3

Scientific Writing

The rhetorical setting of research has consequences for scientific writing as well as scientific terminology. It establishes a universe of discourse which mandates accuracy and clarity, and an object-oriented point of view.

3.1 ACCURACY

Efforts to achieve accuracy in research are ineffectual unless they are communicated to readers as accurately and closely as the language permits. Accuracy is therefore central to scientific writing. For accuracy, the first requirement in reporting research is that the data reported be absolutely accurate. The accuracy of numerical values is especially important in reporting measurements or values derived from statistical data or analyses. Data cited from earlier research must be verified to ensure that no error is made in transcription. All pertinent data should be presented. An omission may be as important to readers as the data included.

Falsification is a cardinal sin in scientific research. When a research scientist intentionally fabricates or falsifies data, the falsification is considered so heinous an offense that it causes serious disturbance in the discipline and in science at large. It raises questions about scientists, the conducting of research, the training of scientists, and about the scientific enterprise in general. It may undermine the confidence of nonscientists in science and scientists, and raise questions about their reliability, credibility, and even about monitoring. Research scientists are more likely to be led into *unintentional* misrepresentation, because of bias. They may not adequately report exceptions or variations that threaten their favored interpretation, or they may present their research in a biased manner. While less flagrant than intentional falsification, such biased reporting muddies the waters and impedes the advancement of science. Therefore, although accuracy in reporting measurable entities can be achieved simply by reporting quantities and units of measurement correctly, in all else, accuracy depends on the use of words, and in science, words must function with the accuracy and precision of measurements. Because of this dependence on language, accuracy is inextricably linked with clarity and is not possible without clarity.

3.2 CLARITY

3.2.1 Accuracy, Clarity, and Validity

Clarity is the central requirement in writing a scientific paper. It is not merely a desideratum of style. It is important for fundamental scientific reasons, because of the innovative character of scientific research and the need to validate it. Clarity is unqualifiedly necessary for validity, and is thus the canon for scientific writing. Clarity is also essential because a scientific paper is the primary source for the research. The research is not fully available to other scientists unless the scientific paper is written clearly.

It is important to recognize that the accuracy is antecedent to clarity, that clarity has only to do with accuracy in transmission. Even with clear denotation and clear reporting, it may be difficult to validate the research. However, if the research is not clearly presented, it is *ipso facto* impossible to validate it. For example in *Table 3.1c* and *d,* it is not possible to address the observations reported because they include the inaccuracy in transmission as well as any original inaccuracy. More important, there is no certain way for readers to distinguish between the two sources of inaccuracy. Clarity cannot correct for inaccuracies or confusion in the original observations or concepts. It is the importance of accuracy of transmission that makes clarity central to scientific writing. If a research scientist's report is accurate, then it will result in an accurate transmission of the observation to the reader, whether the observation was accurate (*Table 3.1a*) or inaccurate (*Table 3.1b*). If the transmission is inaccurate, or unclear, then the original accurate observation will be inaccurate when received, regardless of the accuracy of the observation (*Table 3.1c,d*).

Consequently, to achieve the necessary accuracy in transmitting information to readers, the writer must aim for maximum clarity. This means first that words must clearly denote the meaning of the entity that they represent. Then they must be so ordered into sentences and paragraphs that the language (1) matches the writer's intended meaning precisely and (2) can be decoded by the intended reader to match closely the writer's meaning.

TABLE 3.1 Effect of accuracy* of observation and transmission† of observations on report of observation and reception by peers

Observation	Transmission	Report	Reception by peers
a. Accurate	Accurate	Accurate	Accurate
A	T	AT	A_T
b. Inaccurate	Accurate	Accurate	Inaccurate
a	T	aT	a_T
c. Accurate	Inaccurate	Inaccurate	Inaccurate
A	t	At	A_t
d. Inaccurate	Inaccurate	Inaccurate	Inaccurate
a	t	at	a_t

*A = accurate, a = inaccurate relative to observation.
†T = accurate (clear), t = inaccurate (unclear) relative to transmission.

3.2.2 Precision of Language: Words and Meaning

Clarity in scientific writing encompasses the meaningfulness of words, attained by the precision of language at the word and phrase level, and the meaningfulness of relationships, attained by a logical conceptual structure at the sentence and paragraph level and beyond.

Precision of language is an absolute requirement for scientific writing. It is made possible by the scientific terminology that has been developed in each discipline. However in scientific writing, even everyday words, which are not as strictly delimited in meaning as scientific terms, should be used precisely.

Denotation versus connotation. Scientific terms constitute the first step in the objective delimitation of natural phenomena for scientific measurement and operations, and for scientific communication. Ideally, a scientific term will have only one meaning. This is decisive in limiting scientific writing to denotative rather than connotative or figurative language. The need for accurate, precise language, therefore, precludes uses of the language that are often effective in general writing, because they *are* imprecise or indefinite. Such usages may be imprecise because of (1) their elaboration in figures of speech—metaphors, similes, analogies, euphemisms, cliches, and other forms of connotative language, or (2) their indefiniteness, vagueness, abstraction, or generality. The figure of speech may magnify, diminish, emphasize, heighten, or color the idea expressed, or it may cast a particular light on it or give it a particular tone in a way that the displaced denotative word or term cannot—and in scientific writing, should not.

The connotative use of language is also not consonant with the international character of scientific writing and impedes the dissemination of research. Connotative and figurative language requires that readers know the language well enough to recognize the play on words. For research scientists for whom English is not a first language, such language, like colloquial and informal usages, is confusing or incomprehensible.

Using words anthropomorphically, that is, to ascribe human attributes to nonhuman entities, also departs from denotative language (*Table 3.2*). The use of anthropomorphic language is partly due to making an object of scientific import the agent of human action. For example, in scientific papers, statements such as the following may be made:

Ex. 3.1

This *study, research, report, paper, investigation:*

reports	determines	disputes	plans to
demonstrates	examines	intends	agrees with
displays	establishes	compares	proposes to
shows	attempts	questions	takes issue with
indicates	displays	claims	hypothesizes
outlines	relates	investigates	asked two questions
describes	found	argues	objects

where the verbs make the statements increasingly anthropomorphic from left to right. The anthropomorphic language can be avoided by providing an agent or focusing on the substance of the research as in *Ex. 3.2b:*

Ex. 3.2

a. Critical attribution ***research has*** largely ***ignored*** the different functions that attribution serves and ***has*** usually ***been content*** to take them at face value as expressions of casual belief.

b. The different ***functions*** that attribution serves ***have*** largely ***been ignored*** in critical attribution research, and social scientists ***have been content*** to take . . .

The most serious problem with anthropomorphic statements arises when they are teleological, that is, giving nonhuman entities intention toward a goal or objective, as in *Table 3.2* no. *4–6*.

Pretentious writing is also not consonant with denotative language. Scientific writing is formal writing, because it is the serious, permanent documenting of scientific research. It therefore has a formal structure, and scientists use formal words suited to this formal structure. However, some formal words may be pretentious or even pompous:

Ex. 3.3

aforementioned	delineate	endeavor	possess	upon
amongst	depict	exhibit	prior to	utilize
anticipate	display	hereafter	reveal	whence
circa	elevated	herein	sacrifice	wherein
commence	employ	inaugurate	therein	whereof
concerning	encounter	initiate	thereof	

It is no less pretentious, however, to use language that is too informal. When writers use language to draw attention to themselves or their writing, whether casual or punctilious, they are no longer focusing on the research, but about themselves.

Humor is a departure from the unity of structure, form, and tone of the dis-

TABLE 3.2 Sentences in which words are used anthropomorphically

1. The current long-term persistence *models can have no trouble* reproducing the Hurst coefficients.
2. The *research concluded* that there was a strong correlation between the two variables.
3. The *farms* in the sample *packed* their silage differently.
4. The important idea to emerge is that complex *physical systems* with infinitely many available degrees of freedom *choose* to execute a dynamical motion.
5. The *enzyme needs* a pH 4 to break the bond.
6. Figure 3 shows that in line with experimental indicators (18) *putrescine prefers* binding at the T sequence.
7. The extensive theoretical *studies examine* this anomaly, but only a few *studies have tried* to solve the problem empirically.

course in a scientific paper. A scientific paper has an implacably declarative and documentary character, which precludes humor. To believe that tossing in a bit of humor lightens the formality or "heaviness" of scientific writing is to misunderstand the rhetorical setting, the universe of scientific discourse, and the nature of humor. A scientist in the discipline interested in the research does not find it dull and may even find the humor intrusive.

Humor is also topical and cultural. Readers who are not insiders may not recognize the humor or be confused by it. These include readers outside the discipline, nonnative speakers of the language, and future readers. Ultimately, only the historian of science may know that humor was intended.

Sex-biased language. The use of masculine forms (*he, man, mankind*) as neuter forms is inaccurate and therefore not appropriate for scientific writing. One of the commonest problems in avoiding sex-biased language is the use of personal pronouns with gender (*he, she, him, her, his, him*). Since the plural pronouns (*they, them, their, theirs*) lack gender, then whenever a sentence can be structured so that the pronoun can be plural, bias can be avoided. When it is necessary to use the singular pronouns, both pronouns are used, for example, *he or she, his or her, himself or herself*. When such phrases are used repeatedly, they may be abbreviated. The form *he-she* or *his-her* is to be preferred to the form with a slash.

