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The Language of Science

Science writing can refer to two kinds of writing: writing *about* science (i.e., scientific subject matter) or writing *in the context* of science.

It is possible to write about science in a non-scientific way: Different written forms can take science as a subject about which something is said. An ode to the atom, a song celebrating the elements, a novelistic reconstruction of the discovery of X-rays—all of these could, strictly speaking, be considered types of writing that take science as their *subject matter*. The *form* of that subject matter would derive its structure and conventions from different genres like poetry, fiction, drama, and the essay. In other words, "science writing" could describe a type of writing in which the subject matter of science found a context within the conventions of literature.

But *science writing* may refer to another kind of writing, and it is this kind of writing that concerns us. Science writing may refer to writing that takes place within the context of science, governed by a specified set of conventions. Those conventions will be elaborated below. Because science writing refers to the manner of presentation, and not the topical content, any subject is a possible subject for scientific treatment.

Understood in this sense (writing generated within the context of a specific methodology), science writing belongs to category of writing called *technical writing* (as opposed, for instance, to the category of writing called *literary writing*). Technical writing refers to types of writing that report factual information in an objective manner, often for a targeted audience; it is a broader category than science writing. Science writing, as here defined, concerns itself with describing observations and/or results, and the manner by which they are derived through experimental or non-experimental methods, including classification, statistical analysis, mathematical analysis, and comparative studies. Such writing will now be stipulated *scientific writing* to differentiate it from types of writing that take science as a subject rather than as a context. Chapter 6 will provide a detailed discussion of the

formal components of a scientific paper; this chapter will describe the attributes of technical communication.

Technical Writing

Because technical writing presents factual information objectively, technical communication emphasizes the message. In this context, language functions as the means to an end, that of presenting information clearly and concisely. The writer does not encourage you to remark on the great beauty of the language; language should be transparent, a vehicle for the meaning. In fiction, poetry, and non-technical prose, the writer has a different end in mind. Sometimes these forms will communicate a subjective impression of an object or phenomenon; the writing may call attention to the language itself or the writer may give animate or human characteristics to non-human subjects. Sometimes non-technical prose is oriented to persuade the audience to take a particular point of view; in such cases, facts may be employed to solicit your approval. Such writing presents facts subjectively not objectively.

A casual glance at James Tate's "The Blue Booby" (below) tells you that it is not technical writing. In poetry, sentences or phrases are broken up and set on different lines. Line breaks are a poetic punctuation mark; they may direct your attention to the meaning, to the rhyme, to an image at the end of the line. The form signals you—through line breaks instead of full paragraphs—to read the words in a certain way. Line breaks are part of the code that says "This writing is poetry."

"The Blue Booby"[1]
James Tate

The blue booby lives
on the bare rocks
of Galapagos
and fears nothing.
It is a simple life:
they live on fish,
and there are few predators.
Also, the males do not
make fools of themselves
chasing after the young
ladies. Rather,
they gather the blue
objects of the world
and construct from them

a nest—an occasional

Gaulois package,
a string of beads,
a piece of cloth, from
a sailor's suit. This
replaces the need for
dazzling plumage;
in fact, in the past
fifty million years
the male has grown considerably duller,
nor can he sing well.
The female, though

asks little of him—
the blue satisfies her
completely, has a
a magical effect
on her. When she returns
from her day of
gossip and shopping,
she sees he has found her
a new shred of blue foil:
for this she rewards him
with her dark body,
the stars turn slowly
in the blue foils beside them
like the eyes of a mild savior.

Even if you rearranged the text of the poem and changed the line breaks—

> The blue booby lives on the bare rocks of Galapagos and fears nothing. It is a simple life: they live on fish, and there are few predators. Also, the males do not make fools of themselves chasing after the young ladies. Rather, they gather the blue objects of the world and construct from them a nest—an occasional Gaulois package, a string of beads, a piece of cloth, from a sailor's suit. . . .

—the passage would remain non-technical.

It would no longer be poetry; it would be prose—non-technical prose because the lines continue to convey the writer's *subjective* impression of the subject matter. The behavior of the booby is represented in human terms: Males "do not make fools of themselves chasing after young ladies" (only a human could be a fool or a lady); the female gossips and shops. The details used to describe the booby are selected and organized to enhance the effect of this anthropomorphism. "The male has grown considerably duller, nor can sing well"—these details are not the systematic part of a description but are, instead, specifically chosen for an effect. We do not receive other information about the evolutionary changes that have occurred in the past fifty million years; the writer has selected some information and excluded other information. The passage does not present us with

data but with anecdotal detail. So the description is not objective, nor are facts reported that can be verified.

In the following passage, taken from a technical work on boobies and gannets, the writer provides an objective account of courtship behavior.

> [A]n important context of Sky-pointing* is that of a male advertising his sexual receptivity to a female—overflying females commonly elicit it from males—[but] it has become equally or perhaps more important as a mutual display between partners that have already formed a bond. The term mutual is used to indicate that partners may actually display simultaneously—one like the mirror image of another—rather than merely one after the other, which I have called reciprocal. In the blue-foot both mutual and reciprocal Sky-pointing are strongly developed, the pair facing each other and repeatedly performing this bizarre display.
>
> A further aspect of Sky-pointing in a sexual context is its use in short-term co-ordination of sexual activity. Thus, it frequently precedes copulation and may be assumed to play a role in making the female receptive (or conversely, if initiated by the female, in stimulating the male).[2]

This passage provides an objective rendering of the courtship behavior of the blue booby. The writer describes what he has objectively observed and regularized in a pattern of courtship display. While Tate represents the behavior of the booby as a kind of domestic romance, Nelson portrays it as a pattern of behavior. Because no one knows what a booby thinks or feels, Tate's treatment animates them in human terms; he projects his own view of their interaction into the description.

