his specific field of endeavor. It overcomes the inertia that exists against bringing into researchers' hands the marginal literature they might otherwise skip. It also leads to the reading of considerable literature outside one's field that arouses interest but would otherwise be missed. For example, among the most widely circulated articles are the ones on creativity.

Articles on Creativity.—These are an important part of the literature. They are important because from time to time they present new methods to promote creativity. Such methods as the brainstorming procedure or the Gordon technique can be just as useful or important as a newly published method of chemical synthesis or analysis.

For example, let one open up an idea mine—the latest *Industrial and Engineering Chemistry*—and for our purposes consider just the technical articles and the advertisements. For each in turn ask this question: what is the relationship of this to any part of my job or professional interest? Force a relationship. However remote it may be, force it! Some will be useful. Practice will make the developed relationships tend to be more useful, and the relationships will also come more readily to mind with the practice. And this process is logically sound, because the relationship between technical experience (A) and the newly presented piece of information in the journal (B) represents a new combination(C). You have to keep forming these until you get one that in your judgment looks like it has potential for social worth. The word "potential" is meant to include ideas of new directions of search, or good experiments to try, as well as direct or final answers.

In his recent article on Creativity in Research, Goldenberg[11] wrote:

"In a recent issue of *Chemical and Engineering News*, I found eleven pages of direct interest to our group. I checked off three items on the "Reader Information" page to get technical brochures offered. Three other pages offered similar bulletins in individual advertisments, requiring separate letters to the suppliers. Four pages of ads were simply cut out and filed under appropriate categories, they were sufficiently informative in themselves. One advertisement stimulated a completely unrelated idea not involving the supplier's product, which started one of our chemists on the track of an interesting consumer item. In addition, a news item of a report by a leading university caused us to write directly to the author for a copy. Finally, one article was Verifaxed and passed on to our legal department and product managers. The important thing to note in all of this is that none of the items of interest would have been spotted from a simple perusal of the table of contents."

An excellent discussion of creative methods, with a long list of techniques, including brainstorming, input-output, and forced relationship, is given by Bittel.[12] Another good article is by Kelley.[13]

Another important service of the literature on creativity is for inspiration. Creativity is one of the great joys of the human personality. From reading about it, the stimulation is bound to come to try one's own hand. We should never undervalue the importance of generalized motivation for creativity. Knowlson[14] wrote that, when the mind has a set to discovery, then the discoveries may arise in entirely unexpected directions.

Maurice Nelles[15] wrote this impressive statement: "Shakespeare and many others must have known the techniques of creation, and how to control their own minds and bodies so that the creative process could take place, and the goals which they must have deliberately set could be achieved."

This kind of philosopher's stone to aid creativity is the inspiration for each particular individual, in the literature about creativity.

Climate.—The industrial literature is especially full of articles on the nature of professional status, professional employment, and favorable climate. A proper understanding of professional duties as well as rights and how these are modified by the organizational conditions of industrial employment is bound to help orient the industrial chemist to his job. Stein[16] has analyzed the facets of the employment of the industrial researcher into the several roles he plays:

As a scientist he is one, who suspending judgment in favor of facts, discovers truth, proves it, and reveals it.

As a professional, industrial scientist, the truth he discovers may be shared only within the Company.

Before he is a scientist, he is an employee, who must accept his status position in a hierarchy, follow organizational rules, bow to organization decisions, and develop awareness of costs and finance. He must also function effectively in team research.

So, the "industrial professional" limits scientist, and "employee" further limits "industrial professional."

Within this framework must be developed a climate favorable to creativity, and on this there is much literature. A good deal of this literature is to be found in industrial journals. It can be read with considerable gain to industrial creativity because it is there for a very good reason. Ten years from now, half the business of many a company will be in products not now on the drawing-board. So the companies must do research and development costing into the billions in order to get them. But we are still struggling to find the way to manage this operation, and develop the climate for it. There are many more articles about this than there are about the basic nature of creativity.

Conclusion.—Thus, the literature is of help in every aspect of creativity. It provides the material to establish a creative structure, and then the vital piece that is waiting to complete it. The industrial chemist is concerned with especially diverse literature, which he uses in many ways. The aid of the library is essential if he is to keep up on the broad front that is needful.

There is one other literature, of importance not to be minimized.

That is the "literature" of the great creations in all fields. It is a great aid to creativity to know and understand this literature and its creators—artists and poets and musicians and scientists. If a researcher knows what they did, and how they worked, and how they got and elaborated insight, some of it may rub off on his own creative skill. He learns why these works are superior, and that is, basically:

1. Each was understood as whole by its creator, and unified.

2. The detail is more meticulous, and yet, in keeping with the unity, more harmonious, than the lesser work.

From this understanding, the student has the blueprint for his own larger achievement—a wider view, and a determination not to skimp in shaping the product. Understanding the creative work of others builds creative taste, knowledge of method, and determination to give one's own work professional finish. For that is the way to be a professional that none can gainsay.

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The Aims of the Institute of Information Scientists Ltd.*

By G. MALCOLM DYSON and JASON E. L. FARRADANE

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It is well known that the rapidly increasing output of scientific literature, greatly accelerated by the impetus of two world wars and modern competition and tensions, has created a major scientific problem. Two important international conferences—the Royal Society Conference on Scientific Information in 1948, and the International Conference on Scientific Information at Washington in 1958—clearly set out the difficulties before us, but produced no general solutions. Libraries have grown apace, and librarians have improved their techniques to serve their readers, and yet these are far from resolving the dilemma. Scientists realize that they can no longer hope to cope individually with the mass of recorded knowledge, even with the aid of such tools as *Chemical Abstracts*, and must delegate much of their literature searching in order to be able to concentrate on essentials. Therefore, from about 1920 in England, and perhaps a little later in the United States, there began to be employed scientists who specialized on the literary side. As in any new specialization, the emergent phases were confused. Many scientists did not, for a long time, believe that another person, even though he might be a fellow scientist, could successfully discover literature relevant to their researches, and consequently belittled the possibilities of such work. Many employers regarded the work as merely some extension of librarianship, since much of the work must be undertaken in libraries; if they employed a scientist they often expected him to take charge of the library, a post for which he usually was not trained. Since the new specialization, correctly regarded, is that of deputizing (in a skilled manner) for the research scientists, and hence part of research work, librarianship cannot be sufficient as a training and scientific qualifications are needed. This will be evident in such work as the writing of evaluative reports, or abstracting.

The understanding of the possibilities of information work and its development was, however, slow, and the work was undertaken only in limited ways, often rather haphazardly and inadequately. The persons employed had mainly to learn their job and evolve methods of overcoming difficulties by the painful process of long experience. Since the second world war, moreover, industry and governments have increasingly recognized the need for information departments, and the number of persons employed in such work has increased rapidly. Although many university appointments departments now recognize information work as a career equal in opportunities to many industrial and research posts, the lack of proper training for such work has made the nature of the work appear somewhat nebulous. In 1948 Aslib, in England was already discussing the possibilities of special education in the expanding field, though it was at that time more often confused with special librarianship, and the proposals aroused the opposition of the Library Association. Such discussions continued for ten years without practical outcome, though it became increasingly evident that some clear exposition of the work and aims involved was needed and that the establishment of standards for the work had to be undertaken. The International

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