

TO BE A SCIENTIST¹

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One of the things that attracted me to linguistics thirty-five years ago was the realization that it dealt with a large area of natural phenomena not yet well understood that could be approached scientifically. It was a frontier with the challenge of the unknown. Linguists advertised their discipline as a science, and it did seem reasonable that there could be a linguistic science, for there were complex phenomena that could be observed, and the observations could be replicated. It reminded me of the complex phenomena in cosmic-ray physics that I had been working on, but it seemed more important and more interesting.

Then as I got into the discipline and started doing research, it came over me that linguistics had serious problems in regard to its scientific status. One of the first things I noticed was that much of the writing in linguistics was polemical. This was in stark contrast with the well-mannered writing that I had become accustomed to in physics. Furthermore, it developed that there were many different theories and points of view in linguistics, and the criteria for choosing among them were not clear. At first I thought it was simply because the discipline was not yet very highly developed, for physics, too, had been polemical in earlier centuries. The thing to do was to try to develop linguistics further as a science. So when I put forth a scientific hypothesis about the relation of phrase structure to temporary memory, I expected that linguists working on different languages would test it on the languages they studied, and some did and found that the hypothesis held. But the most vociferous reaction in this country was a polemical attack as if the hypothesis were a competing political ideology or religion. Some people were obviously not playing by the same rules that I had learned through my apprenticeship in science.

Believing that this was a temporary aberration in the discipline, I circulated a letter to some colleagues to see if I could get agreement on how to play the game — on what constituted good scientific practice. The letter contained a hundred odd points elaborating on the conduct of scientific research as I understood it and on the ways in which some of the work appearing in the linguistics literature fell far short of even the minimum standards of scientific acceptability. The letter was responded to with apparent agreement by the linguists to whom I sent it. There may be some here who received it and responded.

I don't know what effect it may have had on the recipients, but this exercise helped me to be explicit about what I saw as serious problems in the discipline. It has helped to guide the conduct of my research, and it has served as a background for reading the history of linguistics and the history of science. I have also used these points in class from time to time, a few at the end of each period, and they have been taken up eagerly by the students, for they are brief and invite discussion and elaboration.

I have recently become convinced that the problem is not a temporary aberration, it is a growing cancer. Much that has occurred in linguistics in the last several decades has pulled the discipline in a direction opposite from science. A knowledge of what science is, and what it is to be a scientist, cannot, or can no longer, be taken for granted as part of the normal equipment of a trained linguist. So with the anticipated publication of my book *Linguistics as a Science* in November, it is appropriate that I also lay out in more detail what it is to be a scientist.

How does one learn to be a scientist? The answer is to study science under scientists. I would certainly encourage students contemplating a career in linguistics to take all the science they

can get, for science is a way of life that is best learned by osmosis during an apprenticeship. It is a tradition that has been developed through trial and error by scientists over the last four hundred years or so. One learns about these things best by doing, and by studying under good teachers what others have done. Lacking such opportunities, one should read in the original the works of scientists, especially under the guidance of knowledgeable scientists. I would particularly recommend starting with the works of Galileo, which are quite readable in the English translations of Stillman Drake, and under the guidance of his essays on Galileo. These are particularly helpful, for linguistics today faces some of the same sorts of problems with philosophy, folk theory, authority, and entrenched opinion that physics faced in Galileo's time. Galileo wrote for a general audience, and he wrote clearly.

What I am publishing here may be of some help, especially if you get a chance to discuss the points with true scientists. You can look on these points as notes for an ethnographic report on the culture of science by someone who also has some acquaintance with the current linguistic culture and has tried to bring out some of the important contrasts. It is a report based on my education and socialization in science through three degrees in physics and while studying under some of the most illustrious physicists of their day.

Next a few words on the relation of philosophy to science. There is a literature on the philosophy of science that looks deceptively like a prescription for doing science. That is not its purpose, however; its purpose is to investigate philosophical questions in epistemology and the theory of knowledge, not to teach science, and you will likely be misled. Different philosophers differ on what they think scientists are doing, and their writings are largely ignored by scientists, who take full responsibility for their own disciplines. At best these philosophers serve as critics, but one would not learn to play the violin from a music critic, no matter how insightful his comments might be.

