L-forms of bacteria, and lysis—are all explained by the loss of the integrity of the cell wall that follows interruption of cell-wall synthesis. Simultaneously with our work, Lederberg has shown that *Escherichia coli* cells are quantitatively converted to protoplasts in the presence of penicillin and sucrose. The protoplasts reverted to bacilli after removal of penicillin, thus showing that the cells retained their full capacities. We believe that Lederberg has correctly interpreted these morphological observations as evidence that penicillin interferes with maintenance of the cell wall or with its synthesis (*29*). Hahn and Ciak have studied lysis of *E. coli* in the presence of penicillin and have also postulated that loss of cell-wall integrity induced by the drug is responsible (*30*).

In our view, therefore, the selective toxicity of penicillin is due to its interference in a metabolic sequence that is not found in animal cells, the biosynthesis of the cell wall. Crystal violet, another antibacterial substance also bound in the cell membrane or wall, seems to inhibit the same metabolic sequence, although at a different point (*31*). Possibly other antibacterial substances may owe their selective toxicity to interference at some point in this reaction sequence.

It seems attractive to speculate further that competitive inhibitors related to the several unique components of the wall and nucleotide, and which would be useful as chemotherapeutic agents, might now be devised. Purification and study of the reactions leading to synthesis of the wall might also contribute greatly to this goal, and the availability of uridine nucleotide intermediates suggests that this possibility lies in the not-too-distant future.

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Scientific Communications Should Be Improved

Fred W. Decker

Authentic, complete, prompt, and understandable reports of scientific developments have always been needed, and in the past they have always inestimably aided scientific achievement. The accelerated pace of science today requires more than ever the aid of full and accurate communications among science, business, and the public. However, during the past decade some questions of ethics and communications have grown until they now threaten to hamper critically the status of science in modern society. These questions demand review and action by the scientific community at large. The time is long overdue for all scientists to examine these questions in the contexts of their own professional fields and to share with other scientists their experiences in improving scientific communications.

Channels

Information about developments on the scientific frontier may reach the public through the channels of professional publications, newspapers, or advertising. All channels of communication are active when technologic development has economic implications. "Scientific facts" may then be proclaimed by several parties, and the public is thoroughly confused by sharply conflicting "scientific" conclusions.

Science is represented to society not only by qualified impartial scientists guided by objective logic but also by specialists and former scientists whose scientific conscience may have been more or less eroded by commercial interests, by specialists not broadly enough trained to speak with adequate perspective, by promoters operating on the fringe of science with little or no concern for the long-range growth of science, and by outright charlatans totally unqualified in science but yet accepted by many laymen as "scientists." Moreover, journalistic practices tend to aid the spectacular claims more than the cautious, qualified reports. Demands for brevity sometimes cause omission of essential features even in valid statements and leave erroneous impressions.

Several recent cases demonstrate a need for researchers to give special attention to examining their means of communication with one another and with the public on the results of scientific investigations. Conflicting reports have appeared, and in some cases controversy has raged over such subjects as battery

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additives, lung cancer, fluoridation, cloud seeding, the Salk vaccine, and radiation danger. Press reports to the public have featured assertions and counterassertions. Research scientists cannot ignore the means for dissemination of their research results. Today, the financial support of research is being generously provided by members and leaders of society who cannot reasonably be expected to search the technical journals to learn what science is accomplishing. To gain public attention for candid, understandable, and prompt reports on advances in science and to avoid the diversion of public support to pseudo science are among the problems the scientific community must face.

Consider, for instance, the controversial field of cloud seeding. In the past decade the effort to modify the weather has grown from the research stage into a full-blown, million-dollar industry with a dozen companies active in the United States (*1*). At the same time, a sharp controversy has developed over the basis for evaluating and accepting the claims of the commercial operators. Thus, within the past few years we have seen the growth of an industry representing itself as "scientific" while many impartial scientists are extremely skeptical of the broad claims advanced or implied by promoters of that industry. Compressed within a short life-span, the field of cloud seeding presents an excellent case study involving a number of questions of scientific ethics, policy, and communications which can arise and have arisen in other fields of scientific endeavor.