Two important sex-biased nouns are often used in the biological sciences: *man (Man)* and *mankind (Mankind)*. Both are synonyms for *human beings*, and "mankind" is a synonym for the little-used *humankind*. Both make the part stand for the whole; they also make the name associated with the distinctive anatomy of one sex stand for the equally distinctive and different anatomy of the other sex. They are therefore less accurate than the "human" forms. It is true, of course, that *human beings* and *humankind* do not carry the connotations of *man (Man)* and *mankind*, but that is due to their having been long used in their particular niches, so that they have preempted that space for their particular associations of meanings. With similar usage and enough time, the unbiased terms can come to have the connotations of *man* and *mankind*.

Dehumanizing terms are also inaccurate, as well as diminishing. Referring to persons as *cases* or *subjects* instead of clients, participants, or respondents is depersonalizing.

3.2.3 Clarity and Structure

Words are not meaningful unless they are meaningfully ordered; therefore, clarity is dependent on structure as well as words. The two main structural prerequisites for clarity are coherence and conciseness. Conciseness is also required to save space in journals and to save readers' time and effort.

Coherence. Coherence is the ordering of words into sentences, sentences into paragraphs, and so on, so that they develop a closely reasoned, logical, line of thought, both within and between units. Coherence is fundamental to clarity and makes the greatest demands on writers to think, write, and read clearly. Writers must formulate their ideas and then find the words and syntactic structures to express them so that they represent the conceptual structure of their thinking. This translation is very difficult, because there is no direct correspondence between thoughts and their formal expression in words.

The conventional sections of the paper establish the overall structure and so lay the ground for a coherent presentation. Once the line of development has been established for a section, the order of the paragraphs follows, and each paragraph contributes to the line of development. Therefore, much of the writing is focused on structuring paragraphs and the sentences in them.

The paragraph must have unity if it is to be coherent. A collection of sentences on different topics is not a paragraph; neither is a collection of sentences on one topic—the related sentences must be coherently ordered. That is, the sentences within the paragraph must be so ordered and structured that there is a line of thought that begins with the opening sentence and terminates with the last sentence of a paragraph. The paragraph may be variously developed. It has no prescribed shape except that which is prescribed by the structure of the message, but it must have an orderly structure.

In establishing order in a paragraph, the research scientist cannot depend on the topic sentence, the key structuring device recommended for much general writing. A topic sentence is a general statement that states the topic or subject of the paragraph and is developed by succeeding sentences. Instead of topic sentences, research scientists require a kind of organizing structure that allows the specific, detailed, and complex relationships found in scientific research to be developed into a logical line of thought. This can be accomplished to some extent, *externally,* by connectives, that is, transitional words or phrases. Scientists sometimes express the connections implicitly by structuring successive sentences so that their content and meaning expresses the relationship. Such implicit connections leave readers adrift or require them to supply connections from the context and structure alone. This is not conducive to clarity, since the reader's connection may only approximate the connection that the writer intended.

Carbohydrate loading on the High Performance Diet was developed in the United States based on studies by a team of Swedish physiologists. These studies show that the average concentration of glycogen stores is 1.75 g/100 ml with a normal diet. If this diet is then changed for 3 days to one of high fat and high protein, then the glycogen level drops to .6 g/100 ml. If the diet is modified again to include large amounts of carbohydrates for 3 days, then the glycogen stores will increase to 3.5 g/100 ml. If this carbohydrate phase is accompanied by strenuous exercise, then the glycogen level will rise to 4.7 g/100 ml. This is almost a three-fold increase in glycogen stores compared to a normal diet.

Figure 3.1. Paragraph illustrating coherence achieved by hook-and-eye linkage. Word (in oval) in one sentence linked to word (in rectangle) in preceding sentence.

Internal connections are more effective and important constructions for achieving coherence in scientific writing. A kind of hook-and-eye construction, in which one sentence is explicitly connected to the preceding sentence, clearly establishes the relation between the two sentences. This is accomplished by relating one sentence, often the beginning of it, to the preceding sentence by repeating a word or phrase from the preceding sentence, or by referring to a word directly or indirectly.

The example in *Fig. 3.1* illustrates this kind of connection in an almost exaggerated form. Near the end of each sentence is a word (the eye), which is in the central line of development of the sentence. Near the beginning of the next sentence the same or a similar word (the hook) links the rest of the sentence to the preceding one and thus continues to develop the line of thought. The hook and eye need not be the same word (see *Ex. 11.8*), but they must be clearly and closely enough related that the link between them can be readily recognized.

Coherence at the sentence level, referred to as cohesion, requires the internal ordering of a sentence syntactically and meaningfully so that the parts clearly make the statement intended and the sentence forms part of the logical progression of the paragraph.

Coherence is also effected by consistency. A consistent point of view avoids distracting the reader from the main approach in the presentation. Consistency of form makes clear the coordinate character of the elements in a series or list, or the parallelism of concepts. Consistency in the titles of tables and figures, in footnotes, and in bibliographic references provides a formal order, which allows the various parts to emerge as ordered units, and thus contributes to clarity.

Conciseness. Writing is concise when everything that needs to be said is stated in whatever detail is needed in as few words as possible—that is, just the right words and the right number of words, in the right order—no more, no less. This economical matching of words to message contributes to clarity, because it eliminates verbiage, excessive details, and repetition.

Forms of Verbiage. Verbiage may consist of excess words or of words with little meaning. It constitutes noise in writing and stands in the way of clarity and conciseness. The wordiness may be due to common empty, filler words or phrases:

Ex. 3.4

due to the fact that	the test in question
in a considerable number of cases	at this point in time

(see also *Appendix A*). Such phrases are readily recognized and easily eliminated without loss. Many are vacuous prepositional phrases; others are introductory phrases that the writer seems to need to wind up before getting into the substance of the sentence. They may be used as transitions, but they are feeble or pseudotransitions that may be superfluous, as in the phrase, "it is of interest to note"-- if it is not, saying so will not make it so.

Repetition is a form of verbiage. It may be contiguous; for example, it is not uncommon to state an idea in one sentence and then restate it in the next sentence in different words, as though it were a different idea. Such tautology is more likely in writing about concepts than concrete observations and measures. Or the repeated material may be distant. In a paper that is not well organized, the same idea or information may be repeated at different points in the paper. When more than one idea is repeated, the line of development is likely to become confused. In fact, repetition is a good clue that the organization may be faulty, a clue that the writer can use in revising and editing the paper.

Verbiage may consist of excessive detail, which also interferes with clarity, for example, long series of words or phrases or long lists of numerical quantities or values. Writers must show readers a pattern in the details or series; otherwise, the paragraph becomes a confusing conglomeration of details.

Conciseness versus Brevity. The need for conciseness must not override the need for clarity. It is not a call for brevity. The objective is not simply to save words or space; the objective is to make *optimal* use of words, that is, to use every word that is needed for expressing an idea, no more, no less.

This confusion of brevity for conciseness leads to writing elliptically, implicitly, or in summary. Ellipsis is the omission of words. An attempt at brevity may lead to misconstructions such as shifts and dangling or misplaced modifiers. Stating ideas implicitly omits connections and leaves the reader to make connections and interpretations that have not been expressed. Writing in summary is minimal writing; it is writing what one essentially means, but it omits some of the information, interpretation, and connections that readers need to arrive at the essential meaning. Making brevity a dominant objective may lead to a telegraphic style that distorts normal idiomatic language patterns and so interferes with clarity.

Writers who aim for brevity may follow personal guidelines. The cultivation of short simple sentences is often a cult of brevity and simplicity, and it results in an abandonment of the writer's responsibility—to determine the necessary relationships and to state them explicitly and clearly for readers. Some writers even omit articles, but the automatic omission of so regular a particle in the language is unidiomatic. Since it is impossible to omit all articles, readers are left to interpret the writer's intent whenever an article is omitted or included.

The choosing of short forms in preference to long forms, for example, the preference of the *-ic* form of the adjective to the *-ical* form, illustrates the difficulty of following "logical" guidelines for language. The two forms are not merely long and short forms; they often differentiate between meanings (historic, historical, economic, economical), between usages (optic, optical), and between functions (statistic, *n*; statistical, *adj*). In sum, if writing is prolix, the verbiage obscures the meaning; if it is general or indefinite, the vagueness makes the meaning unclear; and if it is terse, the omissions leave gaps in meaning.

3.2.4 Types of Development

Deductive versus inductive. Scientific research is essentially inductive, moving from the known to hypotheses about the unknown, and from specific findings to generalizations. This method is particularly well adapted to the development of parts of the paper that are short, simple, or straightforward and that conform to the conventional structure of the paper. For example, hypotheses are effectively developed by following the inductive method. When the development is a long and complex discussion requiring elaborating on the conceptualization of a problem, and drawing on different ideas and material, starting with the general concept or statement may make it easier for the reader to follow the argument, and so makes for clarity. This deductive method is adapted to theoretical and complex papers or sections, for example, a discussion section with a complicated explanation and interpretation.

In the inductive method of development, readers do not know the destination until they arrive at it; therefore, they cannot recognize or verify a wrong turn along the way. They must follow the writer very attentively to avoid becoming lost. The writer must therefore be absolutely clear and logical in the development to avoid confusing or misleading readers.

In the deductive method, readers are told the destination at the start and so have it as a point of reference along the way. As the development unfolds, they mentally nod their heads in agreement, unless the path seems to diverge from the logical route to the destination. They can then pause to determine whether they have missed a turn or whether the writer has digressed from the logical route. Because the deductive development thus deviates from the form that would reflect the research, and starts with the end result, the writer must be wary of giving the development the authenticity or validity of definitiveness, generality, or universality.

