Reading Selections
Take This Fish and Look at It

Samuel H. Scudder

Samuel H. Scudder (1837–1911) was an American scientist who was educated at Williams College and Harvard University. One of the most learned entomologists of the day, his main scientific contributions were in the study of butterflies and Orthoptera (an order of insects that includes grasshoppers and crickets). Scudder was a student of Louis Agassiz (1807–1873), the distinguished Harvard professor of natural history, who used to subject his students to a rigorous but useful exercise in minute observation. The following is Scudder’s account of one such exercise.

It was more than fifteen years ago that I entered the laboratory of Professor Agassiz, and told him I had enrolled my name in the Scientific School as a student of natural history. He asked me a few questions about my object in coming, my antecedents generally, the mode in which I afterwards proposed to use the knowledge I might acquire, and finally, whether I wished to study any special branch. To the latter I replied that, while I wished to be well grounded in all departments of zoology, I purposed to devote myself specially to insects.

"When do you wish to begin?" he asked.
"Now," I replied.

This seemed to please him, and with an energetic "Very well!" he reached from a shelf a huge jar of specimens in yellow alcohol. "Take this fish," he said, "and look at it; we call it a haemulon; by and by I will ask what you have seen."

With that he left me, but in a moment returned with explicit instructions as to the care of the object entrusted to me. "No man is fit to be a naturalist," said he, "who does not know how to take care of specimens."
I was to keep that fish before me in a tin tray, and occasionally moisten the surface with alcohol from the jar, always taking care to replace the stopper tightly. Those were the days of ground-glass stoppers and elegantly shaped exhibition jars; all the old students will recall the huge neckless glass bottles with their leaky, wax-besmeared corks, half eaten by insects, and begrimed with cellar dust. Entomology was a cleaner science than ichthyology, but the example of the Professor, who had unhesitatingly plunged to the bottom of the jar to produce the fish, was infectious; and though this alcohol had a "very ancient and fishlike smell," I really dared not show any aversion within these sacred precincts, and treated the alcohol as though it were pure water. Still, I was conscious of a passing feeling of disappointment, for gazing at the fish did not commend itself to an ardent entomologist. My friends at home, too, were annoyed when they discovered that no amount of eau-de-cologne would drown the perfume which haunted me like a shadow.

In ten minutes I had seen all that could be seen in that fish, and started in search of the Professor—who had, however, left the Museum; and when I returned, after lingering over some of the odd animals stored in the upper apartment, my specimen was dry all over. I dashed some fluid over the fish as if to resuscitate the beast from a fainting fit, and looked with anxiety for a return of the normal sloppy appearance. This little excitement over, nothing was to be done but to return to a steadfast gaze at my mute companion. Half an hour passed—an hour—another hour; the fish began to look loathsome. I turned it over and around; looked it in the face—ghastly; from behind, beneath, above, sideways, at a three-quarters' view—Just as ghastly. I was in despair; at an early hour I concluded that lunch was necessary; so, with infinite relief, the fish was carefully replaced in the jar and for an hour I was free.

On my return, I learned that Professor Agassiz had been at the Museum, but had gone, and would not return for several hours. My fellow-students were too busy to be disturbed by continued conversation. Slowly I drew forth that hideous fish, and with a feeling of desperation again looked at it. I might not use a magnifying-glass; instruments of all kinds were interdicted. My two hands, my two eyes, and the fish; it seemed a most limited field. I pushed my finger down its throat to feel how sharp the teeth were. I began to count the scales in different rows, until I was convinced that was nonsense. At last a happy thought struck me—I would draw the fish; and now with surprise I began to discover new features in the creature. Just then the Professor returned.

"That is right," said he; "a pencil is one of the best of eyes. I am glad to notice, too, that you keep your specimen wet, and your bottle corked."

With these encouraging words, he added, "Well, what is it like?"

He listened attentively to my brief rehearsal of the structure of parts whose names were still unknown to me; the fringed gill arches and movable
operculum; the pores of the head, fleshy lips and lidless eyes; the lateral line, the spinous fins, and forked tail; the compressed and arched body. When I finished, he waited as if expecting more, and then with an air of disappointment:

"You have not looked very carefully; why," he continued more earnestly, "you haven't even seen one of the most conspicuous features of the animal, which is as plainly before your eyes as the fish itself; look again, look again!" and he left me to my misery.

I was piqued; I was mortified. Still more of that wretched fish! But now I set myself to my task with a will, and discovered one new thing after another until I saw how just the Professor's criticism had been. The afternoon passed quickly, and when, towards its close, the Professor inquired: "Do you see it yet?"