In listing a number of these questions in subsequent sections, I have cited illustrations drawn from the controversial field of cloud seeding, because in this field I have repeatedly come face to face with many of the potential weaknesses in the existing communications between scientists and the general public. Other scientists may recognize counterparts to these illustrations in their own fields. If so, the scientists confronting these specific issues will gratefully receive the suggestions of fellow-scientists about the best means for handling them. Since others may be confronted by different problems in the general area of communications and policy, it is to be hoped that the channels of scientific publication will remain open to the free expression of the issues and the discussion of solutions to the pressing problems in the relationships between science and society.

Evidence

What constitutes "scientific evidence?" What shall scientists, by precept and example, use as evidence in arriving at conclusions? Dismayed scientists recently learned that the testimonials of 45 satisfied users of a battery additive could help to offset research by the National Bureau of Standards in the deliberations of the Federal Trade Commission. Similarly, testimony by 92 satisfied users of a colorfully advertised water conditioner outweighed the opinions and tests of 22 scientists (*2*).

Validity of data should be a primary concern of everyone in this scientific age. Has the impact of science on society failed to produce a realization that unqualified testimonials have no standing against objective tests? Has the "anything goes" practice of some advertisers gained ascendancy even in this "scientific age?" For example, commercial cloud seeders have urged independent evaluators to base their conclusions at least partially on "going out and *seeing* the operations," but many evaluators have been reluctant to accept "data" that are not based on actual measurement, perhaps taking their cue from Kelvin. Unless scientists insist on a standard of objectivity for data, the term *scientifically proved* (or disproved) can easily fall into public disrepute. To prevent this, science must somehow overcome certain commercial interests and enlist the aid of a press that sometimes is either indifferent or hostile.

Experimentation

What constitutes "scientific experimentation?" Well-designed experiments do not happen spontaneously but are the results of careful planning and consultation. However, so-called "experiments" are often conducted for the purpose of obtaining visual or numerical comparisons where such comparisons may not be valid because extraneous factors were not removed from the operations leading to the comparisons. Moreover, the experiment sometimes is valid enough but does not actually deal with the announced subject.

For example, experiments in cold boxes and in the free atmosphere to alter clouds with Dry Ice or silver iodide are often mentioned in publicity about cloud seeding to increase rainfall. However, those cloud-modification experiments did not necessarily concern increased rainfall, and adequate measurements were not made which would permit testing for increased rainfall.

Proof

How much proof must be offered to support conclusions? Scientists agree that conclusions must be based on a careful analysis of all the pertinent data. There can be no suppression of inconvenient data that contribute to statistical variation and tend to undermine or blur the conclusion. Conclusions can be drawn most readily when observed measurements are closely correlated with the variable factors. In the cloud-seeding case, unfortunately, wide variations appear between natural rainfall and computed amounts, even when elaborate multiple-regression equations employing numerous factors related to the amount of precipitation are used (*3*). Then the question arises about how far the actual precipitation must depart from the computed amount to justify labeling it the work of cloud seeding, not merely natural, chance variation.

Disregarding for the moment the considerations of economic speculation, what degree of doubt will scientists accept while being satisfied with a conclusion? This question is complicated by the fact that setting up too stringent a requirement for proof could cause rejection of a valid claim, while relaxing the requirements could produce acceptance of false claims. Because of the inherent uncertainties of historical comparisons and because of the meager data available for evaluation of cloud seeding, one evaluation group compromised between these two kinds of error by adopting a standard of acceptance so low that there was admittedly appreciable danger of declaring that cloud seeding had increased the rainfall even it it had actually decreased the rainfall. Evidently the solution is to use designed experiments that minimize the sources of this error (*4*). The widely advertised commercial rain-making operations have not provided data genuinely satisfactory for evaluation, a point on which agreement was apparent in reports of the Conference on the Scientific Basis of Weather Modification Studies at Tucson, Arizona, 10–12 April 1956 (*5*).