Linguistics owes much to philosophy, for it was born of philosophy. But if linguistics is to be a science it must cut its ties to philosophy as the other sciences have done. This is rendered particularly difficult for linguistics because its basic theory has developed out of the ancient Stoic dialectic or theory of knowledge. As a result, linguistics is still very much dominated by philosophical concerns, which are detrimental to its development as a science. Chomsky's works, for example, are much more in the realm of philosophy than of science, as has been pointed out more than once in the literature. One cannot expect to learn much about science from them; their influence has been to pull the discipline toward philosophy and away from science.

The biggest problem that a scientific linguistics has with philosophy, and the greatest danger that philosophy poses to the development of a scientific linguistics, is that philosophy is not science. The criteria of truth in philosophy are not the criteria of truth in science. The criteria of truth in science have been known and agreed upon by scientists for centuries: they are ultimately observations by the senses, for science studies phenomena in the physical domain. Philosophy, on the other hand, deals with the logical or metatheoretical domain where the criteria of truth have always been and still are controversial. Consider, for example, the continuing controversy over empiricism versus rationalism. So first, a would-be scientific linguist would do well to stay within science and not stray into philosophy for instruction in how to be a scientist. Learn your science from scientists, not from philosophers.

Second, and this would go without saying in science but becomes important for us in contrast to familiar patterns in linguistics: work in the physical domain like other scientists rather than in the logical domain like philosophers. This means in the case of linguistics that we should study people, sound waves, and other linguistically relevant physical objects, rather than the

convenient fictions of language, and we should seek a scientific understanding of how people communicate, rather than a scientific understanding of language, which, as I have shown elsewhere, is impossible.

After twenty years I have had to make only few changes in the following list of points. They have held up well, being a matter of tradition and checkable against scientists willing to serve as informants. I should add that probably no scientist is such a paragon that he always lives up to all the ideals presented here, but if he is a good scientist, he tries his best to do just that.

A. What is Science?

A1. Origin of Science

Science probably has its origin in curiosity about the environment, a trait that man seems to share with many other species of animals.

A2. Adaptive Mechanism

The ability of an organism to ascertain regularities in the environment and to predict events on the basis of the regularities is an adaptive mechanism and has survival value. It is not difficult to think of clear examples where a knowledge of the environment obtained through curiosity would save a person's life.

A3. Control of Environment

Knowledge of the environment and an ability to predict has made it more and more possible to control the environment. The possibility of controlling the environment has provided an additional motive for pursuing knowledge. Application of knowledge to problems of controlling the environment is not, however, included in science as I am using the term.

A4. Search for Knowledge

Science is concerned with a search for knowledge — to know the unknown — to discover new regularities in the environment that can be relied upon as a basis for prediction.

A5. Sophisticated Common Sense

It has been said that science is only sophisticated common sense. I take it that by common sense is meant the ability that most people have of predicting events in their everyday lives on the basis of ascertained regularities in the environment, and of acting in a rational way on the basis of the predictions. Science, however, is concerned more with understanding the regularities in the environment than on taking rational action, and in this it differs from technology, which uses the knowledge obtained by science and applies it to practical ends.

A6. Regularities

Science places an emphasis on a systematic explanation of similarities and underlying unity as a solid basis for predictions. In this it differs from the arts, where emphasis is more often placed on the unique differences that constitute aesthetic qualities, and where it is often said that artistic interest lies in unpredictable deviations from the commonplace or from the norm.

A7. Science and the Humanities

It is sometimes alleged that science and the humanities are incompatible. This is not true for linguistics, however, which is in the humanities on the basis of its subject matter and in the sciences on the basis of its methods.

A8. Classification of Science

The partitioning of science into separate disciplines is for convenience and division of effort only. As science advances, some of the most interesting research takes place at the borders between separate disciplines as conceived in terms of an older classification.

A9. Universality

There is no place for parochialism in science. Specialization and division of labor are, of course, useful. But the various parts of science are interconnected and no area of science should try to cut itself off from the rest.

A10. Linguistics as Part of Science

If linguistics is science, it is not isolated and autonomous, but part of science. The conception here is that there is only one science, and the various parts of it are interconnected and relevant to various different phenomena. It is important to emphasize this unity and interconnectedness because there are many well established results in science that bear on linguistic phenomena in important ways.