"No," I replied, "I am certain I do not, but I see how little I saw before."

"That is next best," said he, earnestly, "But I won't hear you now; put away your fish and go home; and perhaps you will be ready with a better answer in the morning. I will examine you before you look at the fish."

This was disconcerting. Not only must I think of my fish all night, studying, without the object before me, what this unknown but most visible feature might be; but also, without reviewing my discoveries, I must give an exact account of them the next day. I had a bad memory; so I walked home by the Charles River in a distracted state, with my two perplexities.

The cordial greeting from the Professor the next morning was reassuring; here was a man who seemed quite as anxious as I that I should see myself what he saw.

"Do you perhaps mean," I asked, "that the fish has symmetrical sides with paired organs?"

His thoroughly pleased, "Of course! Of course!" repaid the wakeful hours of the previous night. After he had discoursed most happily and enthusiastically—as he always did—upon the importance of this point, I ventured to ask what I should do next.

"Oh, look at your fish!" he said, and left me again to my own devices. In a little more than an hour, he returned and heard my new catalogue.

"That is good, that is good!" he repeated; "but that is not all; go on!"; and so for three long days he placed that fish before my eyes, forbidding me to look at anything else, or to use any artificial aid. "Look, look, look," was his repeated injunction.

This was the best entomological lesson I ever had—a lesson whose influence has extended to the details of every subsequent study; a legacy the Professor had left to me, as he has left to so many others, of inestimable value, which we could not buy, with which we cannot part.

A year afterward, some of us were amusing ourselves with chalking outlandish beasts on the Museum blackboard. We drew prancing starfishes; frogs in mortal combat; hydra-headed worms; stately crawfishes standing
on their tails, bearing aloft umbrellas; and grotesque fishes with gaping mouths and staring eyes. The Professor came in shortly after, and was amused as any at our experiments. He looked at the fishes.

"Haemulons, every one of them," he said; "Mr. ____ drew them."

True, and to this day, if I attempt a fish, I can draw nothing but haemulons.

The fourth day, a second fish of the same group was placed beside the first, and I was bidden to point out the resemblances and differences between the two; another and another followed, until the entire family lay before me, and a whole legion of jars covered the table and surrounding shelves; the odor had become a pleasant perfume; and even now, the sight of an old, six-inch worm-eaten cork brings fragrant memories.

The whole group of haemulons was thus brought in review; and, whether engaged upon the dissection of the internal organs, the preparation and examination of the bony framework, or the description of the various parts, Agassiz's training in the method of observing facts and their orderly arrangement was ever accompanied by the urgent exhortation not to be content with them.

"Facts are stupid things," he would say, "until brought into connection with some general law."

At the end of eight months, it was almost with reluctance that I left these friends and turned to insects; but what I had gained by this outside experience has been of greater value than years of later investigations in my favorite groups.

Writing Exercises

1. Observation
Take an object, a plant, an animal, or a seashell and follow the same procedure as Scudder.

2. Statement of Purpose
When Agassiz asked Scudder what he intended to do with his knowledge, Scudder said he proposed to be an entomologist. Write a statement of purpose in which you, adopting Scudder's persona, explain why you wish to study with Professor Agassiz and what you can learn from him.

3. Analysis
Outline the steps in Scudder's increasingly focused observations. Is there a pattern to these steps? Does Scudder proceed inductively or deductively?

4. Explanation
(a) Agassiz says: "A pencil is one of the best of eyes." Explain. Can you interpret this in light of the difference between casual observation and focused observation described in Chapter 1?
(b) What does Agassiz mean by the point that "Facts are stupid things until brought into connection with some general law"?

Notes

Epidemics, Book I

Hippocrates

Hippocrates* (c. 430 B.C.) was a famous Greek physician who is considered the father of medicine. Even today, practicing physicians take the Hippocratic oath, a code of medical ethics, which is based on the precept: First, do no harm. Hippocrates wrote extensively on many subjects, including epidemics, embryology, and the influence of geographical location on disease. He argued that epilepsy, the "sacred disease," was not caused by possession of the gods. He prescribed practical treatment for fractures and wrote an anatomy of the heart which was important for its careful and direct observation. Even though his writings were not addressed to a specialized audience of medical students but to the general public of his time, his influence among men of science extended through the sixteenth, seventeenth, and eighteenth centuries.