Publication

What scientific work must be published by ethical researchers? The whole structure of science is based on the free exchange of information and not on the hermitlike total security of the alchemist. Research scientists owe other workers in the field publication complete enough to add to the scientific capital with which all must work. Entrepreneurs who want to retain trade secrets should not give the impression that they are speaking as scientists if they announce results without giving the substantial basis for their conclusions.

The claims advanced by some meteorologists in the cloud-seeding business, for instance, create the impression that scientists habitually announce results without subjecting their conclusions to the scrutiny of the rest of the scientific world. With few exceptions, the commercial cloud seeders have failed to publish their work in the scientific journals (*6*). Even an evaluating federal agency, after announcing conclusions favorable to some of the rain makers' claims in February 1956, has failed to publish any technical report to explain those conclusions.

Researchers should expect to be judged by the promptness and completeness of their reporting. Could not scientific societies prepare and publicize candid descriptions of promotional statements circulated under the label of science, categorizing them when appropriate as "never submitted for review by scientists in this field," "generally regarded as unsupported by the scientists in this field," "subject of debate and probably a moot question," and so forth? Should not scientists in public positions expect to give the technical basis when they are announcing their conclusions rather than to allow lengthy delays between the announcement of conclusions and the release of technical reports? Cannot scientists and editors generally encourage professional publication in order to offset the tendency toward publicizing unsubstantiated claims and insist that such reports reveal the evidence supporting the claims and conclusions?

Public Release of Technical Details

How should technical details of scientific research be described in popular releases? Understandable reports by research scientists are particularly hard for the public to obtain (*7*). Not only are scientists sometimes inarticulate even to specialists in nearby fields, but the Fourth Estate finds it particularly hard to secure usable information. The terminology sometimes employed by scientists is obscure or actually misleading. "Statistically significant," for instance, to a layman probably means "large," whereas to the specialist it may mean "large enough (by some required departure) to abandon the null hypothesis."

Science will not profit by permitting nomenclature to develop without regard to the impressions created. For example, in the use of the term *statistically significant,* some cloud-seeding evaluators have omitted to specify the standard of rarity required for "significance." Thus, one agency that was using an unannounced low standard of acceptance declared that cloud seeding "significantly" increased rain on the same project in which another agency that was using a more severe standard of acceptance found no significant increase in rainfall. Certainly all pertinent details must be revealed if such reports are not to appear contradictory.

Scientists can make a real contribution to the general public understanding of science by adopting more specific and understandable language. The language used should be understandable at least to the elements of society concerned with making decisions on the basis of such reports. In this matter, we again see illustrated the need for continuing education in science starting in school and continuing through the functioning of communications aimed at keeping the public abreast of the times. In view of the role of science in modern life, can we be satisfied with the amount of attention directed to understanding the trends and events in science on the part of the lay public?

Margin of Uncertainty

How should scientists describe the nature of their discoveries? Scientific progress has come from the pains-taking solution of the small problems that are parts of the larger problems. Newton recognized that his accomplishments came from "standing on the shoulders of giants." Such expressions of humility might be overlooked in the headlong rush of science toward the discoveries of the past 25 years, but can scientists really afford some of the publicity about their work? *Scientific breakthrough* is a phrase increasingly used in science news stories. Scientists will do well to remind all concerned that in their conclusions there is always a margin of uncertainty.