A11. One Science

There is and can only be one science. There cannot be competing sciences built on different principles. Thus if linguistics is part of science, there can only be one linguistics, a scientific linguistics. This is not to say that there couldn't be competing tentative scientific theories concerned with the same observations.

A12. A Program

Science is not an *ism*. It is a program. It is a program aimed at trying to get as close to the truth about nature as possible. This search requires that one keep an open mind, for one doesn't know ahead of time where the truth may be found. *Isms* imply prior commitments which can only get in the way of doing good science. For the last 150 to 200 years linguists have been scientists to some extent. This modern era in the history of linguistics can be read as a struggle between the science of the future and the *isms* of the past. The abandoning of prescriptivism is but one example.

A13. Regularity in Nature

The scientist believes, or accepts as a reasonable working hypothesis, that nature is regular and capable of being investigated, that there are regular phenomena for us to observe, describe, and to understand. But our theories and hypotheses will always be tentative. One could enter here into a philosophical discussion as to whether this regularity is or is not imposed upon nature by its observers. Nevertheless, the ability to predict what will happen tomorrow is based on observed regularities from the past and the belief that these regularities will continue into the future.

A14. Role of Belief

The role of belief in science is a minor one. A scientist tries to operate with very few beliefs or articles of faith in the realm of science. He does, of course, believe many things in science, but his basis for believing them is not ultimate belief or faith. He knows that knowledge obtained through science is tentative. In any context certain things are accepted (believed) but in appropriate contexts they can be challenged.

A15. Revelation

There is no place in science for revelation or the revealed truth. Belief and revelation belong in the realm of religion, and are outside of science.

A16. Rejection of the Supernatural

Science rejects the occult and the supernatural because no convincing scientific evidence has been provided for accepting them. Magic, superstition, and the mystical are rejected as means for ascertaining or expressing regularities in the environment and predicting events.

A17. Cults

There is no place in science for fervor, sectarianism, discipleship, orthodoxy, conversion, proselytizing, or propaganda. Different points of view confront each other in objective discussion.

B. A Scientist's Choice of Direction

B1. Goals not Absolute

The validity of a scientist's goals and the intrinsic interest of a line of work or results are not absolute, but relative to a frame of reference. Often this frame of reference is some current theoretical question, or some current incompletely understood set of observations.

B2. Divergent Goals

There is the possibility of valid but apparently conflicting goals in a line of scientific research. Any effort expended in arguing about which goal is better or "right" would be wasted, for it is often the case that the knowledge obtained while pursuing one goal turns out to be very relevant to another. A scientist should be free to choose his own goals.

B3. Not a Fad

The validity of a scientist's goals and the interest of a line of work or results is not a matter of fad or vogue. It is true that many of the results in science take place at what may be called a forefront. When certain results become available, certain other work is the natural next step. Therefore there tends to be a natural accumulation of workers in specific areas on the forefront, but if they are scientists or aspiring scientists, they are not there because it is a current fad, but because they feel they can learn more in an area that is rapidly opening up.

B4. Don't Fence Me In

A scientist refuses to be fenced in by a narrow definition of a discipline. If the pursuit of scientific knowledge takes him outside of his area of competence, he will try to interest other scientists in taking up the pursuit, or he may prepare himself in the new area, and go after it himself.

B5. Pursuit of Truth

A scientist shows a willingness to pursue truth wherever it might lead, and his pursuit is relentless.

B6. A Questioning Mind

The scientist is always asking questions and trying to answer them. He actively looks for questions to ask. Perhaps the most tragic event in the lives of some children is when their natural curiosity is squelched.

B7. Meaningless Questions

The scientist refuses to ask meaningless questions, and feels that it is important to examine the questions he is asking to see if they are meaningful or not. A meaningless question is one that might seem reasonable at first, but on adequate examination it would turn out to be incapable in principle of being answered. Often the fact that a question is meaningless is quite obscure, and sometimes considerable scientific progress results from recognizing that a question on which much effort has been spent is in fact meaningless, and thus incapable in principle of resolution. The question of how people use language to communicate, which I was asking in 1969, seemed reasonable, but on closer examination it has turned out to be meaningless.

B8. Clarification

When it is discovered that a question, posed in all seriousness, is actually meaningless, an attempt is made to revise and restate it and to put it into meaningful form. A revised and meaningful question is, How do people communicate?