Nelson departs from a purely objective approach only at one point: He remarks that the booby's sky-pointing behavior is "bizarre." *Bizarre* is a word that reflects his subjective opinion. Does the intrusion of subjective detail undercut the objectivity of a technical piece?

This instance alerts you to a qualification: the distinction "technical/non-technical" should be seen as a continuum with gradations rather than as absolute distinctions.

Reporting Factual Information

Reporting factual information requires you to produce information that can be verified. To convey factual information, use words that are specific and concrete. Give precise measurements, dimensions, condition, speed, molarity, and so on.

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* Sky-pointing: a gesture assumed by the booby's extending its neck lengthwise and pointing its bill to the sky, accompanied by a forward rotation of the wings at the shoulder and a lateral extension of wings.

Be precise in your detail and give detail. Because the communication of information is the core of your writing task, your writing should be clear (your point is expressed directly) and concise (the most economical form of writing is used to convey your point).

Objectivity and Tone

Scientific writing differs from non-technical writing in that the former is objective in tone. An objective tone is built up from words that are concrete, specific and precise. You can write about *any* subject as long as you present your discussion in an objective manner. There is no subject that cannot be treated technically. Love can be discussed in terms of the attractive qualities of pheromones; beauty may be discussed as a feature of patterned mathematic relations. In *The Astonishing Hypothesis: The Scientific Search for the Soul,* Francis Crick treats spiritual matters from the standpoint of scientific methodology. Modern (non-representational) art can be discussed objectively in terms of optics as a repudiation of linear perspective. The fact that anything *can* be written about objectively does not exclude the fact that it may also be written about subjectively. Francis Crick's treatment of the soul does not disallow discussion of the soul in reverential terms in other works; but a reverential attitude would disqualify such writing from scientific writing, just as a romantic attitude conveyed in writing about love or an awe-inspired treatment of beauty would exclude those writings from scientific writing.

Objectivity is conveyed through *tone. Tone* refers to the writer's attitude toward the subject, toward the audience, or toward himself. Tone is perceived through the writer's diction or word choice. An objective tone is created by words that have a clear and specific *denotation* (dictionary definition) and a neutral *connotation* (associations the word carries). For instance, if you were to refer to a horse as a "nag," *nag* would carry the sense that this horse was a broken down equine; it would carry a negative linguistic charge. *Steed* also refers to a horse, but this term carries a positive linguistic charge by the association of *steed* with the qualities of nobility, chivalry, and romance. The objective term, that is, the term with a neutral connotation, is the word *horse.*

Your writing also conveys your attitude to your audience. If you misjudge the audience level, you could come across as patronizing them. If you indulge in sarcasm or irony, you may convey the attitude that you do not take your audience seriously.

Objectivity and the Passive Voice

Compare and contrast the phrasing in the following two sentences:

Active Voice	⇒	I weighed the sample [4 words]
Passive Voice	⇒	The sample was weighed by me [6 words]

In the active voice, the agent of the action takes the subject position in the sentence, and the receiver of the action takes the direct object position. Thus, in *I weighed the sample,* the do-er, "I," is the subject of the sentence. The object, i.e., the receiver of the action, is "sample." In the passive voice, the object of the action takes the subject position in the sentence; the agent of the action, "I" is noted as an object of the preposition or it may be omitted.

Objections to the passive voice note that it is wordy and vague. In cases where the agent is included in the sentence as the object of the preposition, the passive voice is wordy, in the strictest sense that the passive voice requires more words to present the same information as the active. In cases where the agent is deleted—"by me" is omitted—the passive receives the charge of being vague. The context of the writing defines the desirability of including the agent or not. In reporting the methods of an experiment, the focus is not on the person who conducted the experiment but on the experiment itself; the passive voice in such an instance is a better option than the active because the passive emphasizes the action not the agent.

Some writing scenarios are inappropriate for the passive voice; in other scenarios the passive may be most apt. In a lab report, the inclusion of the agent would be awkward and misleading in emphasis: "I measured the sample, then I weighed it, and then I heated it to 310 degrees." To express the same idea but to shift the accent, it is appropriate and desirable to use the passive voice, as in the sentence: "The sample was weighed, measured, and heated to 310 degrees." The "I," while not present in the sentence, is implied.

Persona

While the transmission of information forms the primary purpose of your writing, a secondary effect is produced. Your tone creates a picture of you, the writer. This picture is called a *persona.* Ideally, your persona should convey personal and/or professional integrity. The writer's integrity inspires the reader's confidence in your work and makes your research credible. The writer's trustworthy persona can be established by any one or combination of the following: (1) *authority* (you've read the books, you've done your homework); (2) *position* (professional status); (3) *education* (you have a degree in your subject); (4) *experience* (you've done this before so you know what you're talking about); (5) *reputation* (everyone knows you can be trusted).