* Hippocrates, writing 400 years before the introduction of the Julian calendar, had no convenient method for recording dates. There were several different calendars in use in Greece, and they were all based on lunar months, so that the same date would not always fall on the same day of the solar year. It was therefore common practice to use certain astronomical events as a rough method for dating. The four obvious points are the equinoxes and solstices: 21 March, 21 September, 21 June, 22 December. These are from time to time supplemented by reference to a heliacal rising or setting of certain stars and constellations. Owing to the precession of the equinoxes these are not constant, and various factors prevent an exact calculation of the dates Hippocrates intended. The chief of these mentioned in the text, together with their approximate equivalents are:

The rising of Arcturus . . . . 10 September
The rising of the Pleiads . . . . 10 May
The setting of the Pleiads . . . . 11 November
The rising of the Dog Star . . . . 17 July


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Keep in mind that in Hippocrates’ time, any person could claim to be a physician. There were no medical schools or state licensing. In fact, there was, in those days, no category of “science” at all; the study of philosophy included ethics, logic and nature. Because the study of medicine was considered part of the study of nature, it was considered an appropriate subject for philosophers rather than for doctors. Even the philosopher, Plato, wrote theories on the origin of disease in his work the *Timeaus*. —G. E. R. Lloyd, editor’s introduction to *Hippocratic Writings*.

Hippocrates wrote three books on epidemics; this excerpt is taken from Book 1 and deals with the fever he calls *causus*.

Epidemics, Book I

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13. A little before the rising of Arcturus and during its season there were many violent rainstorms in Thasos accompanied by northerly winds. About the time of the equinox and until the settling of the Pleiads, the winds were southerly, so little rain fell. The winter was northerly with periods of drought, cold, high winds, and snow. There was very severe storms at the time of the equinox. The spring was northerly, dry, with a little rain, and it was cold. There was a little rain at the time of the summer solstice but instead a severe cold spell set in and lasted till the [rising of the] Dog Star. Thence, until the [rising of] Arcturus, the summer was hot. This hot spell began suddenly and was both continuous and severe. There was no rain and the etesian winds began and continued until the equinox.

14. Under such circumstances, cases of paralysis started to appear during the winter and became common, constituting an epidemic. Some cases were swiftly fatal. In other respects, health remained good. Cases of *causus* were encountered early in the spring and continued past the equinox towards the summer. Most of those who fell sick in the spring or at the very beginning of summer recovered, though a few died. In the autumn, when the rains came, the disease was more fatal and the majority of those that took it died.

It was a peculiarity of *causus* that a good copious epistaxis often proved a cure, and I do not know of any in these circumstances who died if they had a good epistaxis. For Philiscus, Epameinon and Silenus had a small epistaxis on the fourth and fifth days; they died. Most of those who were sick had shivering attacks about the time of the crisis, especially those who did not have epistaxis. Such patients also had attacks of sweating.

15. Some cases of *causus* developed jaundice on the sixth day and these were assisted by the evacuation of urine, abdominal disturbance or by a profuse hemorrhage, such as Heracleides (who lay at Aristoclydes’ house) had. Moreover in this case he did not only have epistaxis but trouble in the belly and diuresis as well. He reached a crisis on the twentieth day. The
servant of Phanagras was not so lucky; he had none of these things happen to him and he died.

Most patients suffered from hemorrhage and especially was this the case in youths and young men. Indeed, of the latter who did not have a hemorrhage, most died. In older people the disease turned to jaundice or their bellies were upset, as was the case of Bion, who lay at Silenus' house. During the summer dysentery became epidemic and those who had not recovered by that time had their sickness end up as a sort of dysentery, even when they had a hemorrhage. This happened to Myllus and to Erato's slave, whose illness, after a copious hemorrhage, turned to a sort of dysentery; they survived.

In fact, in this disease, this fluid was peculiarly abundant. Even those who did not bleed about the time of the crisis suffered pain and passed thin urine at this time and then began to bleed slightly about the twenty-fourth day, and there was pus mixed with blood. In the case of Antiphon the son of Crito this finally ceased and the ultimate crisis was reached about the fortieth day. Such cases showed hard swellings near the ears which absorbed and were followed by a heaviness in the left flank and in the region of the iliac crest.