C. The Methods of Science

C1. Democracy

Scientific truth is not arrived at by vote or consensus. Democracy has its place in public life and in the management of scientific institutions and universities, but scientific truth is arrived at by scientific means, not by voting. It is true that observations and theories get accepted or rejected by the scientific community, but there is a higher tribunal, so to speak, than the vote or consensus of scientists. The history of science is full of cases where the respected majority of scientists was wrong, and the scorned minority right.

C2. Authority

Knowledge is not accepted on ultimate authority. Again there is a higher tribunal. It is true that much of what we know we individually accept on authority, but in science there is always the possibility of appeal at any point to the ultimate test against observational evidence, which is open to anyone. Scientists are suspicious of pronouncements put forth with an air of authority.

C3. Observation

Science is grounded in observation, and all scientific knowledge must submit to tests based on careful observation.

C4. Analysis

Scientific progress and understanding is based on the use of reason. All scientific knowledge comes about through observational evidence and reasoning from that evidence.

C5. Balance

There is a delicate interplay between observation and theory. A proper understanding of this interplay, and an appreciation of its importance, is required of every scientist, so that a proper balance may be maintained between the two.

C6. Gambling

In the conduct of scientific research, the hunches of the investigators play an important role. Since science is pursuit of the unknown, the scientist cannot know completely, ahead of time, what he will find out. Thus research must, by its very nature, be a gamble. Some research efforts are relatively sure fire, whereas others are long shots. Successful scientists are those that have the best hunches, often based on a well-developed intuition of what there might be to find out. A scientific hunch is an educated guess. The role of luck may be as important as it is in other forms of gambling. A scientist is not to be derided if he loses a gamble in research.

D. Observation

D1. Pure Observation

Some observations are the result of general exploration, as when a botanist arrives on a new island, or a linguist comes upon a new language. However, all observation is based on theories at a lower level, which influence the way in which the sense impressions of the observer are organized into observations.

D2. Collection of Data

An important activity in science is the collection of data, as when a botanist collects specimens, or the linguist collects texts and notebooks full of informant responses.

D3. Classification

Data collected are often given a preliminary classification on the basis of lower level theories, or on the basis of other convenient criteria that suggest themselves. This classification is of course tentative and for convenience in handling the data.

D4. Experimental Method

Here is where observation makes contact with theory. The predictions of theories are compared systematically with observations. This systematic comparison is called experimentation.

E. Techniques of Experimentation

E1. Experiments Suggested by Theory

A theory that properly accounts for some observations will predict the possible results of other observations. Experiments are then performed to see if the predictions of the theory are confirmed. Thus the theory is put to the test of observation.

E2. Nature of Data

Data taken as a result of observations are always correct, except for instrumental malfunction and simple mistakes in reading. The problem comes in knowing which of the conditions under which the observations were taken are relevant for their interpretation. It is hoped that some of the conditions are relevant and the data are significant. But the data, whether they are significant or not, are correct for the given conditions.

E3. Honesty

Data are not to be disregarded in favor of some theory. A theory predicts what one expects to find if the theory is correct, but it cannot be used for deciding whether the data are appropriate or whether they are correct, for data thus tampered with or fudged cannot be trusted to shed light on the validity of the theory.

E4. Meticulous Care

Great care is taken in collecting data to eliminate mistakes, instrumental errors, and other interfering influences.

E5. Personal Bias

The scientist tries to remove all personal biases, since they may warp his judgment and get in the way of determining the scientific truth. Precautions are often taken to eliminate unintended personal bias through such means as double blind experiments.

E6. Detachment

And the scientist habitually stands in the background so as to remain objective and remove himself and his prejudices as much as possible from the research.

E7. Reproducibility

The scientist is most confident in his data when he can reproduce his observations at will. Thus he will repeat experiments to assure himself that the data can be trusted.

E8. Control of Variables

An effort is made in doing experiments to eliminate all the variables except the ones under observation. This is often very difficult and sometimes involves considerable auxiliary experimentation or the use of statistical techniques in order to discover what all the extraneous variables are or how to keep them constant or eliminate their effect on the results.