Note: the persona is not a conscious construction. It is an *effect* of your writing, conveyed by and through the discussion of your material. Beginning student writers sometimes view the task of presenting a scientific

paper with some trepidation, especially if that paper is presented to an expert in the field. Beginning writers can establish their authority through the literature search. A conscientious search and thoughtful consideration of other research in the field will be reflected in the scientific paper and, in turn, will reinforce trust between the writer and the reader. In this creation of trust, the writer establishes his or her authority.

Your audience equates you with your writing. If your literature search has been thorough, your experimental design appropriate, your discussion relevant, and your interpretation sound, then you create the grounds of your own authority for the reader. Conversely, it is possible to subvert that authority: if your writing is sloppy, your organization chaotic, your paper covered with coffee stains, and your punctuation random, you create the image of a person who is careless. It would not be unreasonable for your audience to infer that a person who does sloppy writing does sloppy science. Take care with both your writing and with the physical appearance of your presentation. Avoid sarcasm or humor; self-irony tells your audience that you do not take your writing seriously. Use the spell-check and the grammar-check on your computer. Spelling errors in a formal paper are one of the most glaring signs of carelessness because they are so easy to correct.

Analogy versus Metaphor

Analogies may be used in technical writing to explain or elucidate a point in the writing. Written for the purpose of clarification, an analogy makes a comparison between things or events. The statement "Spider silk is elastic like rubber" asserts a likeness between an organic substance, spider silk, and a substance well known for its elasticity, rubber. The analogy renders a point by stressing the likeness between elements in the comparison.

In contrast, a metaphor or simile makes a comparison that defamiliarizes, or makes strange, a conventional understanding of the terms linked together through it; in this regard, it calls attention to itself and may be used to evoke a response or express an emotion. For example, in Sonnet 24, Shakespeare compares the seeing function of the eye with the rendering capability of the artist: "Mine eye hath played the painter and hath stelled / Thy beauty's form in the table of my heart." The eye in this line is compared to the painter; the act of seeing has drawn (stelled) the beloved's face on the notebook (table) of the heart. Metaphor here underscores the indelible impression left by the beloved by the ascription of agency to the passive operation of sight.

The purpose of analogy in science writing is clarification. Clarification is rendered by the parallel drawn between some thing that is not well known and some thing that is well known. How elastic *is* spider silk? You know the answer: It is as elastic as rubber.

Analogies may be simple comparisons, one phrase or one sentence long, or they can extended. In the following passage, George Gamov, in *A Biography of Physics*, compares the change in electron orbital with a gear shift in a car:

> If radiant energy can exist only in certain minimum amounts or the multiples therefore, why not make the same assumption concerning the mechanical energy of electrons circling the nucleus? In this case, the motion of electrons in the normal state of an atom would correspond to a larger number of these mechanical energy quanta. Thus, *an atomic mechanism should behave, in a way, as an automobile transmission box:* one can put it in low, in second, or in top gear, but not in between.[3]

In scientific writing, an analogy does not stand out or call attention to itself; instead, it clarifies or explains. If you wanted to be hard-minded about the relationship between metaphors and analogies, the truth is that they are very much alike structurally but differ greatly in function: analogies make familiar, metaphors make strange.

Terminology

Technical writing reports factual information. To convey facts correctly and to demonstrate objectivity, you will often have to explain your reasoning. To this end, you need a clear understanding of the difference between a fact, an inference, and a judgment.

Fact

A fact is a statement thought to be true. It is verifiable. It does not change, although it may be subject to interpretation. Its adequacy obtains here and at the South Pole. The speed of light is constant both here and at the other side of the universe. A ball dropped from the Leaning Tower of Pisa and a ball dropped from the temple at Teotihuican will always fall *down*.

There is one qualification, however, to this definition of a fact. In the history of science, some facts which were thought to be true were later discovered to be erroneous. For instance, the Ptolemaic universe (a classical paradigm) placed the earth at the center of the solar system and described the sun and other planets as orbs that circled the earth. Even though we know that the sun stands at the center of the solar system, those earlier navigators could still arrive at their planned destination by using information that was not based on a "true" fact.

Those navigators had a functional model of the universe, which, though not true, was adequately descriptive. For the purpose of a working definition, however, we will consider a fact to be a point of information that

all people will *agree* is true, i.e., a fact has been demonstrated to most adequately describe events in the world. As discussed in Chapter 1, truth is stipulated in the sense of a provisional truth and is not to be conceived as Truth, a quasi-metaphysical absolute term on which much faith is staked.

Inference

An inference is what we make of the facts. An inference is a reasoned interpretation. Because it is reasoned, someone who replicated your method of reasoning should logically arrive at the same conclusion. Consider, for instance, the relations proposed in the following sentences:

(1) To pass the class, you must pass the final.
(2) Joe failed the final.
(3) Therefore, Joe will not pass the class.

The conclusion (3) that Joe will not pass the class does not reflect a bias or a personal judgment on this person. Rather, it is the logical conclusion of a series of steps and conditions.

Consider the following logical argument:

(1) a=b
(2) b=c
(3) Therefore, a=c

This is a logical pattern called a syllogism. Anyone who performed the logical steps in the same order would arrive at the same conclusion. The major premise (1) and the minor premise (2) are clearly specified, from which the logical and necessary result must be (3).