16. Many women were sick, but fewer women than men, and the disease in them was less fatal. Childbirth was often difficult and was followed by disease. These cases were specially fatal as, for instance, in that of the daughter of Telebulus, who died on the sixth day after giving birth. In most cases, bleeding from the womb occurred during the fever and in many girls it occurred for the first time, but some had epistaxis. In some cases both bleeding from the womb and epistaxis were observed. For instance, the daughter of Daithares who was a virgin not only had uterine bleeding for the first time then but also had a violent discharge of blood from the nose. I know of no case which proved fatal if either of these complications ensued. So far as I know, all who fell ill while pregnant aborted.

17. Generally, in this disease, the urine was of good color but thin with a slight sediment. The belly was disordered, the stools being thin and bilious. In many cases, after a crisis had been reached for other disorders, the malady ended up as dysentery, as happened to Xenophanes and Critias. I will record the names of those patients who had watery, copious and fine urine, even after a crisis, with a healthy sediment, and who had a favourable crisis in other respects too. They were Bion, who lay at the home of Silenus; Cratis, who was at the Xenophanes; the slave of Areto, and the wife of Mnæsistratus. All these subsequently suffered from dysentery.

About the time of Arcturus many reached the crisis on the eleventh day and they did not suffer the expected relapses. About this time, especially in children, the malady was associated with coma and these cases were the most rarely fatal of all.

18. *Causus* lasted on to the equinox, up to the setting of the Pleiads, and
even into the winter. But at this time brain fever became prevalent and most of its victims died. A few similar cases were also seen during the summer. Those suffering from fever of the causus type which proved fatal showed certain additional symptoms even at the beginning of the illness. High fever attended the beginning of the illness along with slight shivering fits, insomnia, thirst, nausea, and a little sweating about the forehead and over the clavicles (in no cases all over), much delirium, fears, and despondency, while the extremities such as the toes were chilled, but especially the hands. Paroxysms occurred on even days. Generally, pain was greatest on the fourth day and the sweat was cold. Their extremities did not regain warmth but remained cold and livid, and they no longer suffered from thirst. They passed little urine, which was black and fine, and became constipated. In none of these cases was there a discharge of blood from the nose but only a few drops. Nor did these cases show any remission but died on the sixth day, sweating. Those patients who developed brain fever had all the above symptoms, but the crisis usually took place on the eleventh day. Where brain fever was not present at the beginning but appeared on the third or fourth day, the crisis did not take place until the twentieth day. In these the illness was moderate in its severity first but became severe about the seventh day.

19. The disease was very widespread. Of those who contracted it, death was most common among youths, young men in the prime of life, among those with smooth skins, those of a pallid complexion, those with straight hair, those with black hair, those with black eyes, those who had been given to violent and loose living, those with thin voices, those with rough voices, those with lisps and choleric. Many women also succumbed to this malady. During this epidemic there were four signs which betokened recovery: a considerable epistaxis, a copious discharge of urine that contained a lot of favorable sediment, biliousness and disorders of the belly coming on a favourable crisis, or if there were dysentery ....

If a patient weeps in spite of himself in acute fever of the type of causus, you must expect an epistaxis, even if there is no reason to expect a fatal outcome. If a patient be poorly, it portends not hemorrhage but death ....

23. The factors which enable us to distinguish between diseases are as follows: First we must consider the nature of man in general and of each individual and the characteristics of each disease. Then we must consider the patient, what food is given him and who gives it—for this may make it easier for him to take or more difficult—the conditions of the climate and locality both in general and in particular, the patient's customs, mode of life, pursuits and age. Then we must consider his speech, his mannerisms, his silences, his thoughts, his habits of sleep or wakefulness and his dreams, their nature and time. Next, we must note whether he plucks his hair, scratches or weeps. We must observe his paroxysms, his stools, urine, sputum, and vomit. We look for any changes in the state of his malady, how often such changes occur and their nature, and the particular changes which
induce death or a crisis. Observe too, sweating, shivering, chill, cough, sneezing, hiccup, the kind of breathing, belching, wind, whether silent or noisy, hemorrhages and hemorrhoids. We must determine the significance of all these signs.

Exercises

1. Stipulative Definition

In the previous chapter on definition, you learned how to write three kinds of definition. These definitions were used to offer an observation about a thing or event in the world; those definitions were used for items which had a determinant reference in the world. But sometimes you will find that you encounter a phenomenon for which you have no referent, although the person writing the description or the report had a clear idea of what he or she saw. In such cases, you cannot construct a definition based on what you know; you must proceed in a different manner by considering what the word means in the context of the writing. When you define a word by the meanings which accrue to it through context, you write a Stipulative Definition. A stipulative definition explains the way that meaning is stipulated through the writing. While you may think you know what the person describes, you may not be entirely sure. Write a definition on the basis of text rather than on the basis of reference to a known event or object in the world.