E9. Sources of Error

When data are reported, they are always accompanied by a careful examination and assessing of the possible sources of error. The experimenter is in the best position to know to what extent the data can be trusted, and it is up to him to report a realistic and honest assessing of the potential errors. In this he tries to be cautious, for he knows that he may be overly optimistic in assessing the accuracy of the data. He knows he may have overlooked errors due to his ignorance of additional variables not brought under control.

E10. Game

Many scientists even talk as if they were playing a game with Nature, trying to wrest her secrets from her, while Nature tries her best to conceal her secrets and to delude the scientist with counterfeits. In other words, the scientist should regard his discoveries with suspicion as possible delusions.

E11. Comparison with Theory

When an experiment has been completed, the resulting data are analyzed and carefully compared with the predictions of theory. In this way light is shed on the validity of the theory in question. All discrepancies must ultimately be accounted for in terms of experimental error or uncontrolled variables, or on the basis of inadequate theory or inappropriate application of the theory.

F. Theory

F1. Stem from Observation

Theories are suggested ultimately by observations, since it is their purpose to express regularities in the environment and to predict events on this basis.

F2. Hunch

Theories often start out on the basis of a hunch or guess concerning what may lie behind certain observations.

F3. From Inadequacies

Theories are often suggested by older theories and their particular inadequacies in handling certain experimental results. Sometimes these experimental results were not at hand when the older theories were developed.

F4. Inference

The processes of inference and induction in working out the first steps of a theory are very sketchy and approximate. The scientist here works intuitively. He may use rough analogies.

F5. Theory Building

As the theory takes shape, decisions are made as to how to generalize from other theories and from observations. It is not necessary that a theory have an a priori or principled basis that can be defended as independently valid, and it is a mistake to search for one. The validity of a theory is tested in other ways.

F6. Simplicity

There is nothing mystical or a priori about simplicity. The need for simplicity in science stems from the need of man to be able to predict reliably as large a range of phenomena as possible with his limited mental capabilities. Some phenomena are complex and require a complex theory for their explanation. Practically never are we in a position to compare two theories that deal equally with observation, and differ only in simplicity, and when theories differ in respects other than simplicity, these other respects are nearly always the controlling factors in acceptance or rejection.

F7. Limits of the Theory

It is often expedient to push a theory to the very limit and beyond in order to find that limit. In so doing, a theory may be pushed into territory that it does not economically handle. Later theories may push back and regain some of the ground.

F8. Taxonomy

A proper theory separates phenomena that are different and puts together phenomena that are the same. In this sense all theories are taxonomic. A taxonomy may also be predictive if it contains open positions that it predicts will be filled.

F9. Experimental Method

When a theory is ready, it is in the form of an hypothesis which can be checked by means of observation and experiment. A theory which cannot be compared with observation cannot be tested and cannot be proved wrong. It cannot become part of science and should at best be considered as speculation. Perhaps new methods will make a test of the theory possible in the future.

G. Techniques of Theory Development

G1. Deduction and Prediction

In order to test a theory against observation, it is necessary to draw predictions from it. This is done by a process of reasoning, often formal or mathematical in nature. The utility of formalism in theory is for ease in drawing predictions, not for comparison with any a priori principles.

G2. Details of Prediction

When predictions are drawn from a theory, it is important to know in detail how each specific prediction of the theory is related to the structure of the theory as a whole. In this way it will become clear for each prediction what the consequences of its not being borne out would have for the theory.

G3. Check Against Observation

The specific predictions of a theory can then be compared with a large body of observations if these are available. This is the first careful check of the theory.

G4. Experiments

A theory generally predicts the results of certain observations which have not yet been made, and in this sense a theory suggests experiments. The results of such experiments can be used to shed light on the correctness of the theory. If two credible theories predict different outcomes for a particular experiment, this experiment assumes the role of a crucial experiment, and is often interpreted as favoring one theory over the other, although neither may turn out to be correct in the end.

G5. Evidence

Often the evidence of experiment is only indirect. Sometimes the evidence bears on a point that is predicted by nearly all theories in the field. Sometimes the line of reasoning from the evidence to the theory requires additional experimental links that have not yet been closed.

G6. Substantiation and Rejection

Favorable experimental evidence for a theory only tends to substantiate the theory, but unfavorable evidence can cause a theory to be rejected in whole or in part. Sometimes the theory can be kept but amended.