Opinion and Judgment

An opinion is a view you hold based on personal preference. A judgment is an assessment of value based on a personal opinion. For instance, the statements "Blueberry pie is my favorite" (opinion) and "A BMW convertible is the best car in the universe" (judgment) reflect personal preference. As expressed here, these statements cannot be proved objectively. Although they may be disputed, there is no binding necessity that can make blueberry pie *your* favorite if you already hate it.

You may be tempted to argue that you could prove a BMW was the best car in the universe. Shun this temptation. You would have to rephrase this statement to include the criteria of evaluation. The troubled term in that statement is *best*. Best could be judged in terms of most efficient design, cost, performance, or other criteria, but because the statement does not specify objective criteria, that statement remains a judgment.

Exercise

Answer each of the following and write a response in a few objective words.

(1) Describe a piece of chalk.
(2) Given that a=b and that b=c, does a=c?
(3) What do you think of North American environmental policy?
(4) What do you think of modern art?

(1) We will agree that chalk is white, or flaky, dusty, or made of calcium. Normally, instructions for a description elicit a statement about the essential attributes. These attributes of substance are facts because they provide observable or measurable data. They are verifiable. Anyone else who was asked the same question would have the same answer or would provide an answer consistent within a range of possibilities (after all, only a few words were specified in your description). To some extent, facts are a product of general agreement. Everyone agrees that the facts about chalk are true. If I said that chalk was a symbol of beauty, you might not agree with me. In fact, if I insisted that it was a *fact* that chalk was a symbol of beauty, you would question my ability to understand facts; the object would not be suspect; the person would be. A description of chalk that specified its physical attributes would make an *empirically true* statement. The chalk can be measured (length) or analyzed (calcium carbonate).

(2) The statement that a=c is *logically consistent*. Anyone who performed the same series of steps would arrive at the same conclusion. Inferences are logically verifiable. Notice that this example specifies a starting premise.

(3) Any decision on this question would depend upon your starting premise. This question elicits a *subjective interpretation*. While you can follow such an interpretation, no logical necessity can force your agreement with it. Your starting premise is a matter of personal choice.

(4) Your view of modern art is subject to your personal opinion. A personal opinion need have no basis in fact nor require any justification. You do not need reasons to have an opinion. Although you might have reasons to account for your like or dislike (It is pretty. It is ugly.), those reasons are ultimately subsumed to matters of personal taste. It is possible to have an opinion about any subject but you cannot prove your opinion or convince others to have the same opinion through reasoning.

True and Correct Language

When we say that a sentence is written correctly, *correct* refers to a context of language rules. A sentence is written in accord with the grammar and the punctuation that make the meaning intelligible. *Correct* means that language conforms to the rules of grammar, diction, and punctuation. Consider the following examples:

(1) A red onion sang pearls against a light green moon.
(2) A a against green light moon onion pearls red sang

What is the difference between (1) and (2)?
They both use the same words.
Example (1) is a *correct* sentence.

It observes the rules for syntax. It has a subject, a verb, and a direct object. Adjectives stand in relation to the words they modify. Example (2), while using the same words, arranges them in alphabetical order. You could recognize that (2) is not a sentence. The words must be organized in a certain way for us to understand they are to be read as a sentence.

- The way words (and sentences) are put together gives us indirect instructions about how to read them.

Word order gives directions or evokes a code: *read this as a sentence.*

The words alone provide us with little meaning. But their arrangement, in (1), instructs us to read them as a meaningful unit, a sentence. Similarly, earlier in this chapter, the line breaks in the poem gave the instructions: *read this as a poem.*

While *correct language* obeys laws of syntax, grammar and punctuation, *true* language is different. When we say a statement is *true*, we mean that a description or statement conforms to the world as we know it or as it is generally perceived to be. Technical language creates a model that stands in correspondence to the world. In contrast, consider the following sentence:

(3) Flying pigs sing orchids to sleep on submarines.

This sentence is grammatically *correct*. It has a subject, verb, and object that are arranged in a way that makes a sentence. But it is not a *true* statement because pigs neither fly nor sing. While orchids may suffer a slower metabolism at night, we do not generally call such a state sleep. This sentence makes a kind of poetic sense; but when you compare its information with the general knowledge you have about animals and plants, it does not make a *true* statement. Within the limits of the world as we know it, pigs do not possess the capacity for flight or vocalization. So this sentence, while *correct* (adequate to the rules of grammar) is *not true*.

The language of science must be both *correct* and *true*. It must possess both conformity to the rules of grammar, punctuation, and spelling, and it must make a statement that is adequate to events in the world.

Limitations on True Language

While scientists strives to use language that is adequate to our knowledge

of the world (*true*), it is possible for language to be false to reality and yet describe an aspect of the world. For instance, you would probably understand the statement, "The sun came up this morning," even though it is literally false. Because the earth rotates, the sun only appears to move. It is possible to make a statement that everyone understands but which is not precisely descriptive of the events as they are.

While language can *report* a fact, it does not *equal* a fact. We attempt to build a model of the world as we perceive it or know it, but language ultimately remains a model, susceptible to the capabilities and restrictions of other models. For example, while we conveniently attribute color as a property of substances—The sky is blue. Roses are red. Clouds are white.—color actually describes a select spectrum of light waves as they are decoded by the optic nerve and registered on our brain. Does the color exist in light? Does it exist in our brain? Does it exist in the thing itself? Does color exist in a dark room?