Sequential. One may follow a sequential development, which is an easy type of development because it corresponds to the sequential, linear character of writing. Such a development is adapted to temporal events, spatial series, or two-dimensional entities. Three-dimensional entities, such as equipment, do not lend themselves to the linear, sequential character of sentences but can be reduced to a two-dimensional path diagram. The development may then proceed linearly from base to top, for objects oriented relative to a base, as for geographical periods; from top to bottom, as for organizational charts; or from side to side, as for block diagrams.

Comparative. Comparative relationships are readily adapted to the linear character of writing. One is either comparing a linear series of entities, A to B to C . . . , or comparing two or more entities relative to a series of attributes, for example, A_1, A_2, A_3 to B_1, B_2, B_3. This serial comparison may be vertical, with the attributes of one entity, A_1, A_2, A_3, compared to the attributes of the second entity, B_1, B_2, B_3. It may be horizontal, with entities A and B compared for one attribute before the next attribute is considered. This allows the writer to shift the order from B to A, if B merits emphasis.

Analytical. Analytical conceptualizations may include a variety of relationships. The development of a concept may include chronological elements, an explanation, cause-and-effect relationships, and comparisons. The conceptual complexity of such multifaceted relationships is analogous to the structural complexity of physical two- or three-dimensional objects, and so one can transform the multifaceted conceptualization into a path diagram that lends itself to the linear form of writing.

3.3 PASSIVE VOICE

The passive voice is commonly used in scientific writing, and scientists are regularly criticized for using it. Since even critics sometimes confuse the passive voice with the linking verb "to be," it seems useful to differentiate the passive from the active voice.

3.3.1 Passive versus Active Voice

In the active voice, the subject acts, and the verb carries the action, often to an object:

Ex. 3.5

a. A control protocol *executed* the transactions.
b. High levels of the drug *may inhibit* synthesis of proteins in the brain.
c. The male birds *surrounded* the female birds.
d. The curve *rises* sharply after each administration of the drug.

In the passive voice, the subject is acted upon, and the action of the verb falls on the subject. The focus of the sentence is on what happens to the subject, not what the subject does:

Ex. 3.6

a. The transactions *were executed* by a control protocol.

b. Synthesis of proteins in the brain *may be inhibited* by high levels of the drug.

c. The female birds *were surrounded* by the male birds.

In the passive voice, the verb is formed with the auxiliary "to be" (is, are; was, were; be) together with the past participle. The verb in *Ex. 3.5d* is in the active voice, but it is an intransitive verb that does not take an object and cannot be transformed to the passive voice.

The passive voice is variously criticized. Three criticisms directed to scientists are addressed here: (1) that they should not use the passive voice because it is weak, (2) that they use the passive voice to give a specious objectivity to their research, and (3) that in not providing an agent, they are avoiding being accountable for their research.

The passive voice is, of course, weaker and less direct than the active voice, as can be seen from *Ex. 3.5a–c.* This weakness is considered a defect in current criteria of "good style," in which an active, vivid, lively, "verby" style is espoused. The active voice is such an important stylistic device in present academic writing, that the passive voice is proscribed, as though it were an aberrant form in the language. The passive does have a function in the language, which is not easily performed by other syntactic structures and which is particularly useful for reporting scientific research.

The passive voice is the linguistic construction available to writers when the object is acted upon or when the object is the topic of interest. Sentences in the passive voice may be general statements which cannot be converted to the active voice, for example: "Aluminum is readily oxidized." The passive voice may be used more specifically:

Ex. 3.7

1. The nitrogen laser, based on the traveling design, *was composed* of a folded Blumlein acting as the storage capacity, a resonator, and a low-inductance spark gap.
2. The formation of tubercles *was stimulated* by the removal of the apical meristem.

Both sentences in *Ex. 3.7* can be revised to the active voice:

Ex. 3.8

1. A folded Blumlein acting as the storage capacitor, a resonator, and a low-inductance spark gap *composed* the nitrogen laser, based on the traveling design.
2. The removal of the apical meristem *stimulated* the formation of tubercles.

but this shifts the topic from *nitrogen laser* to its parts, and from *tubercle formation* to the apical meristem. Although in isolated sentences this shift in topic may be considered negligible in relation to the improvement resulting from a more direct, active construction, the shift is not negligible in a discourse focused on the nitrogen laser or tubercle formation.

As indicated in *Ex. 3.7*, some sentences in the passive voice cannot be written in the active voice:

Ex. 3.9

a. Pycnidia *were produced* copiously on the bark lesions and were morphologically similar to those produced on eucalyptus under conditions of natural infection.

b. The instar *was* most commonly *found* on the soil surface.

c. Proteolysis of azocasein *was* completely *abrogated* when the cells *were separated* from the substrate.

In such sentences, the agent required for the subject of the sentence in the active voice is unknown, irrelevant, or nonexistent.

The following sentences illustrate how the passive voice allows the writer to focus on the subject of interest:

Ex. 3.10

a. Green* (1985) *has used* interferon in a new treatment of cancer to control the division of cells.

b. A new treatment of cancer *has been used* [by Green] in which interferon is used to control the division of cells.

c. Interferon *has been used* [by Green] to control the division of cells in the treatment of cancer.

d. The division of cells *has been controlled* by using interferon in the treatment of cancer (Green, 1985).

Here the sentence in the active voice (*Ex. 3.10a*), focuses on Green, not on cancer research. The remaining three sentences focus on different aspects of the research on interferon in treating cancer. These sentences could not be substituted for one another at a particular point in the development of the paragraph. The examples illustrate how the passive voice makes for a precision of focus that cannot be achieved by the use of the active voice. They also illustrate why the passive voice is particularly suited to reporting scientific research, and is in fact unavoidable (*Table 3.3*). However, in some sentences, the active voice is preferable in the context of the text (*Table 3.4*). Such sentences should be revised so that the verbs are in the active voice.

Other attributes of scientific writing tend to promote the use of the passive voice. Scientific writing is largely descriptive, reportorial, and conceptual. The materials, methods, and results of the research are described and reference is made to those of earlier research. Such description does not make for action verbs or vivid nouns or adjectives. And even the most exciting concepts have more to do with relations and states than actions. Also research focuses on *objects*, not agents, and on new entities that constitute additional *objects* to be named.

**Green, DeBretor, DeBrion, DeCanet, DeLacor.* Fictitious names used in fictitious reference citations.

TABLE 3.3 Sentences in which passive voice is appropriate, functional, or required for rigorous scientific writing

1. Only sound protoplasts with intact membranes *were included* in the counting.
2. Villages representing only 2 of Alaska's 12 native regions *were selected* for the study for reason of controls, comparisons, and economy.
3. Numerical solutions *are obtained* by means of the sequential gradient-restoration algorithm for optimal control problems.
4. Equation (9) *may be used* to describe the relationship between the measured and suspended volume.
5. When bromoergocryptina *was administered* after parturition, a marked increase in milk yield *was observed* in rats and rabbits.
6. Evidence of validity *must be considered* relative to specific purposes for which simulations *are to be used.*

3.3.2 Specious Objectivity

The focus on the object rather than the agent is the basis for the objective reporting required for scientific research. The term *objective* is used here denotatively, but it is used generally with a positive association for unbiased or impartial. To this latter use of the word for scientists, critics take exception. They believe that scientists are imposing on their readers, and on nonscientists, by presenting themselves as objective, when they unquestionably do have a personal investment in their research. Nevertheless, however subjective scientists may be about their research, their writing must focus on the research, and must satisfy canons of meticulous observation and measurement and of rigorous logic in drawing inferences. Moreover, the research must be replicable or confirmed by others, a requirement that places strong restrictions on subjectivity. The writing of research scientists therefore focuses on the *objects* of research rather than on themselves as agents, and the presentation is thus objective in the sense of being *object-oriented.*

TABLE 3.4 Sentences in which passive voice is not required for scientific or rhetorical purposes

1. They showed the effects of the hormone on the *Drosophila* Kc cell line, an established line of embyronic cells. Five stages of cell growth in culture *were described.* [They *showed* . . . and *described.* . . .]
2. The stomata in the leaves were the principal openings through which water vapor *was diffused* [diffused].
3. The pathogen is most commonly parasitic on clovers, both *Trifolium* and *Melilotus* species, but alfalfa can also *be* severely *damaged.* [but can also severely *damage* alfalfa]
4. It *was inferred* by Green* (1986) [inferred] that the low rate of synthesis of these products was a consequence of the low temperature.
5. The size had to be small enough that the implant *could be* easily *adjusted* to by the tissue. [that the tissue *could* easily *adjust* to the implant]
6. For illustration purposes, Fig. 1 shows part of the spectrum examined *by us.* (Delete *by us.*)

*Fictitious author

Some critics make the more sophisticated argument that, scientifically, an observation cannot be made in isolation, without considering the position of the observer. They extrapolate this to mean that scientists cannot make objective observations and therefore should include themselves in the observation in reporting it; that is, they should use the first person. To reify this theoretical position in a rigid practice would reduce the word "objective" to a philosophical abstraction that could not be attributed to *anyone*.