G7. Tentativeness of Theories

No theory is ever established as the ultimate truth. Theories, by their nature, are all tentative. For this reason the scientist is a professional fence-sitter. It has often happened in science that the most strongly held theories have toppled.

G8. Nonuniqueness

It is possible to have more than one valid theory of the same phenomena. An outstanding example of this in physics is thermodynamics and statistical mechanics. A wide range of phenomena is accounted for by both, and each accounts for the phenomena differently from the other. But the theories do not contradict each other: there are certain reduction relations between them.

H. Role of Mathematics in Science

H1. Mathematics as a Tool

The major role of mathematics in science is as a tool or language in which theories can be stated and in which deductions from them can be drawn to be compared with observation. Under mathematics in this sense we must include logic and formal reasoning of all kinds. Informal reasoning is also commonly used at many places in theory building and in comparisons with experiments.

H2. Appropriateness

When deductions are made from a theory for comparison with experiment, the appropriateness of the mathematics and logic used must be examined. If the theory predicts correctly, the appropriateness of the calculations used in this instance tends to be substantiated along with the theory.

H3. Pseudomathematics

A competent scientist does not pepper his manuscripts with mathematical notations that serve no good purpose in computation or exposition. Mathematical notation is not to be used as window dressing.

H4. Innovations in Mathematics

Often the needs of a particular scientific theory can only be met by the invention of new methods in mathematics. These new methods may lack the rigor of the more carefully worked out areas of mathematics, but work perfectly well in the particular scientific application. They are often cleaned up later by mathematicians and made more general and more rigorous. Sometimes whole branches of mathematics have their origins in the needs of a particular scientific theory.

H5. New Applications

It is sometimes the case that a branch of mathematics investigated for its own sake is later applied in science in a way that could not have been foreseen at the time of its development. It offers a mode of reasoning appropriate to the new subject matter.

H6. Role of Statistics

Most of our basic theories are not statistical in nature. Often, however, the difficulties of observation, either inherent or due to unknown interfering effects, prevent an exact comparison of theory with experiment. In such cases statistics are often used to average over the interfering phenomena. We give up the possibility of exact prediction of all details and gain an ability to predict averages, which often can be compared directly with observation.

H7. Role of A Priori

While the role of a priori is very substantial in mathematics and logic, it has no direct application in science. A scientific theory, or any of its parts, are not required to have any a priori truth or justification. Their truth can only be investigated by means of comparison with observations and experiments which would tend to confirm or to disconfirm the theory as a whole or in part.

H8. Pure Mathematics

Although much of scientific theory is couched in mathematical terms, mathematics itself is outside of science, as we have been using the term. Mathematics and logic are based on the a priori and on arbitrary but interesting definitions. They are in the logical domain and thus are not subject to comparison with experiment or observation.

H9. An Inappropriate Model for Linguistics

A linguistics conceived on the model of mathematics or logic, and therefore not subject to comparison with experiment or observation, would not be part of science. It would not have contact with reality, and any relationship to linguistic phenomena would be speculative at best, for it could not be tested.

I. Scientific Knowledge and the Community of Scientists

I1. A Cooperative Venture

Science advances by means of an accumulation of knowledge as a community or cooperative venture of scientists.

I2. Scholarship

A scientist requires knowledge of prior work. This he may obtain through scholarship. There is a very important role of education in science. The tradition is thus handed on and continually reexamined.

I3. Reproducible Experimental Results

Science involves the building of a tradition that includes a body of accepted reproducible experimental results. These results accumulate by accretion, and have to be accounted for by theory. They must be reproducible so that if they are ever brought into question, they can be

checked. They are in fact brought into question and checked whenever any doubts arise. Of course some observations can, unfortunately, never be checked because the occasion is lost in history. If this is the case, the best we can do is to try to assess the amount of confidence we can have in the observations and in any conclusions based on them.

I4. Accepted but Tentative Theory

Science involves the building of a body of accepted but tentative theory. Since theories can never be completely validated, they must always be tentative. However, a tentative theory can be accepted as the basis for building additional theory and as a basis for suggesting experiments.

I5. Progress

Progress in science requires attempting to reconcile conflicting evidence and conflicting theories, often by improvements in theory and in experiment.