Before you spend too much time pondering these questions, bear in mind the larger point: Language gives us a model that *attempts* to be adequate to the world but which *may not* be adequate to the world. Does this mean that people who try to use language at all are trying to cope with an impossible task? Are we fools for thinking we can use language to communicate anything? Such a cynical approach is not accurate either. We can communicate with each other. Remember, language is a social tool or instrument designed to help us interact with other people. Consequently, we can all *agree* that meaning and meanings exist. If I say "dog," you will know, because you have been taught, what *dog* is or means. If I say a foot is twelve inches long, you can comprehend the dimensions because we have all learned common conventions and common words. So while language may not always be adequate to the world, it is still possible to communicate with each other. Language use is conventional and the stipulation given above about true language is one such convention.

Two Criteria for Science Writing

Science writing must satisfy two criteria: it must be *empirically true* and *logically consistent.*

Let us go back to the syllogism, denoted by the scheme: (1) a=b (2) b=c (3) a=c. If we substitute sentences for letters, we can produce the syllogism you have previously seen in Chapter 1:

All copper conducts electricity.
This piece is copper.
> Therefore, this piece conducts electricity.

This order of sentences reflects steps in thought, and those steps will, per the rules of logic, consistently produce a common conclusion.

But logical consistency is not the only criteria for science writing. A statement may be logically consistent but not empirically true.

C. L. Dodgson was a British mathematician who wrote two books on logic. (Dodgson is better known as Lewis Carroll, the author of *Alice in Wonderland.*) The following syllogism is adapted from his book, *Symbolic Logic.*

All chickens speak French.
This creature is a chicken.
> Therefore, this creature speaks French.

What is wrong with this conclusion?

This syllogism is logically consistent, but it does not arrive at a conclusion that is accurately descriptive of the world as we know it. *This creature speaks French* is the logical conclusion (and a grammatically *correct* statement), but we know that chickens do not speak French or English or Spanish. Chickens do not speak at all. Therefore, the first premise and the conclusion fail to conform to our knowledge of the world. While this syllogism makes a logical inference, it is not adequate to the facts we have about animal behavior.

If you accept the premise, the starting statement, logic compels you to accept the conclusion.

But you do not have to accept the premise.

This syllogism starts with a premise that fails to correlate with facts. This premise is not a remark that derives from a fact; it derives from a sentence that is grammatically correct but logically nonsense.

Both these syllogisms are logically consistent in their train of reasoning; however, each builds upon different kinds of premises. The premises in the copper syllogism are true statements about the world; in contrast, Dodgson's syllogism proceeds from a nonsense premise.

Scientific reasoning rests on premises based on facts and proceeds logically. Such reasoning is therefore both empirically true and logically verifiable; arguments based on such reasoning are said to be sound. Both criteria must be met. Logical consistency alone is insufficient.

You ensure that your writing is empirically true when you include data, measurements, quantities, and conditions; these specifications are contained in the Materials and Methods section. It is also important that your paper include information about the instruments used to make those measurements. You ensure logical consistency by explaining your results in a reasoned manner.

Exercises

1. Technicalities

Go back through this chapter, and, after synthesizing what you read, make a

table to compare technical writing with non-technical writing on the following points: purpose, tone, subject matter, style, or any other points you may note.

2. Objective or Not?

What is the subject matter? How is the subject matter treated? Recall that the distinguishing mark of scientific writing lies in the treatment (the "how") and not in the subject matter (the "what"). (A description of an object does not make a description objective.) Using the distinction between subject matter and subject treatment, comment on the subjectivity/objectivity of passages below. Refer to particular words or phrases in the text to support your view. Then rewrite the subjective accounts to make them objective.

(a) At tea, however, a shape began to emerge which brought back our spirits. Three chains twisted around each other in a way that gave rise to a crystallographic repeat every 28 Å along the helical axis. This was a feature demanded by Maurice's and Rosy's pictures, so Francis was visibly assured as he stepped back from the lab bench and surveyed the afternoon's efforts. Admittedly, a few of the atomic contacts were still too close for comfort, but after all, the fiddling had just begun. With a few hours' more work, a presentable model should be on display.[4]

(b) When the NMDA glutamate channel opens, it allows the passage of not only sodium and potassium atoms but also an appreciable amount of calcium ions (Ca++). These incoming calcium atoms appear to be the signal that initiates complex chains of chemical reactions that at the moment are only partially understood. We can now begin to see the beginnings of the explanation of cognitive processes, such as memory, in terms of molecular events.[5]

(c) He was a very small frog with wide, dull eyes. And just as I looked at him, he slowly crumpled and began to sag. The spirit vanished from his eyes as if snuffed. His skin emptied and drooped; his very skull seemed to collapse and settle like a kicked tent. He was shrinking before my eyes like a deflating football. I watched the taut, glistening skin on his shoulders ruck, and rumple, and fall. Soon, part of his skin, formless as a pricked balloon, lay in floating folds like bright scum on top of the water: it was a monstrous and terrifying thing. I gaped bewildered, appalled. An oval shadow hung in the water behind the drained frog: then the shadow glided away. The frog skin bag started to sink. I had read about the giant water bug, but never seen one. "Giant water bug" is really the name of the creature, which is an enormous, heavy-bodied brown beetle.[6]

(d) Hemipteran mouthparts are modified to form a piercing beak. Whereas most terrestrial bugs are phytophagus, using the beak to pierce plant tissue, aquatic hemipterans (including many *Corixidae*) inject enzymes to liquefy the tissues of animal prey that are sucked up through a food channel in the beak. Prey normally consists of small insects and crustaceans, although there are accounts of giant water bugs (Belostomatidae: Lethocerinae) attacking and subduing frogs, fish, and water snakes. The largest aquatic insects are members of the genus *Lethocerus*.[7]

3. Analysis of Ethos

Ethos refers to the individual's character. Ethos is conveyed through the writer's *persona* (image) created through writing.