If research scientists' objectivity is spurious, then their subjectivity should bias their results and their interpretations and make them undependable; yet a gigantic space program is built on such undependable, subjective research, to say nothing of the material artifacts of modern civilization. And if research scientists, who operate within the controlled confines of the scientific method are subjective and biased, how unbiased and objective are the judgments of those who operate under no such restrictions? This is not to say that research scientists are without bias in reporting their research, but when they are, subsequent research or the skepticism or objectivity of their peers is likely to bring their bias to light.

3.3.3 Agent and First Person

Critics who fault scientists for using the passive voice argue that scientists use the passive voice to make scientific research appear more objective than it is and to avoid responsibility or accountability for their research. The critics maintain that an agent—the researcher—can be provided and therefore that scientists should write in the first person and in the active voice.

Actually, there may be no person as agent. In most reporting of scientific research (*Ex. 3.4*), the agent may be of secondary or no importance or relevance. The interest of most readers of scientific papers is focused on the research, not the agent.

The use of the first person creates problems both substantive and stylistic. Scientists are often seen as having the "facts" or knowing the "truth," terms that have little meaning in a scientific context. Scientists are therefore accorded much more authority than they claim or can claim. Nonscientists challenging such authority see the use of the first person as restricting that authority and making scientists accountable. But scientists are less apt to think of their empirical research as being "truth" than nonscientists. They know from their own and their peers' professional experience, and from the history of science, that original observations or measurements or interpretations and explanations have had to be modified, and that factors unknown at the time had influenced their earlier findings and interpretations. Moreover, the subject of discourse in scientific papers is not the research scientists; therefore the "I" is not the real subject of discourse.

Moreover, just as the frequent use of the passive voice tends to lead writers into using it when it is neither needed nor appropriate, so the prescription of the first person leads to its use even when it is inappropriate or not needed to avoid the passive (*Table 3.4*). In the following sentences:

Ex. 3.11

a. We combined extensive records with clinical, serological, and pathological examinations, and we were able to document a high incidence of autoimmune diseases in the animals studied.

b. Combining extensive records with clinical, serological, and pathological examinations made it possible to document a high incidence of autoimmune diseases in the animals studied.

c. Extensive records combined with clinical, serological, and pathological examinations showed a high incidence of autoimmune diseases in the animals studied.

sentence *3.11a*, in the first person would be more appropriate for an announcement in a lecture than a written paper. A paper reporting the methods, findings, and interpretations of the scientist in the first person is a paper about the writer, not about the research. In the procedure described in *Table 3.5a*, every sentence is in the third person and the passive voice. When this excerpt is revised to put it in the active voice and provided with an agent (*Table 3.5b*), the subject of every sentence is "I," instead of *cells, coverslips, chamber, micropipette, pipette, pressure*, and so on. Although this revision may have made the excerpt more direct, active, and stronger, and the scientist more accountable, the subject has shifted from the various objects, which are the foci of interest to readers, to the author, who is of little interest relative to the procedure described. In fact, at the beginning of each sentence, the reader meets with a barrier, the "I" and its verb, before getting to the topic of interest.

TABLE 3.5 Excerpts from methods section written in (a) passive voice and revised to (b) active voice, with subject of sentences in italics

a. *Passive voice*

Cells were placed in a thin chamber (10 × 20 × 1.5 mm) consisting of two glass coverslips separated by a U-shaped brass spacer and held together with vacuum grease. The *coverslips* were siliconized to reduce adhesion of the cells to the glass. The *chamber* was placed on the stage of an inverted (Nikon-M) microscope. A *glass micropipette* formed by breaking off the tip of a glass microneedle and filled with PBS was inserted into the chamber through the open side of the U. The *pipette* was connected to a water-filled reservoir, the height of which could be adjusted with a micrometer. The *pressure* inside the pipette was controlled by adjusting the height of the reservoir. *Zero pressure* (±25 dyn/cm^2) was determined by stopping the motion of cells or particles in the fluid at the pipette tip. [Biophys. J., 51, 1987, 364]

b. *Active voice*

I placed cells in a thin chamber . . . consisting of two glass coverslips separated by a U-shaped brass spacer and held together with vacuum grease. *I* siliconized the coverslips to reduce adhesion of the cells to the glass. *I* placed the chamber on the stage of an inverted . . . microscope. *I* formed a glass micropipette by breaking off the tip of a glass microneedle and filling it with PBS, and *I* inserted it into the chamber through the open side of the U. *I* connected the pipette to a water-filled reservoir, the height of which *I* could adjust with a micrometer. *I* controlled the pressure inside the pipette by adjusting the height of the reservoirs. *I* determined zero pressure . . . by stopping the motion of cells or particles in the fluid at the pipette tip.

In any case, accountability, in the sense of who performed the research, is not strictly relevant to scientific research. The research is expected to stand by itself, capable of being repeated, developed, expanded, retested, et cetera, no matter who performed it originally. In this sense, scientists may have a nicer perception than their critics of how avoiding the first person helps them to affirm the importance of their research over their importance as individuals or scientists. The use of "I" prevents them from attaining their central objective of focusing on their research.

Finally, the strong efforts made to eliminate racist and sex-biased language represent a recognition of how strongly and subtlely language does affect thinking and values. It can be expected that language that focuses on the object rather than on the person is more likely to promote objectivity than language that focuses on the writer.

The first person singular is appropriate when the personal element is strong, for example, when taking a position in a controversy. But this tends to weaken the writer's credibility. The writer usually wants to make clear that *anyone* considering the same evidence would take the same position. Using the third person helps to express the logical impersonal character and generality of an author's position, whereas using the first person makes it seem more like personal opinion. When it is necessary to cite oneself, it is almost a convention to refer to "the author," or the "writer," but one can use "I." The "present research (work, study)" can substitute for these. References to the writer's publications may be made by number or date, as in any reference: "Green and DeBretor showed. . . . "

3.4 TENSE AND SCIENTIFIC RIGOR

A scientific paper is primarily a report of observations and experimental manipulations performed in the past, and any literature referred to is also in the past. However, the paper usually also includes discussion, which may include present commentary. The tense of verbs is an important means of differentiating between reporting and commentary. The writer must avoid two pitfalls: unexpected shifts in tense and using the present tense for particular observations and relationships. This gives them an aura of authenticity and authority that is not consistent with the rigor of scientific inquiry.

In the introduction and discussion sections, the present tense is used for statements of purpose, importance, generally accepted knowledge, or conclusions (*Appendix 3A*):

Ex. 3.12

a. The purpose of this paper is to examine the less explored nonsyntactic portion of the mind-machine analogy in language processing.
b. It is important to classify employment in terms of compatibility with child care.
c. Like hydrocarbons, oxides of nitrogen contribute to the formation of photochemical smog.
d. The source is, therefore, either transient or variable by at least a factor of 10.

3.4.1 Reporting Results in the Present Tense

It is the use of the present tense in reporting results or drawing conclusions that raises questions about scientific rigor. A scientific paper is a report of research which is in the past at the time the writer writes the paper and in the past at the time the reader reads the paper; therefore the appropriate tense for reporting the findings is the past tense. The observations and findings in empirical research can never be considered final, because they are forever subject to modification as a consequence of subsequent research. One cannot therefore generalize and report the findings from an experiment in the present tense, as though they were universal or general truths. Consequently, avoiding the present tense is not simply a grammatical decision about tense, but a recognition of the severe limitations of scientific research, that is, its narrow sphere and its limited generalizability.

Research scientists sometimes find it difficult to report findings in the past tense, when they are still "true," as presumably they are, until further research shows them to be otherwise. However, it is this proviso that necessitates the past tense. For example, the past tense in the statement in *Ex. 3.13a* makes it a rigorously accurate scientific statement of a result:

Ex. 3.13

a. Dohler and Wuttke (1974) found [find] a sharp increase in prolactin at day 21 (about 40 ng/ml on day 20 and 80 ng/ml on day 21).
b. There is a sharp increase in prolactin at day 21 (. . .).
c. Prolactin increases sharply after treatment with. . . .

When the past tense is replaced by the present tense, "find", the statement becomes inaccurate, since Dohler and Wuttke are not continuing the experiment, and it is not certain that they would obtain the same result if they did. The present tense in *Ex. 3.13b* changes the statement of a research finding into a statement of generally accepted knowledge. The statement in *Ex. 3.13c* would be a very broad generalization, without adequate scientific support.

Writers may try to express the past event of a finding in the past but its continued "truth" in the present by using the present tense *Ex. 3.14a*:

Ex. 3.14

a. It *was found* that the concentration of luteinizing hormone in the plasma *increases* with the injection of higher doses of progesterone.
b. The increase in the dose of progesterone injected *results* in an increase in luteinizing hormone.

However, these results might not be obtained in future research. Reporting the results entirely in the past would not only be accurate at the time of writing, but would also ensure that the statement would remain accurate in the future, even with different results. The statement in *Ex. 3.14c* generalizes and so is not accurate.

3.4.2 Past versus Present Tense in Other Sections

In the introduction, it is easy to confuse the paper (present) with research performed (past). When the research scientist writes the *paper* it is in his-her present. Consequently the present tense is used in statements about the paper (*Ex. 4.10*), but the past tense is used in statements related to the research (*Ex. 4.11*). Similarly, the writer should not confuse what was done in the research with what is being said in the paper and should not write "a mean sex ratio of 1:1 female per male *will be used*."

Since references to the literature introduce the research of others, which precedes the research being reported, the past tense is clearly the tense of choice. The present tense is sometimes used for the literature in a general discussion,

Ex. 3.15

> "Green states that feedback facilitates meaningful learning through. . . . However, he points out that feedback is less important than. . . ."

but is not appropriate for reporting the literature.