Fortunately, the science of statistics furnishes excellent means for defining the area of uncertainty. That the public does not always hear of this uncertainty is illustrated by the repeated claims by commercial cloud seeders pointing to extraordinary increases in precipitation. Sometimes not even a day elapses between the rainfall and the confident announcement that cloud seeding produced more rain than would have fallen naturally (*8*). Drouth-breaking rains have been claimed by the rain makers, even though the available measurements are too meager to support the claims with any appreciable confidence. Some segments of the public seem already to have associated the term *rain maker* with exaggeration and overzealous salesmanship involving a dubious product, as witness the use of the term to describe Soviet diplomats visiting India (*9*).

Overstatement of Results

Will overstatement of results choke off future development? When research seems to have succeeded, the drive for new discoveries may slacken. Having achieved the goal, scientists may look toward new challenging areas, and financial support quite logically shifts. Referring again to cloud seeding, large sums of money are being spent for operations that are based on the assumption that various processes are actually producing economically important changes in the precipitation pattern. Cloud-seeding operations that were initiated as "applied research" are usually proceeding now without any effective evaluation checks. Operations are conducted dogmatically, despite the inability of statistical analysis to attribute favorable results to cloud seeding with any high level of confidence.

Actually, the technical basis for cloud seeding is not at all settled. It seems highly probable that important discoveries remain to be made in this field. The physical and chemical nature of effective seeding agents must be established definitely. It is not even certain that flame-type silver iodide generators are producing silver iodide crystals. Moreover, the atmospheric mixing processes should be investigated; there is some question whether the seeding agents are really carried rapidly enough above the freezing level (*10*). These uncertainties must be faced frankly, not submerged by glittering claims of success, if progress is to be made. There would appear to be a point of broad scientific importance in this aspect of cloud-seeding work and publicity.

Exploitation prior to Verification

Can an unsettled technical process be exploited commercially prior to full verification? When this type of problem arose during World War II, "field service tests" were conducted where the equipment might contribute a critical advantage, even though the equipment was still undergoing development. Clients who were unwilling to forego hail-suppression activities for the periods needed to establish "nonseeded" storm records for comparisons could now set up "hail-suppression proving grounds." There the various claims could be examined, and possibly the processes could be developed and optimized while the field operations continued on the clients' target areas. It could even be argued that the doctrine of *caveat emptor* obliges the client to be wary and to adopt measures calculated to protect his own interests.

The scientist is, in such cases, under obligation to lend his support and assistance to submit to impartial tests the claims for new techniques whenever the name of science is used directly or indirectly to sell the innovation to the public. Failure to do this can only prejudice the position of science in our society.

Unfortunately, when designed experiments are proposed aiming at creating the necessary observational network and working toward optimizing the process of cloud seeding, certain commercial cloud-seeding meteorologists stoutly and openly oppose such experiments. Is not the individual's scientific stature directly related to the alacrity with which he adopts such objective experimental methods? Perhaps the controlled experiment starting in 1957 at Santa Barbara, California, will establish a new pattern for other commercial rain-making attempts.

Bases of Decisions

Can scientists assist in making decisions when "scientific proof" seems to be lacking? An objective criterion is needed for deciding whether to continue a service like cloud seeding in the absence of acceptable scientific proof that the claims of success are valid. Clients are told that they cannot afford to omit the service because the cost is small compared with the claimed benefits. However, to accept all such proposals can bankrupt the client.

Scientists who are attempting to determine for the client whether the process is an acceptable business gamble would do well to avoid such expressions as *statistically significant* and, instead, to use language that clearly distinguishes the results as an estimate of business risk which does not imply proof.

Acceptance of Authentic Work

What must scientists do to assure acceptance of their work as authentic? Cultivation of ethical practices in science will earn public recognition and confidence in scientific results. The increasingly intimate relationship of many branches of science to society calls for the kind of review that produced the Hippocratic Oath in medicine. Clearly defined duties of the scientist to society can avert misunderstandings and increase society's recognition of science. Laymen who turn to scientists for expert advice on goods and services should have no doubts concerning the scientists' independence of judgment.