We have said before that any subject can be treated from a technical point of view, that no subject matter is intrinsically forbidden. This assertion appears straightforward, and we have come to believe that we live in a such a modern time

and place that any subject can be discussed with objectivity; yet, there are still topics that might appear on the margins of legitimate scientific inquiry.

In the early 1980s, the Dean of the Princeton School of Engineering/Applied Science was asked to write a paper on ESP. A highly regarded professional journal, the *Proceedings of the Institute of Electrical and Electronics Engineering* (*IEEE*), solicited this article from him. The Dean of the Princeton School of Engineering did write that paper, with surprising results.

But before we consider what Dean Jahn wrote, let us spend a few minutes considering his position. R. G. Jahn was the dean of a hard-science discipline, Applied Science. He was also the dean at a prestigious university, Princeton. His official position made him a figure with much authority. He was invited to report on a subject that was probably seen as a marginal subject, perhaps something like magic or voodoo. Dean Jahn could have refused, but he did not. He produced a comprehensive, analytic, documented essay on the subject.

In the following sections, you will see three instances of introductory writing: the introduction provided by the journal, the abstract, and Jahn's introduction to the paper are all designed as types of writing that acquaint the reader with the subject. Read through the passages and then answer the following questions.

a. Look at all of the passages. According to each of them, what has been the previous professional attitude toward ESP research?
b. What has been the traditional popular view? Does the popular view conflict or coincide with the professional view?
c. Compare and contrast the tone in the journal's introduction with that in Jahn's introduction.
d. How did Jahn get involved in the project? How did his attitude change from the time he became involved in this subject to the time that this paper appeared?
e. Does Jahn currently spend all of his time now on ESP? How deep is his involvement? Why does he explain this?
f. Aristotle once said, "A speaker worthy of belief is the most potent of all the means of persuasion." On the basis of c. above, how would you characterize Jahn's ethos? Is he "worthy of belief"? What aspects of his writing can you point to in support of your view? Does Jahn come across as an eccentric administrator? As a careful scientist? Do you feel that he sacrificed any of his professional authority in dealing with this subject?

I. *IEEE* Introduction to R. G. Jahn, "The Persistent Paradox of Psychic Phenomenon."

The introduction to this essay, which appears in the introduction of Vol. 70, No. 2, *IEEE*, February 1982, describes Jahn's contribution as follows:

> **The Persistent Paradox of Psychic Phenomenon: An Engineering Perspective** *(Invited Paper), Jahn,* page 136—The persistent fragmentary indication of the possible existence of psychic phenomena requires us, in the interests of scientific integrity and intellectual honesty, to apply the same spirit of objective inquiry that we have focused on the more traditional and accepted branches of science and technology.
>
> It was nearly six years ago—in March 1976, to be exact—that the *Proceedings* took the unusual step of publishing a paper on the psychic phenomenon called remote viewing. That paper was received with great interest, considerable skepticism, some

hostility, and even a bit of shock. In the intervening years, no breakthroughs have occurred to prove or disprove the existence of this and other psychic phenomena, but interest and research have continued unabated. Where does the research on these topics stand now? It was with this question in mind that the paper in this issue was invited.

This paper reviews the history, nomenclature, conceptual organization, and status of the generic field of psychic phenomenon; presents a few detailed examples of contemporary research that could have ultimate technological implications; and attempts to offer a balanced view of the viability and value of continued study of this fascinating and controversial field.

This paper is believed to represent the first attempt at a comprehensive engineering survey of the field. Most readers will likely approach it with a healthy blend of curiosity and skepticism. It is hoped all will find it informative and thought provoking.

II. R. G. Jahn's Abstract

Although a variety of so-called psychic phenomena have attracted man's attention throughout recorded history, organized scholarly effort to comprehend such effect is just one century old, and systematic academic research roughly half that age. Over recent years, a sizeable spectrum of evidence has been brought forth from reputable laboratories in several disciplines to suggest that at times human consciousness can acquire information inaccessible by any known physical mechanism (ESP), and can influence the behavior of physical systems or processes (PK), but even the most rigorous and sophisticated of these studies display a characteristic dilemma: The experimental results are rarely replicable in the strict scientific sense, but the anomalous yields are well beyond chance expectations and a number of common features thread through the broad range of reported effects. Various attempts at theoretical modeling have so far shown little functional value in explicating experimental results, but have served to stimulate fundamental re-examination of the role of consciousness in the determination of physical reality. Further careful study of this formidable field seems justified, but only within the context of very well conceived and technically impeccable experiments of large data-base capability, with disciplined attention to the pertinent aesthetic factors, and with more constructive involvement of the critical community.

III. Introduction: R. G. Jahn, "The Persistent Paradox of Psychic Phenomenon"

In the introduction, Jahn explains the history of his involvement in the project. This segment comes from his formal paper.