Some research scientists believe that using the present tense to refer to the literature indicates confidence in the research and is a courtesy due to the authors. This is moving out of the frame of scientific inquiry to the frame of collegial solidarity, which is not at issue in reporting research.

A scientific paper does not in itself confer authority. Scientific papers report particular experiments, and the results obtained are the results pro tem. They become part of the body of scientific research and can be used as evidence and for application, but they cannot be taken as given. To report earlier research in the past tense is therefore rigorous scientific practice. It allows the research to assert its authority on the basis of its rigor, validity, the evidence, and ultimately, subsequent empirical support, whereas reporting it in the present tense confers authority without substantiation.

When the literature must serve to set up the theoretical framework for the research being reported, it may become an introductory discussion on the subject, and may be sometimes treated in essay form. But the universe of discourse in an essay is different from that in a report on scientific research. An essay is essentially general and allows a great deal of freedom, whereas a scientific paper is specific and much more restricted in content, form, development, and point of view. In an essay one might make the statement in *Ex. 3.16a*:

Ex. 3.16

a. Drugs that are effective against human leukemia cells are also effective against L1210 cells.
b. Drugs that had been found to be effective against human leukemia cells were effective against L1210 cells.
c. The drugs that were effective against human leukemia are effective against L1210 cells.

The statement is a generalization about drugs in general. The statement in *Ex. 3.16b* is an accurate report of the literature, and the generalization in *Ex. 3.16c* more closely approaches this accuracy than *Ex. 3.16a.*

Discussions are too often largely in the present tense, presumably because the findings, both of the present and past research, are accepted as fact. In such a treatment the writer has stepped out of the role of a scientific inquirer and reporter into that of an authority. The discussion then becomes a discussion of a position, rather than a consideration of evidence. If the discussion is in the present tense (see *Appendix 7A*), it may assume the form of an essay, which is then focusing on the *subject* rather than the research.

Conclusions raise the same question as results about the present versus the past tense:

Ex. 3.17

a. It is concluded that altitude *did* [does] not *affect* the color.

b. Thus even controlling for skills, unions *provided* new jobs and promotion ladders to advance mobility of men's work.

c. The results of the present study *seem* to provide some evidence about the reliabilities and validities that *can* be achieved by standardized case simulations.

d. The close correspondence between the chemical uptake by plants and the RWD *indicates* [indicated] that the rate of root growth *was* more important than the specific absorption rate.

The statement about the conclusion may be past or present, but the tense of the substantive statement of the conclusion determines the rigor of the statement. The statement in *Ex. 3.17a* maintains the conclusion as a past inference of the past results; the present tense would make the conclusion a general statement about the results, which is scientifically less accurate. Specific conclusions are stated in the past tense (*Ex. 3.17b*). Conclusions about the research may be in the present tense (*Ex. 3.17c*), but those that generalize the finding are best kept in the past tense (*Ex. 3.17d*). The statements in the past tense are more rigorous scientifically than are those in the present tense.

The present lends itself to general discussion. It is the conventional tense for mathematical and theoretical models, and for the discussion of relationships that are not determined by the time of operations:

Ex. 3.18

Reactivity Control in Polymerized Vesicles

There are four extreme sites of reactant localization in polymeric vesicles. Hydrophobic molecules can be distributed among the hydrocarbon bilayers of the vesicles. Alternatively, they can be anchored by a long chain terminating in a polar headgroup. Polar molecules, particularly those that are electrostatically repelled from the inner surface of the vesicles, may move about relatively freely in the vesicle-entrapped water pools or they may be associated with or bound to the inner and outer surfaces of vesicles. Polar molecules can also be anchored to the vesicle surface by a long hydrocarbon tail. A large variety of reactivity control can be realized in polymeric vesicles. Conceivably, the position of a reacting substrate will be different from that of the transition state

> and that from the product formed in the reaction. Such spacial relocation of molecules as they progress along their reaction coordinates can be exploited in catalyses and product separation. A type of functionally polymerized vesicle-reactant interaction can be visualized in which the reactant, an organic ester, for example, would enter the vesicle. Hydrolysis would then occur in the matrix of polymeric vesicles and the products would subsequently be expelled into the bulk solution. With use of nonpermeable reagents, reactions can be limited to sites located at outer vesicle surfaces. Alternatively, finely tuned processes can be realized by allowing reactions to occur consecutively (at controllable rates) in the separate halves of the bilayer in the vesicles. This type of flexibility is only feasible in polymerized vesicles. [Accts. Chem. Res. 17, 1984, 8]

The present tense is of course regularly used in discussions and developments that include equations (*Chapter 6, Appendix 8C*).

3.5 DESCRIPTION IN SCIENTIFIC WRITING

Because scientific research consists of new operations and observations, description is an important part of scientific writing, and scientific papers regularly include description. Descriptive writing in scientific papers differs from general descriptive writing because of its subject matter and purpose. It differs in three ways: (1) the focus is conceptual, cognitive, or abstract, rather than sensory; (2) it is analytical and selective; and (3) it is direct; that is, it is predicative, rather than attributive.

3.5.1 Conceptual Character

In most general descriptive writing, the sensory characteristics of the objects described are the important and may even be the central characteristics of the description. In a scientific paper, however, the sensory characteristics are described only as they might be pertinent to the research. Readers do not need to be able to see, touch, hear, or feel what is being described; they need only be able to develop a concept of it, largely a visual concept. But even when sensory attributes are described, the description is written for cognitive, not for affective or expressive purposes.

This difference is seen in the ordering of the description. A linear, sequential, walk-through, visual description, which is a common type of description in general writing, is not suited to scientific description:

Ex. 3.19

> As one enters the growth chamber one is met by a dazzle of lights and enveloped in a humid atmosphere pervaded with the pungent aroma of the foliage. To the right are rows of tall bean vines; around to the left is a forest of tomato foliage. Passing through between the benches to the next chamber, brings a quarter acre of flats of seedlings into view. . . .

Such a walk-through description imitates the movement of the eye through space. It is too unsystematic for scientific research. It does not give the reader an understanding of the whole or of the separate parts, their relative dominance, their connections, nor does it focus on a part of particular interest.

When this sequential method is used in the description of an instrument, it becomes a description by construction, in which one part is described and then a second, adjacent part added, and then another, without regard to the relationships of the parts.

3.5.2 Analytic Character

Scientific descriptions are analytical in that the writer usually describes only those parts that are new or pertinent to the research. For example, when an apparatus is described, the writer may not describe the whole apparatus or may describe it only in outline, or only refer to it and then describe the new part(s) in detail. In a general description, this would put the part described in limbo. In scientific writing since writer and reader have a shared background, the writer can take this as a given in writing descriptions. For example, a research scientist can simply write "The experimental animals were male weanling, 28-day-old, Fisher-334 rats," and research scientists in the discipline working with rats require no further description. If they visualize the rats, they are more likely to "see" the rats as having certain scientific and research attributes than as little, white, soft, furry, baby boy rats. The analytic character of descriptions in a scientific paper is also reflected in the graphics that regularly accompany descriptions and in the type of graphics. When graphics are used, they too present only the details of interest.

3.5.3 Predicative Character

Finally scientific description is direct and predicative; research scientists cannot describe by indirection. The writer of a story can write the sentence in *Ex. 3.20a:*

Ex. 3.20

a. Her deep blue eyes mirrored the blue eyes of a long line of Norsemen.
b. The female offspring had blue eyes, a genetic character found in both parents in four generations. All of these progenitors had been born and raised in Norway.
c. The 107 Navajo women who participated in the study were primarily self-selected according to whether they volunteered at a given site.
d. The participants in the study were 107 Navajo women, who were primarily self-selected. They constituted all the women who volunteered to participate in the study when the investigator visited their villages.

A scientist writing about the inheritance of eye color would have to state explicitly that she had blue eyes, as in *Ex 3.20b*. In a story, such a statement would be unthinkable (except possibly to satirize scientists).

This difference is not merely stylistic. It is important scientifically because direct description is more precise than indirect description. If in describing the Navajo participants in a study, the research scientist writes the sentence in *Ex. 3.20c*: The "107 Navajo women" may be part of a larger cohort of Navajo women, some of whom did not participate. They may be the Navajo women who participated in the study as distinct from some other group of women, for example, 107 Hopi or non-Indian women. Actually the 107 Navajo women were simply 107 Navajo women who agreed to participate in the study when the research scientist traveled to various villages to recruit participants. A direct description such as that in *Ex 3.20d* makes this clear.

Indirect description of time (*Ex. 3.21a,c*) is also not accurate enough for scientific description. Within a sequential series of steps in a procedure, statements such as those in *Ex. 3.22b, d* are more accurate:

Ex. 3.21

a. An incision was made beginning at the base of the sternum . . . *after* the anaesthetic was injected into the cannula in the jugular vein.
b. The anaesthetic was injected into the cannula in the jugular vein; then an incision. . . .
c. In a 96-well plate, 100 μl of the cell solution, adjusted to 2 × 10^6 cell/ml was added to the well, *which already contained* 100 μl of diluted ConA, PHN, PWM, LSP, and TSST-1.
d. To the wells in a 96-well plate, 100 μl of diluted ConA . . . were added. Then 100 μl of the cell solution, adjusted. . . .