I6. Limitations of Theory

In science it is imperative that there be full knowledge of and discussion of the limitations of current theory. Such discussion should not be construed as attacks on the theory or its inventor. It is appropriately initiated by the inventor himself.

I7. Discrepancies

When discrepancies are discovered between different theories, between different observations, or between theories and observations, the way may be opened up to achieve new insights. Such discrepancies are to be viewed as opportunities and not an occasion for polemics.

I8. Presentation

In presenting the results of a scientific investigation, facts and theories should speak for themselves. No argument for them should be brought forward that is irrelevant to the way in which they have been arrived at or could be judged.

I9. Advocacy

The scientist is a searcher for knowledge, not an advocate of a position, like a lawyer before a judge or a jury. In science it is presumed that all scientists are on the same side, that is, the side of trying to find out the truth about the phenomena in question; whereas in law the presumption is that there are adversaries, each with a personal stake in a different outcome. This point of view is foreign to science.

I10. Polemics

Polemics and prowess in argument and disputation do not settle questions in science or prove a view to be right or wrong. Scientific truth is arrived at not by argument, but by reasoning from the evidence.

I11. Character Assassination

There is no room in science for character assassination. A scientist, in his publications and private utterances, keeps his eye on the subject matter and the cooperative venture of arriving at scientific truth.

I12. Means to an End

The burden of building and maintaining this body of knowledge falls mainly on publication by scientists and accumulation of publications in libraries. The importance of libraries in storing the information and arranging for easy and convenient access to it cannot be overemphasized.

J. Publication

J1. Purpose of Publication

The purpose of publication is to add to the available knowledge in such a way that other scientists can make use of it.

J2. Open Publication

It is important for the advancement of science that results be published in an open manner so that they are available to all other scientists. The burying of important results in manuscript form, or leaving them as rough notes or as tentative reports to sponsors, act to impede the unrestricted flow of scientific information. Likewise, the restricting of results to employees of one company or citizens of one country is to be deplored. The cooperative effort necessary for scientific progress cannot flourish if unnatural barriers to information flow are erected.

J3. Prompt Publication

It is important, when a piece of scientific research is finished, that it be reported promptly. Delays in the publication of important results impede scientific progress and tend to foster duplication of effort.

J4. Complete Publication

When a piece of research is published, it should be published in complete enough form so that the work can be repeated and verified by others.

J5. Responsible Publication

It is important that the scientist refrain from publishing prematurely, carelessly, or repetitiously. Sloppy scientific publication wastes the valuable time of the more competent workers by competing for their attention against more worthwhile activities, and by introducing misinformation into the literature that could impede our future understanding.

J6. Honest Publication

It is important that standards of honesty, truthfulness, and accuracy in publication be of the very highest. A piece of work is of no use if it is suspected that it has been put forth with less than complete honesty, truthfulness, and accuracy, for other scientists would hesitate to use the results until they had verified them themselves.

J7. Sources of Errors

It is important that a publication include a careful reporting of all discrepancies, doubts, and sources of error remaining after all due care has been taken. The scientist who did the research is in the best position to assess the sources of error and it is incumbent upon him to report them clearly and honestly.

J8. Fair Publication

Authors would do well to give credence to the possibility of conflicting theories or experimental results. They should present a fair discussion of the pros and the cons.

J9. Credits

All publications should contain careful and honest citation of prior work so that due credit is given to other investigators.

J10. References

For the benefit of future students and researchers, bibliographic references should be given for important citations. It should be possible for a person who becomes interested in the work to follow back through the references and uncover all the important prior work on this point. The references should ultimately lead back to initial or basic papers.

J11. Who to Cite

Citations and references should be chosen on the basis of their relevance to the subject matter for readers of the work at hand, not on the basis of personal considerations of the author. Citations are not to be used as impressive window dressing, as symbols of solidarity with a group, as salutes of allegiance to a leader or a movement, or as patronage for one's friends; and the exclusion of relevant citations should not be used as ammunition in a war between opposing camps.

J12. Advertising

The purpose of publication is not for advertising a particular theory, a particular group or school, or any other entity.

J13. Personal Aggrandizement

The purpose of publication is not to build personal reputations.

J14. Built-in Conflicts

There is the possibility of conflicts within the individual scientist because his personal advancement often depends strongly upon the research that he has done and therefore upon his publications. Thus each scientist tends to find himself in a position where personal considerations might conflict with the requirements of science and scholarship. The scientist resolves these conflicts in favor of science.