. . . I venture to begin the most extraordinary writing task I have yet attempted: to respond to the request of the Editors of this journal for a critical review of the status and prognosis of scientific research into so-called psychic phenomenon. I do so with some trepidation, first because the topic is far from my principal line of scholarship and my involvement with it has been brief and tightly circumscribed, and second, because of the intensity of reactions any commentary on this subject tends to call forth from many quarters.

For these reasons, it may be well at the outset to specify my perspective on the field and the purpose that I hope this article will serve. My formal training is that of an engineer and applied physicist, and the bulk of my research has concerned a

sequence of topics in the broad domain of the aerospace sciences: Fluid mechanics, ionized gases, plasma dynamics, and electric propulsion. In my present position as Dean of the School of Engineering and Applied Science of Princeton University, I have occasion to be involved with an even broader selection of topics selected for undergraduate independent projects, and it was in that context some four years ago that I was requested by one of our very best students to supervise a study of psychic phenomena. More specifically, this young lady proposed to bring her talents and background in electrical engineering and computer science to bear on some experiments in controlled low-level psychokinesis. Although I had no previous experience, professional or personal, with this subject, for a variety of pedagogical reasons, I agreed, and together we mapped a tentative scholarly path, involving a literature search, visits to appropriate laboratories and professional meetings, and the design, construction, and operation of simple experiments. My initial oversight role in this project led to a degree of personal involvement with it, and to a growing intellectual bemusement to the extent that by the time the student graduated, I was persuaded that this was a legitimate field for a high technologist to study and that I would enjoy continuing to do so. I have since assembled a small professional staff, secured the requisite funding from a few private sources, and undertaken a modest experimental program in selected aspects of the field that could ultimately have some engineering implications. I should emphasize that my fractional involvement with this program remains quite minor in comparison to my other responsibilities, and that the work is still very preliminary and tentative, but it provides the base of cognizance for my broader observations on the field as a whole.

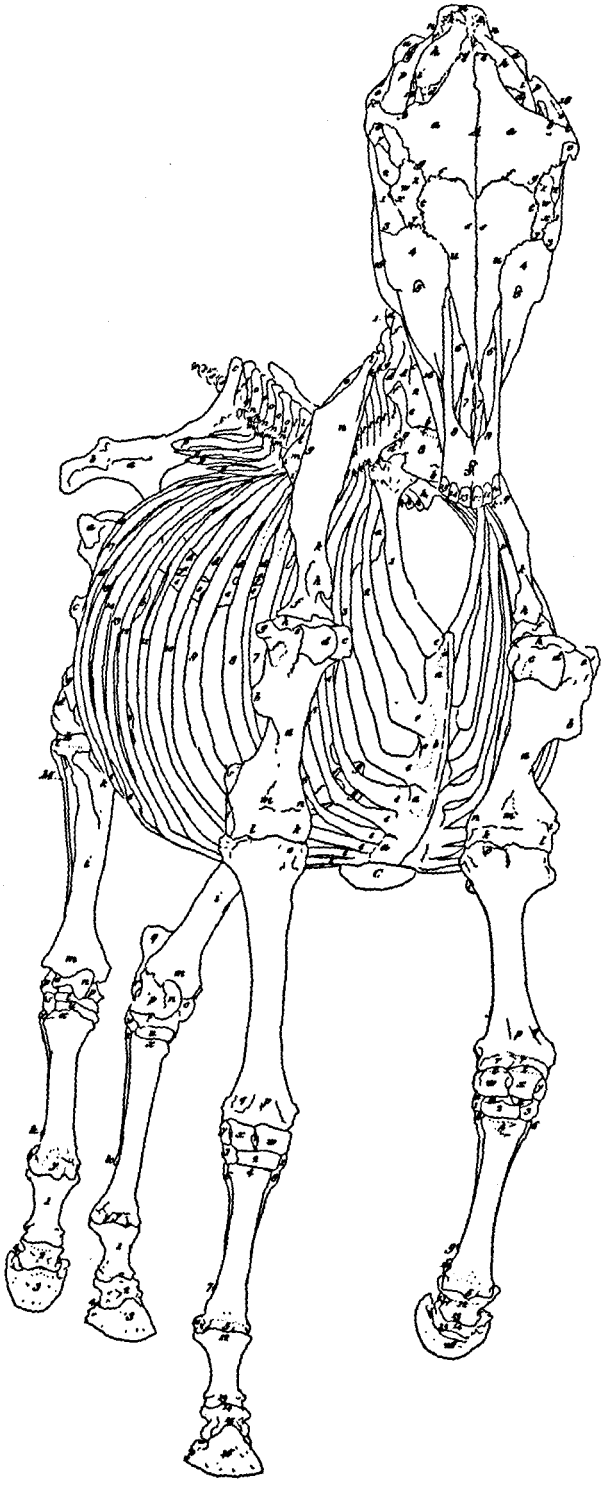
The intention of this article is to provide some balanced perspective on the modern status of this conceptually and logistically difficult subject. Certainly no field of scholarly endeavor has proven more frustrating, nor has been more abused and misunderstood, than the study of psychic phenomena. Dealing as it does as much with impressionistic and aesthetic evidence as with analytic substance, and carrying by its nature strongly subjective and numenistic overtones, it has been incessantly prostituted by charlatans, lunatics, and sensationalists, categorically rejected by most of the scientific establishment, and widely misunderstood by the public at large. Interspersed with this, and greatly encumbered by it, a pattern of legitimate effort to comprehend and utilize the purported phenomena has evolved to a point where some dispassionate assessment of its accomplishments can be attempted. (136–37).