In descriptive studies, observations may be very extensive and result in long, detailed descriptions. Some scientific descriptions are highly stylized and follow a conventional format:

Ex. 3.22

CARDINALIS CARDINALIS CARDINALIS (Linnæus).

CARDINAL GROSBEAK.

Adult male.—Lores, anterior portion of forehead, anterior part of malar region, chin, and throat, black, forming a conspicuous *capistrum*, entirely surrounding the bill; rest of head vermilion red, duller on pileum (including crest), brighter on auricular region and cheeks; under parts pure vermilion red, becoming slightly paler posteriorly, the flanks slightly tinged with grayish; hind-neck, back, scapulars, rump, and upper tail-coverts dull vermilion red, the feathers margined terminally with olive-grayish (wearing away in midsummer); wings and tail dull red, still duller on greater coverts and secondaries, the tertials usually, and sometimes the rectrices, more or less edged with olive-grayish; bill bright orange-red or red-orange in life, fading to orange or yellowish in dried skins; iris, deep brown; legs and feet, horn-color. . . . [Ridgway, 1901]

The conventional position of noun and adjectives is reversed; the descriptive adjectives *follow* nouns, instead of preceding them. Other differences between scientific writing and a comparable type of general writing, that is, academic writing, are summarized in *Table 3.6*.

3.6 SCIENTIFIC WRITING IN THE SOCIAL SCIENCES

One of the major consequences of the rhetorical setting of social science research is that it makes social scientists more dependent on words than natural scientists. Whereas much research in the natural sciences is quantitative, in the social sciences

TABLE 3.6 Characteristics of academic and scientific writing

Characteristic	Academic writing	Scientific writing
Purpose	Expression, exposition	Communication
Generality	Often general, rarely highly specific and detailed	Highly specific, concrete, detailed; infrequently general; abstract for theory
Writer vs. subject	Personal, subjective, or objective	Impersonal, objective, i.e. object-oriented
Audience	Everyman, selected but unspecialized, author	Writer's scientific peers
Rhetorical setting	Writer most important; purpose, subject, readers less important	Writer least important; subject, readers, and purpose more important
Form	Intrinsic, chosen by author, molded in process of composition	Extrinsic; determined by convention, material, structure of discipline
Realism of content	Reflective, sometimes realistic, or imaginary, often imaginative	Observational, factual, reportorial, not imaginary
Form vs. content	Shaped for literary, aesthetic, or other objectives	Constrained by scientific content and purpose, closely matched to content
Interest of readers	Designed to interest	Inherent in content; readers self-selected by interest in subject
Accuracy, clarity	Not central requirements	Central requirements
Language	Expressive, connotative, vivid, metaphorical	Accurate, precise, denotative, concise
Variation, synonyms	Desirable for expressiveness, variety, interest	Avoided for conflict with accuracy, precision, and clarity
Jargon (scientific terminology)	Unacceptable, except for literary or aesthetic purposes	Essential for precision of meaning among peers
Passive voice	Proscribed because weak, not direct	Required to focus on object as topic of discourse
Coherence	Effected by topic sentences and transitional elements	Effected by internal hook-and-eye connections and transitional elements
Process of writing	Largely composing, writing, rewriting; finally revision and editing	Largely writing, revision, and editing, relatively little composing
Source of material	Writer's knowledge and experience	Discrete body of scientific data and concepts in present and past research
Graphics	Exceptional, supplementary, complementary, or embellishing	Required for empirical demonstration; integral part of writing
Format	Writing integrated, headings not common	Headings essential, often numerous

case histories, descriptive, analytical, and other types of qualitative studies are also common. Even when their research is more quantitative, social scientists must use language as a tool for their scientific measurements. Variables are frequently measured by words or by a numerical scale that represents verbal measures. Data to be analyzed are derived from questionnaires, interviews, or observation—all forms of verbal measures. The description of participants and sites and theoretical models are largely verbal. The consequences of this dependence on words is that the standardization of terminology and nomenclature, which is extremely important in the natural sciences becomes crucially important in the social sciences, where it is most difficult to achieve.

Social science papers also tend to include more discussion throughout, and it is difficult to report results accurately with so much discussion. This makes organizational structure more critical for clarity at the same time that clarity is difficult to achieve. With so much discussion, it becomes easy to move into abstraction both in terminology and in conceptualizing. Writing a paper in the social sciences therefore requires very close attention to structure and meaning, and social scientists have to make a special effort to achieve coherence and conciseness.

The strong dependence on words has its roots in the earlier scholarly tradition. Before the development of the scientific method, nature was the purview of the natural philosophers, scholars who were interested in natural phenomena. Similarly, the study of social groups was the domain of scholars interested in social phenomena—social philosophers, often political philosophers. Their writing was general, reflective, learned, philosophical, and accessible to the educated elite generally:

Ex. 3.23

> Neighborliness is not restricted to social equals. Voluntary labor (*Bittarbeit*), which has great practical importance, is not only given to the needy but also to the economic powers-that-be, especially at harvest time, when the big landowner needs it most. In return, the helpers expect that he protect their common interests against other powers, and also that he grant surplus land free of charge or for the usual labor assistance—the *precarium* was land for the asking. The helpers trust that he will give them food during a famine and show charity in other ways, which he indeed does since he too is time and again dependent on them. In time this purely customary labor may become the basis of manorial services and thus give rise to patrimonial domination if the lord's power and the indispensability of his protection increase, and if he succeeds in turning custom into a right.
>
> Even though the neighborhood is the typical locus of brotherhood, neighbors do not necessarily maintain "brotherly" relations. On the contrary: Wherever popularly prescribed behavior is vitiated by personal enmity and conflicting interests, hostility tends to be extreme and lasting, exactly because the opponents are aware of their breach of common ethics and seek to justify themselves, and also because the personal relations had been particularly close and frequent.
>
> The neighborhood may amount to an amorphous social action, with fluctuating participation, hence be "open" and intermittent. Firm boundaries tend to arise only when a closed association emerges, and this occurs as a rule when the neighborhood becomes an economic group proper or an economically regulatory group. This may happen for economic reasons, in the typical fashion familiar to us; for example, when pastures and forests become scarce, their use may be regulated in a "co-operative" (*genossenschaftlich*) manner, that means, monopolistically. However, the neighborhood is not necessarily an economic, or a regulatory, group, and where it is, it is so in greatly varying degrees. [Weber, vol. 1, 1978, 362]

Scholars studying natural phenomena early adopted the scientific method, which gradually displaced the earlier general scholarly studies. Scholars studying social phenomena did not adopt empirical methods until later. Moreover, these did not displace studies in the earlier scholarly tradition. In the social sciences, therefore, the two traditions have continued side by side, so that studies in the social sciences vary from scholarly essays to rigorous experiments.

Social scientists continue to draw on the older tradition. They continue to use words from the general language for scientific terms. Furthermore, they may draw on the older tradition in the interpretation of their research and blend ideas derived from the scholarly tradition with theoretical concepts derived from empirical studies. This may lead to a blending of essay-style and reportorial writing. The dual tradition therefore makes it more difficult for social scientists to report on their research, and it subjects them to criticism on three fronts: Peers in the older tradition dismiss the empiricists as reductionists. Natural scientists may criticize them because their research is not as controlled and rigorous as they expect. Nonscientists criticize them for using pretentious language for commonsense notions.

3.7 MULTIPLE STUDIES OR EXPERIMENTS

Scientific papers may report preliminary or preparatory experiments or several studies or experiments that are too closely related to be published separately. Such papers are confusing to follow unless the various experiments are clearly designated and ordered. The studies can be characterized by name, for example, the plasma study, the high-protein, high-fat experiment, and so on. Or they can be designated by numbers or letters, for example, Experiment 1, 2, 3, or Experiment A, B, C. The ordering of the different parts depends on their relation. When they are independent, they are best treated in parallel; when they are interdependent, they are best treated in series.

3.7.1 Independent Studies

In independent studies, each study is treated separately and completely: the introduction, methods, results, and discussion are presented for Experiment A; then the introduction, methods, results, and discussion for Experiment B and similarly for Experiment C, as illustrated in Model I in *Table 3.7.* A general introduction precedes the series and a general discussion follows it.

For example, in a study of a new natural preserve in Africa to determine its present character as a base line for maintaining the preserve and possibly introducing endangered species, three separate, independent studies may be performed: one of the geology and soils, one of the fauna, and one of the flora. The three studies may be conducted in any order or simultaneously; no one study depends on the other. The paper begins with a general introduction. Then the three studies are presented, separately. They may be presented in any order, since they are independent.

TABLE 3.7 Models of scientific papers reporting several experiments, illustrating differences in ordering of parts

I. Independent	II. Interdependent	III. Independent-Related
Introduction	*Introduction*	*Introduction*
Experiment A	*Experiment A*	*Methods*
Introduction	Methods	Common to A, B, C
Methods	Results	Experiment A
Results	Discussion A	Experiment B
Discussion A	+ Introd. to B	Experiment C
Experiment B	*Experiment B*	*Results*
Introduction	Methods	Experiment A
Methods	Results	Experiment B
Results	Discussion B	Experiment C
Discussion B	+ Introd. to C	
Experiment C	*Experiment C*	*Discussion*
Introduction	Methods	Experiment A
Methods	Results	Experiment B
Results	Discussion C	Experiment C
Discussion C		
General discussion	*General discussion*	*General discussion*

However, they may be interrelated even if not interdependent; then the order reflects the interrelation. For example, the plants are likely to be closely related to the types of soil, and the animals to the kinds of plants. If so, the soil study may be presented first, then the study of the flora, and last, the study of the fauna. The general discussion then addresses the interrelation of the three studies and their relation to the overall problem of the preservation, introduction, and reintroduction of species, and so on.