K. Terminology

K1. Careful Use of Terms

It is important that terminology be used carefully for the purposes of communication, and to carry accepted meanings.

K2. Change in Terminology

Terminology should not be changed needlessly. This can only introduce confusion. The development of agreed-upon terminology is part of the community effort in science.

K3. Banners, Badges, or Trademarks

Words should not be used as banners, badges, or trademarks to indicate allegiance to a particular point of view or school, or for empire building. Neither should unfavorable allusions be added to words to make them into weapons to hurl against other scientists. Such use of words removes the author from the cooperative endeavor of science, and puts him into a position of advocacy of special interests.

K4. Narrow Definitions

A scientist will not insist that his narrow and egocentric area of interest be used to define the scope of a broad field such as linguistics, and then use this definition as a club in argument, claiming that his adversaries are not linguists. Such usage again removes the author from the community of science.

L. Personal Characteristics

The scientist therefore cultivates the following personal virtues, among others:

L1. Inquiring Mind

A scientist will cultivate an inquiring mind and will actively seek out new sources of data and new questions to ask.

L2. Competence

A scientist will try to develop his competence as an investigator, and not be satisfied with mediocrity in his own performance as a scientist.

L3. Pride of craftsmanship

The scientist takes pride in craftsmanship — in doing the best job that he is capable of. He does not go to the extreme, however, of worrying unduly and protractedly over minor and petty details that are clearly not relevant to the scientific and scholarly quality of his work.

L4. Scholarship

The scientist maintains contact with the intellectual tradition in his field. He makes it his business to know what has been done. He is careful to achieve a thorough understanding of the prior work and to assess it on its merits. He distrusts secondary sources.

L5. Open-Mindedness

The scientist tries to maintain an open mind, and is ever ready to entertain new ideas and new theories. He is tolerant of new approaches, and realizes that a diversity of backgrounds among scientists in a given discipline can be the source of great strength.

L6. Collegueship

The scientist is a good colleague of other scientists. He considers them to be his teammates, playing in a game with the only adversary being Nature and her secrets.

L7. Intellectual Honesty

A scientist develops intellectual honesty and personal integrity. These he makes habits not only in his scientific work, but also in his personal life, believing that there can be no compromise in these matters.

L8. Perseverance

A scientist will cultivate an ability to push an idea that shows promise as far as necessary, even in the face of great discouragement, but he maintains an ability to know how far to push an idea and when to drop it. This takes finesse because good ideas should be pushed to completion and bad ideas should be dropped as soon as possible. Often it is not known at the outset whether an idea is good or bad.

L9. Modesty

The scientist is fully aware that his work may turn out to be wrong in spite of his best efforts. He therefore puts it forth with all due modesty.

L10. Arrogance

Arrogance is out of place in a scientist, since it tends to commit him emotionally to the position he is currently holding, and makes it more difficult for him to change as progress is made. Excessive arrogance may lead to the personal domination of other scientists with a resulting constricting and inhibiting effect.

L11. The Right to Be Wrong

A scientist does not cling stubbornly to an idea that proves to be wrong, and he grants to other scientists the right to have been wrong. He knows that science can only advance by means of change and improvement in theory and observation. What is right on the basis of current evidence may turn out to be wrong when additional evidence is in. Some of the world's greatest scientists have been wrong and it does not detract from their stature.

Finally, this last point is perhaps central to why there can be no *isms* in science.

L12. Personal Responsibility

A scientist assumes personal responsibility for the work that he chooses to do and for the decisions as to what theories he will tentatively accept and what methods he will use. In these matters he does not bow to external authority or to scientifically irrelevant considerations, as his personal scientific integrity is at stake. And, as we have seen in earlier points, he applies scientific criteria in deciding what to believe. This idea of personal responsibility and the application of scientific criteria of truth is the reason that science, in the long run, converges on agreement as to the best current tentative understanding of nature.

Note

¹This paper was the Presidential Address presented at the annual LACUS meeting in the summer of 1986 and published in the proceedings: *The Thirteenth LACUS Forum 1986*, ed. by Ilah Fleming, pp. 3-15. Lake Bluff, Ill: LACUS, 1987.