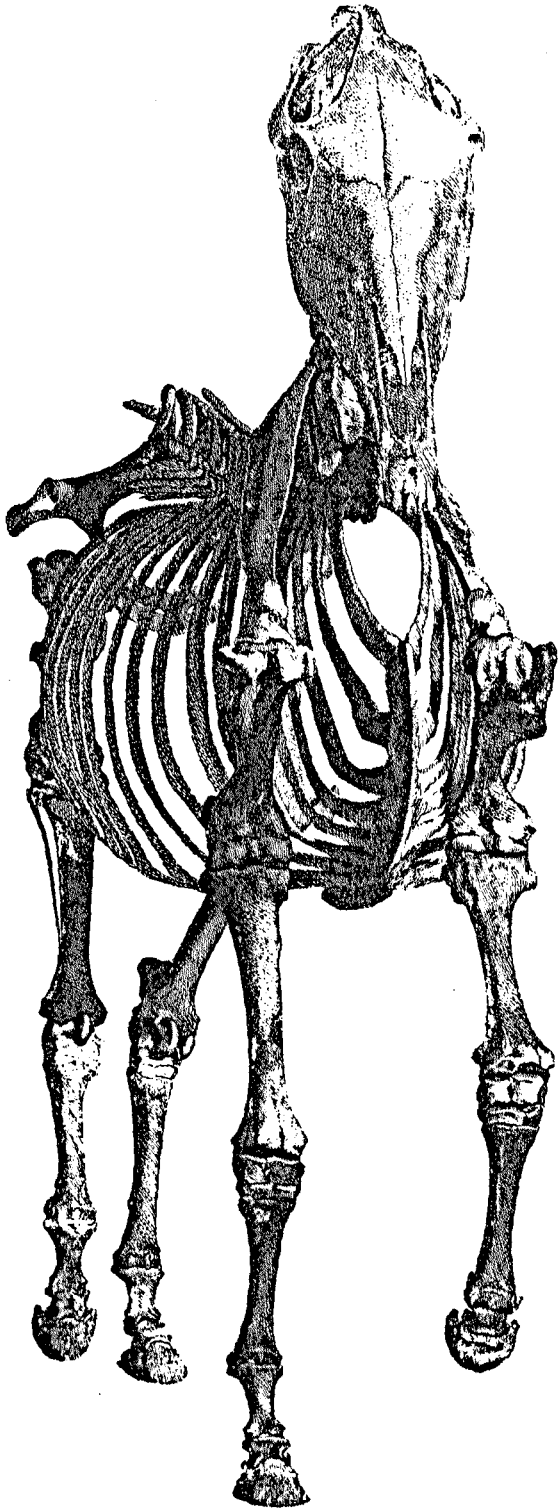
4. Analysis of Graphic Illustration

George Stubbs was born (1724–1806) in Liverpool. His father was a currier, or leather dresser, and George must have been accustomed to tan yards and slaughterhouses at an early age. By the time he was 8, Stubbs was drawing with an amazing talent. He continued to make drawings of animals all his life. Although he tried to make a living by painting portraits and landscapes, his greatest success came from his publication of etched anatomical drawings. After traveling abroad, he eventually established himself in London where he began his work on *The Anatomy of the Horse* (published March 4, 1766). His work included plans for a series of drawings that compared the anatomy of an ape, a tiger, and a horse.

The following illustrations come from *The Anatomy of the Horse*. Notice that the line drawing of the skeleton contains letters and numbers; these are keyed to a

Figure 1 (overleaf spread): Second Skeleton Table (plates 88 and 89) from Stubbs's *Anatomy of the Horse*.





description of the labelled parts that occurs in the written text accompanying the illustration.

Formulate the criteria for technical writing and then apply them to Stubbs's etchings in order to make a determination about the technical or non-technical nature of these illustrations. Can you define criteria to distinguish an "objective" drawing from a "subjective" drawing?

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Notes

1. James Tate, "The Blue Booby," in *The Oblivion Ha-Ha: Sixty Poems by James Tate* (Boston: Little, Brown & Co., in association with the Atlantic Monthly Press: 1967, 1968, 1969, 1970), pp. 5–6.
2. J. Bryan Nelson, *The Sulidae: Gannets and Boobies* (New York: Oxford University press, 1978), p. 555.
3. George Gamow, *The Biography of Physics* (New York: Harper & Row, 1961), p. 239. The emphasis is mine.
4. James D. Watson, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA,* Norton Critical Edition, edited by Gunther S. Stent (New York: W. W. Norton & Co., 1980), p. 56.
5. Francis Crick, *The Astonishing Hypothesis: The Scientific Search for the Soul* (New York: Charles Scribner's Sons, 1994), p. 101.
6. Annie Dillard, *Pilgrim at Tinker Creek* (New York: Harper's Magazine Press, 1974), pp. 5–6.

7. J. V. Ward, *Aquatic Insect Ecology: 1. Biology and Habitat* (New York: John Wiley & Sons, Inc., 1992), p. 11.