3.7.2 Interdependent Studies

In an interdependent series of studies, each succeeding study depends on the preceding one (Model II, *Table 3.7*). The organization is essentially the same as in Model I, in that each study is completely described, but its order is fixed, and the discussion of each experiment has a double role: (1) to discuss the previous experiment(s) and (2) to provide the background for the next experiment. The general discussion is not an equal treatment of the various experiments, as in Model I, because the discussion after each experiment has been cumulative.

Sometimes an unplanned procedure or analysis is performed as a result of the findings. If it is very brief, it may be included in the results; otherwise it is described in the methods section, prefaced by a statement that the results made the procedure or analysis desirable. In the social sciences, research in which a program is tested or in which each analysis is followed by an analysis suggested by the results of previous analysis follows the interdependent pattern. For example, when the data are analyzed statistically, the result may suggest a different type of analysis, more rigorous or refined analysis, or a different configuration of variables. The paper then proceeds as follows:

Ex. 3.24

analysis 1 ⟶ results 1 ⟶ discussion of results and analysis 1, type of analysis needed for (2) ⟶
analysis 2 ⟶ results 2 ⟶ discussion of results and analysis 1, 2, type of analysis needed for (3) ⟶
analysis 3 ⟶ results 3 ⟶ . . .

3.7.3 Independent-Related Studies

A series of experiments may be independent experiments but too closely related to be treated as the separate experiments. In this model (III, *Table 3.7),* the methods for the experiments are described separately in the methods section, the results are presented separately in the results section, but there is no separate discussion of the different experiments until after the last experiment. Such discussion is followed by a general discussion. In this type of research, procedures may be varied, while the subject of research remains the same. For example, in a study to determine the effect of temperature, humidity, light cycle, and water stress on growth in plants, the common methods of treating the plants in preparation for the different experiments are described. Then the methods for the temperature, humidity, and water stress experiments are described separately in the methods section. The results for each experiment are presented separately in the results section, and they may be discussed separately in the discussion section. Then the general discussion addresses the interrelationships among the various experiments.

3.7.4 Preliminary Studies

A preliminary study or experiment sometimes precedes the main experiment. Planned, formal preliminary studies are reported; incidental preliminary studies are described if rigorously performed, and if their relation to the research warrants their being reported. Preliminary studies may be preparatory studies necessary to performing the main experiment. They may be exploratory experiments to help make the main experiment more rigorous or to suggest modifications:

Ex. 3.25

> The river stage was raised, because the preliminary experiment indicated that detention time, as determined by dividing a given inflow rate by pond volume, was too low for maximum pond efficiency.

Preliminary studies are sometimes performed as a trial of the method, as in some pilot studies, which are often small-scale trials of the experiment.

The position of a preliminary study depends upon its objective and results. When the preliminary study is important for indicating the direction of the research, it may be made a subsection of the introduction or a separate section between the introduction and methods section. The discussion of this preliminary study focuses on the meaning or importance of the results for the subsequent main study. When the preliminary experiment is decisive for the methods finally adopted in the main study, it may be preceded by a discussion of the research design, which leads to the necessity for a pretrial, or it may be part of the discussion of the choice of method. The discussion of the preliminary experiment evaluates it to determine the method to be followed for the main experiment. When the results of the preliminary study are related to the results of the main study or raise questions for discussion, it may then be discussed briefly, in the discussion section.

3.7.5 Theoretical Model

A theoretical model is often developed as a basis for empirical research. Most commonly the model is developed and then applied. The paper then consists essentially of two parts: one that describes the development of the model and the other that reports on its application (Model A, *Table 3.8*). The introduction addresses the problem and ends with an explanation of the kind of model needed or proposed. In the next section, the theoretical model, which may be quantitative or qualitative, is then developed. This section may then end with a discussion of the possibile applications or limitations of the model.

The next section reports on the particular application of the model. The discussion of the applied study may be a part of the section on the application of the model (*Table 3.8*) or part of the discussion section that follows, which is a general discussion section. Here the results of the application of the model relative to the predictions of the model, that is, its validity, promise, modifications needed, and so on, are discussed.

In some studies, data are collected as a basis for developing a theoretical model. The paper may then have a section reporting on the collection of data (Model B, *Table 3.8*). This section precedes and is directed toward the development of the theoretical model. For example, in a study of browse, data might be collected to relate browse to rainfall and other conditions. These data together with data of other studies may be used to develop a mathematical model for predicting browse under a variety of conditions. The applicability of the model and its limitations are then discussed. Research can then be designed to apply and test the model. The results are then discussed relative to the applicability and predictive power of the model and to possible modifications of it. In this type of study, the development of the model is not simply a preliminary to the empirical research, but part of it.

In disciplines or problems in which experimentation is difficult but prediction desirable, data may already be available for use in developing a theoretical model

TABLE 3.8 Models of scientific papers with theoretical model illustrating different positions of model

A. *Theoretical* Beginning with model	B. *Empirical* Preceded by collection of data	C. *Applied* Based on accumulated data
Introduction Background Problem Criteria for model *Model* Assumptions, data Development of model Discussion: applicability *Application* *Methods* *Results* *Discussion: results* *Discussion* Results if not discussed earlier Model Application General discussion and modifications needed	*Introduction* Background Problem Need for data for model *Collection of Data* (Introduction) Methods Results Discussion relative to model *Model* Discussion if not already discussed Development of model Discussion: applicability, limitations *Applications* Methods Results *Discussion* Predictive power of model Model and application Modifications needed	*Introduction* Background Problem Types of data available *Model* Collected data Implications of data Development of model Discussion, limitations *Application* Methods Results *Discussion* Predictive power Model and application Modifications needed

(Model C, *Table 3.8*). In hydrological studies, extensive data have been collected regularly over many years on water table, water-bearing strata, rainfall, river levels, ice flows, silting, and so on. It is not possible to experiment with such unpredictable and enormous natural phenomena; yet it is important to be able to predict underground water reservoirs, the subterranean paths of pollution, possible collapse of dams, and so on. Research draws on the extensive data and on theory to develop a predictive model. The model can then be tested both against past records and future events and conditions. In this type of treatment, the model is developed after assembling and analyzing the available data. It can then be applied to other existing data and to subsequent observations. Its predictive power and application are then discussed.

3.8 STARTING TO WRITE

3.8.1 Process of Writing

Writers think that writing is simply recording one's thoughts, whereas writing is part of the process of formulating and clarifying them. One's thoughts are multifarious and many-sided, and they are embedded in a network of other multifaceted thoughts. In writing, the writer must extricate the thought, together with all its external and subtle internal relations, from this complex network of thoughts and try to express it in words. In doing this, the writer must face the basic difficulty of writing—trying to fix immaterial thoughts in material words, which themselves are only symbols of actual referents.

In preparation for writing, the writer should establish conditions conducive to writing. The ideal conditions are whatever conditions the writer finds congenial. Guidelines for making optimum use of such ideal conditions have not been better stated than by Barzun and Graff (1977, pp. 324–328). Just as the conditions of writing should be adapted to a writer's preferences, so should the method of writing. No one method of writing is adapted to everyone, and no one method will guarantee a well-written paper. Some writers prefer some kind of structure—notes, an outline, or summary; other writers find that these fetter them and prefer to write spontaneously. Whatever one's preferences, in the end, the writing must be tightly structured. Moreover there is no magical way to transform research into a written paper. Writing requires effort and attention.

3.8.2 Methods of Writing

Unstructured and structured. The least structured form of writing is to write rapidly and spontaneously, without a definite plan or outline, composing as one goes, without stopping to organize ideas logically, develop paragraphs coherently, or structure sentences concisely. This kind of writing is most useful when one gains insight into a process or concept or when the material begins to come together and take shape. Writers can eliminate the barrier of the paper altogether, by dictating. This method calls at least for the amount of structure of an informal discussion with a colleague. The presentation should be structured at least as to sections or subsections. The writing will of course be rather informal, loosely structured, clumsily phrased, wordy, and repetitious. However, focusing on an invisible listener will help to maintain a consistent tone and point of view.

One may write by expanding a smaller piece of writing that is in summary or skeletal form. This establishes the central structure of the paper, which can then be elaborated, while keeping the elements in proper relation and proportion to each other and to the whole. This can start as no more than a series of summaries of the major parts of the paper, which can then be expanded into a minipaper. In expanding such a summary, one may expand the whole summary at each step, filling in with all the necessary details as one follows the summary. Or one may expand it by accretion, expanding now here, now there, as one collects material or develops one's ideas. Proposals can also be expanded into a paper, if they describe specific studies rather than research projects. A proposal has a well-developed introduction, review of literature, and description of the methods and materials. These are not *substitutes* for the sections of the paper, but can serve as rough drafts for them. The results, discussion, and conclusions must be added, and then the whole can be further expanded and developed into a rough draft.

Outline. The most structured and time-honored method for structuring a piece of writing is to prepare an outline. This usually structures the whole paper, and is customarily prepared before the paper, but the outlines for the various sections may be prepared just before each section is written.