Causus is such a term. Some people think that Hippocrates was blending descriptions of different illnesses when he used the word causus. Read the passage from Hippocrates again and write an extended stipulative definition for causus. Organize your description using the techniques you have already learned and which are listed in the Definition section. Consider the cause, the spread, and the symptoms of the disease. Consider also what Hippocrates means by the crisis.

2. Comparison/Contrast

Hippocrates claims that it is important to consider aspects of the person in the pathology of the disease. He notes that the disease leads most commonly to death among those with thin voices, those with rough voices, etc. Look at all the passages in which Hippocrates deals with the personal life of the patient, not only in his description of the pathology but also in his list of those who died.

Analyze the role of the individual in the pathology of disease according to Hippocrates; then read Fracastoro and do the same for him. Finally, write an essay in which you compare/contrast the significance of the individual person in the spread of disease. Would Thucydides' account of the plague of Athens be closer to Hippocrates or to Fracastoro?

3. Inference

Read Hippocrates' account carefully and then write an essay in which you explain what model of diseases underlies his description. Unlike Fracastoro, he does not rely upon the germ model of disease. How would you characterize Hippocrates' assumptions about what causes disease? What is the connection between weather and disease?
The Plague of Athens

Thucydides
(c. 460–400 B.C.)

The following excerpt, "The Plague of Athens" (430 B.C.), is taken from Thucydides' history *The Peloponnesian War*. Thucydides was a general on the Athenian side against Sparta. He fell ill of the plague but later recovered. Thucydides was a careful observer, and even though he would not have possessed knowledge of the germ theory of disease (diseases are spread by infectious organisms), his description has much merit. —Thucydides, *History of the Peloponnesian War*, trans. Rex Warner (New York: Viking Penguin Books, 1985), pp. 152–55.

The plague originated, so they say, in Ethiopia in upper Egypt, and spread from there into Egypt itself and Libya and much of the territory of the King of Persia. In the city of Athens, it appeared suddenly, and the first cases were among the population of Piraeus. . . . As to the question of how it could have first come about or what causes can be found adequate to explain its powerful effect on nature, I must leave that to be considered by other writers, with or without medical experience. I myself shall merely describe what it was like, and set down the symptoms, knowledge of which will enable it again to be recognized, if it should ever break out again. I had the disease myself and saw others suffering from it.

That year, as it is generally admitted, was particularly free from all other kinds of illness, though those who did have any illness previously caught the plague in the end. In other cases, however, there seemed to be no reason for the attacks. People in perfect health suddenly began to have burning feelings in the head; their eyes became red and inflamed; inside their mouths there was bleeding from the throat and tongue, and the breath became unnatural and unpleasant. The next symptoms were sneezing and
hoarseness of voice, and before long, the pain settled on the chest and was accompanied by coughing. Next the stomach was affected with stomach-aches and vomitings of every kind of bile that has been given a name by the medical profession, all this being accompanied by great pain and difficulty. In most cases there were attacks of ineffectual retching, producing violent spasms; this sometimes ended with this stage of the disease, but sometimes continued long afterward. Externally, the body was not very hot to the touch, nor was there any pallor: the skin was rather reddish and livid, breaking out in small pustules and ulcers. But inside there was a feeling of burning, so that people could not bear the touch even of the lightest linen clothing, but wanted to be completely naked, and most of all would have liked to plunge into cold water. Many of the sick who were uncared for actually did so, plunging into the water-tanks [cisterns] in an effort to relieve a thirst which was unquenchable; for it was just the same with them whether they drank much or little. Then all the time they were afflicted with insomnia and the desperate feeling of not being able to keep still.

In the period when the disease was at its height, the body, so far from wasting away, showed surprising powers of resistance to all the agony, so that there was still some strength left on the seventh or eighth day, which was the time when, in most cases, death came from the internal fever. But if people survived this critical period, then the disease descended to the bowels, producing violent ulcerations and uncontrollable diarrhea, so that most of them died later as a result of the weakness caused by this. For the disease, first settling in the head, went to affect every part of the body in turn, and when people escaped its worst effects, it still left its traces on them by fastening upon the extremities of the body. It affected the genitals, the fingers, the toes, and many of those who recovered lost the use of those members. There were some also who, when they first began to get better, suffered from a total loss of memory, not knowing who they were themselves and being unable to recognize their friends.