Even valid findings can be suspect if the scientists or individuals who are retained as scientists by the buyer should soon enter the services of the seller. Individuals who are accepted as scientists by the public can bring discredit upon the scientific community by such action, even when their individual motives are quite innocent. Can scientists find a way to avoid the misunderstandings that develop when, for instance, either scientific or executive personnel of an evaluation agency leave to engage in commercial rain making after the agency has published a controversial endorsement of cloud seeders' claims?

Open Criticism

Can science afford an absence of open criticism? Contemporary writers have observed a decline of criticism in literature, and a similar euphemistic tendency may well be developing in science. For instance, critics who point to the uncertainties in the cloud-seeding claims are now falsely labeled as "negativists" or "obstructionists" and are accused of assuming a "can't do" attitude. The critics' valuable role in the advance of science could be stifled if the scientific world does not rally to insist on recognition for those who call for scientific proof, not advertising claims. Being human, they must eventually bow, as did Galileo, if other scientists will not stand with them.

In this regard, every scientist should carry the message that there are in reality the following three categories of individuals in any scientific controversy over conclusions: (i) the enthusiastic innovators; (ii) those who conclude that the innovators are wrong; and (iii) those who insist on obtaining more definitive data before they join either of the first two groups. A scientific tragedy today is that often the third group is ignored and carelessly classed with the second group.

Science cannot progress without searching inquiries developed by those who reserve judgment and will not hastily accept conclusions or dogma. Hoaxes like the "Piltdown man" (*11*) should stand as warnings to any who would cry down the independent critics. Teachers of science should contribute to public appreciation of scientific critics by emphasizing with Conant that "the innovator is by no means always right" and should prove this to their students with cases "where some bold man put forth a new idea based on alleged facts that turned out to be erroneous or erroneously interpreted" (*12*).

Public Understanding and Appreciation

How can science gain better understanding and appreciation from the public? This thorny problem has been faced, for instance, by the medical profession for many years. People often are willing to believe that a profession or an industry has conspired to suppress truth or new discoveries. Such canards easily gain attention, but their refutation gets little attention or acceptance. Playing upon the desires and suspicions of the people and making a great show of zealous effort, clever promoters today demonstrate the truth of Caesar's observation that "in most cases men willingly believe what they wish" (*13*).

For instance, in contract negotiations many of the rain makers stress the need of the client for water, the earnestness of the seeder, the size and versatility of the seeding organization, and the fringe services to be rendered. However, they have generally omitted the specific engineering details of the "experiments" to be conducted and have neglected to supply the valid technical reports that might be expected from experiments. A few of them have diverted attention by attacking valid scientific research which is in progress.

Confronted by the inability of many of the public to understand scientific method, results, and language, scientists could easily abandon any hope of a *rapprochement* with society. The methods and facts of science have advanced so far as to leave some of the most learned and influential professions "behind the pace of the times" (*14*). This situation is not the fault of the scientists, but perhaps only they can solve it. A well-organized, continuing effort by the scientific community as a whole could produce a keener understanding of science, particularly if this effort included "progress reports" in science and if it reached teachers, students, and the public generally.

Ultimately, the best hope is in developing a realization that, no matter how great the earnestness, hope, sincerity, or need of the would-be innovator, discoveries can occur only if they already exist in nature. All people should understand this fundamental if they are not to be disappointed and bilked and in order that they will continuously support the methodical work aimed at satisfying human needs and desires.

Conclusions

The world of science needs more than ever an active conscience in ethical dealings with the public, a clear understanding of the requirements of objectivity, the ability understandably to articulate the results of scientific work, and constructive criticism of both innovation and dogma.

Society today urgently needs a closer liaison leading to a more complete knowledge of the products of scientific work and a more general acceptance of the objective processes of scientific thought. Public leadership should foster a heightened appreciation of scientists and should not permit valid scientific work to be offset by promotionalism and unfounded charges. Scientists can inform, but other elements of society must seek knowledge and understanding of trends in science, if genuine progress in science is to be recognized and exploited. The public cannot hold the legitimate scientist to blame after the public has followed the promoter who scorns the disciplines of science. Keeping up with the pace of the times is still the duty of all.