An outline serves writers as a guide to the content and the order of the paper. Preparing it helps writers to collect their material, organize their thinking, and specify the relationship of the parts. Then when they are writing, they can devote their full attention to the writing without having to stop to organize. The outline also serves as a record, which is useful simply to ensure that nothing is omitted that should be included in the paper. It also helps writers to note the data or graphics that will be needed for each section. A well-prepared outline thus reduces the amount of major reorganization and rewriting.

Some writers use an outline as a finished structure and adhere to it closely. This requires that the outline be complete and developed in full detail. It is a difficult type of outline to develop successfully, especially for a whole paper, but it can be used effectively for a section or subsection, and it makes writing easier and expeditious. Others use the outline only as a guideline and modify it as they write. This type of outline is easiest to prepare, but carries the greatest risk of a confusion in development and omission of information or conceptual points. Others view the outline as a working outline. They develop a skeletal structure and use it as a basis for fitting in additions, reorderings, and other changes before each part is written. This is useful in a long paper, for which all the details are not available at the time of writing or for which it is not possible to see how all the details are related. This method is therefore useful in writing concurrently with research.

The outline is not the answer to a writer's prayer, however. Writers who are resistant to structure may not find them useful. Also, an outline can only ensure unity, that is, that each part will be devoted to a particular topic, and a linear ordering of the parts. An outline lists elements and shows their order and hierarchical position, but it does not make clear *how* the elements are related. It cannot ensure the coherence that it is designed to achieve, because it cannot reflect the internal relationships that are not fully conceptualized and structured until the writer actually writes. This gap between outline and written text is part of the difficulty of converting the multidimensional and multirelational structure of one's thoughts to the sequential, linear structure of the outline, which is structurally maladapted to reflecting such structure.

The elements in the outline and their hierarchy may be designated by numerals and letters or by a decimal system. The decimal system is well adapted to theoretical, mathematical, or closely reasoned papers; it should not be used merely as a means of dividing the paper superficially into sections. Presumably the final draft of the outline reflects the proportional treatment of the parts. Actually the space given to a section in the outline need not reflect the emphasis intended. It is easy to overexpand sections for which one has much information, those that one understands well, and those that are easy to develop. And some types of information may take up proportionately more space in the outline than in the paper. A list or a series of elements may take up more space in the outline than a concept, yet in the paper, the explanation of the concept may require as much space as the list or more.

The outline may be developed from a path diagram, or a path diagram may substitute for the outline. This method is particularly useful for a section or paper with complex interrelationships. First, the elements of the paper are laid out spatially in clusters, for example, hypotheses, methods, collection, theoretical structure, findings, et cetera. The clusters are laid out so that arrows can be drawn to show relationships both between clusters and within them. The clusters, the elements in the clusters, and the arrows will probably have to be restructured several times before the relationships displayed match one's conceptual structure of the paper. Separate path diagrams may be developed for different sections. If the path diagram is subtlely structured, it may be more effective than the outline as a basis for writing. If it is possible to lay out the path diagram in a tree diagram, the translation to the writing will be even easier.

3.8.3 Writing Concurrently with Research

One method of making writing less onerous is to make it part of the research process and write throughout the course of the research.* Writing concurrently with the research has several advantages. It makes writing an integral part of the research, as it should be. The reporting is likely to be easier, because the writer usually has equipment, material, data, sources at hand and can write from them directly. This method also helps research scientists to clarify their ideas during the research. This clarification feeds back on the research while it is in progress. Such feedback is especially important for graduate students, because it reveals gaps, raises questions, or suggests changes in the research before the research is completed. With this method, by the end of the research, the paper is largely written, at least as a preliminary draft, with only the results and discussion sections left to write. This method also allows time to elapse between drafts so that the writer can return to the paper with a fresh eye. It thus can reduce the number of major revisions, and it certainly improves the writing.

Writers should start to write as soon as they have something to write. The best

*This method is similar to one termed "writing in increments" (Michaelson, 1974). Writing concurrently with research differs in that the paper is not necessarily written in an orderly sequence from beginning to end.

place to start is *not* the introduction. First, it is always difficult to begin; second, the introduction has an integrative function and so is not easy to structure. The best place to start is the methods section, because this is least dependent on the other sections for its content or form. As soon as the experiment or data collection is under way, the writer can write this section. It entails only describing the materials and methods, and one can write directly from observation. If procedures are later modified, the preliminary draft can be revised, or annotated for later revision. In a dissertation, if the review of literature is not strongly dependent on the introduction, it may also be written before the introduction. The acknowledgments and biographical sketch can also be written in preliminary form. The abstract should be written after the paper is completed, from a nearly final draft.

3.8.4 Writing for the Reader

In writing a scientific paper, research scientists have two main tasks: (1) to transform their insubstantial and multifaceted thoughts into concrete, linear (i.e., sequential) writing and (2) to make the linear writing transmit their multifaceted thoughts to readers. The first is a familiar task to research scientists, who are constantly putting new ideas and new findings into words. The second task is rarely seen as a separate task. It is assumed that achieving the first accomplishes the second. Yet the difference in readers' interpretations of the same material belies that assumption. The writer must therefore make an effort to translate the thought into words in a form that allows readers to derive the thought exactly as the writer intended it. Furthermore, he or she must make it *easy* for the reader to do this. This last objective in writing is usually called *readability*.

The term is not used here in the usual sense of readability formulas for short familiar words or short simple sentences. Such formulas are not applicable to scientific writing or readers of scientific papers who are well acquainted with most of the scientific terms used in the paper, and with long words and complex structures used in scholarly writing. Readability is used here to mean writing in which readers do not have mentally to bridge gaps, reread to decode, or halt even momentarily to interpret what is written. The writer's objective is immediate comprehension by the reader so that he-she does not have to study the paper.

When research scientists talk to their colleagues about research, their listeners can ask questions when the exposition is confusing. In writing, writers must anticipate how readers will read what they have written and anticipate their questions and confusions. The research scientist and reader both have a conglomeration of concepts and data—thoughts—in their minds, which are very similar, though in different configurations. Both also share the same scientific language. In fact readers have much more information and ideas than are needed. What they lack, however, is the particular conceptual structure that the writer has in mind. Writers must therefore extract from the multitudinous concepts, data, and thoughts in their minds those elements that constitute the conceptual structure that they wish to transmit to readers. They must then incorporate that conceptual structure into language patterns that reconstruct it, so as to elicit from the multitudinous concepts, data, and thoughts in readers' minds, only those details and concepts required for apprehending the conceptual structure that the writer intended.

In developing an argument, the writer must lead readers step by step. Readers expect writers to provide cues or directions; therefore writers must not mislead them, raise false expectations, or confuse them by omitting cues or by supplying implicit or wrong cues. Writers must not surprise them by leaving gaps or changing direction without warning.

Whenever the writer leaves a gap, readers bridging the gap may continue in a different direction. When the writer makes a turn without cueing readers, readers may continue in the original direction and arrive at a different destination, or they may become confused and have to go back to find their direction. Even if they recognize immediately that the writer has not cued them, they must stop to determine the writer's intent. They may choose a different bridge or direction from the writer's. Moreover, readers may not discover that their interpolation or interpretation does not match the writer's. Therefore, leaving readers undirected or misleading them makes for confusion and miscommunication. Such haltings may break readers' train of thought and so distract them or discourage them from reading attentively.

Appendix 3A

Use of Present Tense in Sentences from Introduction and Discussion Sections

a. Statements of Generally Accepted Knowledge Not Requiring Citation of source

1. Many species of insects are associated with fungi.
2. The electron plasma waves produced upon stimulated Raman scattering (SRS) from laser-produced plasmas are known to generate high-energy electrons.
3. Polaris is the Cepheid with the lowest light amplitude.
4. Tse'an Bida Cave (1,460 m elev.) is located in a large canyon where a small perennial spring supports a local riparian plant assemblage.

b. Present Importance, Interest, Usefulness

1. Specifically, Boolean-based algorithms are particularly well suited for the task of holistic comparison.
2. The oxides of nitrogen are of considerable current interest to atmospheric and environmental chemists. . . .

3. Sensitivity analysis is an important numerical tool for the physical investigation and validation of mathematical models.
4. An interesting point of contrast between this and previous work is the selection of molecules from which to derive the pharmacophore.

c. General Comment, Concept, Explanation

1. We can characterize two conceptions of the role of language in the study of theoretical cognitive constructs.
2. Expectations about the effect of alcohol on social behavior are thus present on a cultural level, to be learned by anyone before taking the first drink.
3. The use of simple stencil masks does restrict pattern geometries, since patterns which close on themselves are not permitted.

d. Purpose of Paper

1. This paper considers optimal control problems which arise in the study of aero-associated orbital transfer.
2. The study presented here deals with isolation and further characterization of hamster oncofetal pancreatic antigens.

e. General Statement of Findings

1. Capture efficiency may be affected by aphid, vegetational, environmental, and methodological-machine factors.
2. The results of the present study provide some evidence about the reliabilities and validities that can be achieved with standardized case simulations.

f. Limitations of Study or Method

1. In addition to these limitations, the study is limited in how easily the results can be generalized.
2. The treatment of calcite and siderite as separate minerals rather than a solid solution causes some degree of error, but cannot be overcome at this time.

g. Conclusions or Inferences

1. Of the two net migration models covered by this study, Model III appears to be a better model for rapidly growing areas and Model II for slowly growing or declining areas.
2. Thus it seems that there is, as yet, no consistent explanation for the DeVoe-Brewer data.