Scientific societies should foster discussion of the means of scientific communication, develop clear codes of scientific ethics, and publicize information on the actual status of claims or discoveries, particularly when widespread publicity is being given to unproved or false claims.

Science should be interpreted to society generally through the use of "progress reports" on science which are aimed at demonstrating the methodical processes of research, the pitfalls and disappointments, and the philosophy of objective reasoning. Science news consists as much in the processes as in the final results. The effort required for such interpretation is not the obligation of scientists alone, but must be augmented by all the means described in the preceding paragraphs and by better interpretations in the mass media. It is an encouraging sign that science newswriters generally recognize these obligations and problems. Closer cooperation between scientists and science writers would result in a better general public understanding of science and scientific evidence.

Educators should explain the demands of scientific objectivity to their students. The mere teaching of subject content alone will not give assurance that the academically trained scientist is aware of the pitfalls of premature claims or the proper relations between science and society. Each future scientist should be taught the responsibilities of his position as a representative of science to society generally.

Every practicing scientist should reflect seriously on his own opportunities to assist in representing to the public the way in which science advances, the need for tests of the validity of conclusions, the logical processes of science, the demands for objectivity, the need for adequate and valid data, and the difference between claims and proved results. His own research reports should be models of objectivity and clarity. Performing this duty might not result in personal rewards, but scientists have a unique responsibility to see that false opinions do not eclipse the accurate information needed for progress.

Public confusion about the meaning of scientific work must eventually produce a negative reaction. Exaggeration and overselling in order to gain financial support for science will ultimately stand revealed. Unless such fringe practices have been publicly and specifically disowned by legitimate scientists, the reaction may affect all of science; then public confidence, understanding, and support may vanish. In that event, the scientific community may deeply regret having neglected to clarify the nature of science in the public mind. Scientific societies and individual scientists can lead to a solution by attracting more attention to the progress of science and by communicating with one another and with the rest of society in completely candid terms.

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Biochemical Mutations in Man and Microorganisms

Herman M. Kalckar

It is a well-known fact that normal development of mammals is possible without an external supply of galactose. Galactoside synthesis, especially of the complex galactosides that are constituents of cellular structures, is an essential feature of normal growth and development. Mammals, like most organisms, are able to convert glucose to galactosides. The galactolipids, for example, which constitute a large bulk of the brain, are examples of structural galactosides that are deposited exclusively after birth (*1*). As will be discussed in subsequent paragraphs, these compounds can be synthesized from dietary glucose as well as from dietary galactose.

The dispensability of galactose raises the question of why lactose is ubiquitous in mammalian species. It is possible that early in their evolution mammals were subjected to influences that made it advantageous for them to produce milk containing lactose for their progeny. The possible advantages of lactose in the diet of the progeny have not been explored. The influence of lactose on the bacterial flora of the gastrointestinal tract should certainly be considered, for the microorganisms in the intestine play a role in making certain vitamins available or unavailable to the host. It is known that replacement of lactose by sucrose in the diet greatly increases the need of the host organism for vitamins such as pyridoxine and riboflavin (*2*).

If galactose is administered externally, it is largely used as a fuel through conversion to glucose-6-phosphate. Most microorganisms use galactose for this purpose provided that they are able to adapt and that they cannot get access to glucose. Part of the administered galactose is used, as mentioned, for the synthesis of cellular galactosides.

Complexity of Galactose Metabolism

The activation of galactose, unlike that of glucose, is initiated through a direct phosphorylation of the reducing group, giving rise to α-galactose-1-phosphate (G-1-P) (Kosterlitz, *3*). The metabolic mobilization of galactose, also unlike that

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This article is one of a group of four articles on galactose metabolism that appear in this issue. The other three articles appear at the beginning of the "Reports" section.