Terrible was the sight of people dying like sheep through having caught the disease as a result of nursing others. This indeed caused more deaths than anything else. Yet the ones who felt most pity for the sick and the dying were those who had the plague themselves and recovered from it. They knew what it was like and at the same time felt themselves to be safe, for no one ever caught the disease twice, or if he did, the second attack was never fatal.

A factor which made matters worse than they already were was the removal of people from the country into the city, and this particularly affected the in-comers. There were no houses for them, and living as they did during the hot season in badly ventilated huts, they died like flies. The bodies of the dying were heaped on top of the other, and half-dead creatures could be seen staggering about in the streets or flocking around the fountains in their desire for water. The temples . . . were full of the dead bodies of people who had died inside them. For the catastrophe was so over-
whelming that men, not knowing what would happen next to them, became indifferent to every rule of religion or law. All the funeral ceremonies which used to be observed were now disorganized, and they buried the dead as best as they could. Many people, lacking the necessary means of burial because so many deaths had already occurred in their households, adopted the most shameless methods. They would arrive first at a funeral pyre that had been made by others, put their own dead on it, and set it alight; or, finding another pyre burning, they would throw the corpse that they were carrying on top of the other and go away.

Reading Questions

a. How does Thucydides explain his reason for describing the plague?

b. Outline the course of the symptoms as they are described in the second paragraph. How does Thucydides organize his description? (By time, by space, from inside to outside; from outside to inside; from beginning to end?)

c. Although Thucydides' greater pattern of organization is arranged temporally—how the disease appears in time, from its onset in the patient to the patient's death—there are other patterns within this larger temporal account. Identify some of these patterns.

d. Consider what is missing from this description: What parts are left out? Why does he continue his description beyond the death of the patient? Why does he not describe an autopsy or a pathology report? Why does he not describe microbes or bloodwork?

e. What does Thucydides think caused the disease?

f. In most scientific reports, we expect the writer to remain objective, but Thucydides occasionally says things that indicate his personal view. Identify passages where Thucydides seems to make a subjective remark.

g. Thucydides suggests that the effects of the plague were intensified by the fact that it occurred within the city of Athens. How are the effects of the plague concentrated in the city? How do population dynamics affect its transmission?

h. What are the sociological effects of the disease? What happens to society as a consequence of the disease? What rituals or celebrations change? Let us suppose that you, like Thucydides or other Greeks, had no knowledge of the progress of the disease. How would you interpret this disaster in the city?

Exercises

1. Definition

You think that the plague which Thucydides describes might be either typhoid
or typhus. When you look up the definition for these diseases, you find the following:

**Typhoid fever**: A highly infectious, septicemic disease of humans caused by *Salmonella typhi* which enters the body by the oral route through ingestion of food or water contaminated by contact with fecal matter.

**Typhus fever**: Any of three louse-born human diseases caused by *Rickettsia prowazakii* characterized by fever, stupor, headaches, and a dark-red rash.

Compare (contrast) these definitions with the passage. Do the definitions give sufficiently limiting criteria for you to identify the disease as one or the other? If these definitions are insufficient, look up the disease and complete the definition.

2. Formal Report

By this point, either in your notes or in your mind, you have compared and contrasted the characteristics of typhoid and typhus with the description of the plague in Athens.

Meanwhile, the Center for Disease Control has expressed interest in your diagnosis: The Center has requested that you send them a report of your comparison/contrast. Although the CDC will eventually want to see your entire report, they specifically asked you to fax them the "Discussion" section of your paper.

Write a "Discussion" section for a formal paper in which you identify the disease and explain your reasoning.
The Germ Theory of Disease

Girolamo Fracastoro
(1546)

An infectious (or contagious) disease is a process (not a thing) that occurs in a host as a result of an interaction with a parasite. The parasite isolated from the host is not the disease but merely the potential causer of the disease. The disease itself is a complex interaction between parasite and host. With a given host and a given parasite, under the usual environmental conditions, a given disease usually arises. This disease is recognized in the host because of certain symptoms which become evident to an observer. In many, if not most cases, two hosts of the same species usually exhibit similar symptoms when infected with a given parasite. Because of this, we can recognize the same disease in several or many individual hosts.

It was only these symptoms which were available to early observers. They had no knowledge of microorganisms, and even little knowledge of the nature of the host. But because a number of diseases, such as syphilis, plague, tuberculosis, small pox, usually had characteristic symptoms, it was possible to observe these diseases in populations of individuals. By such observation, it was possible to infer these diseases were transmitted from person to another. Remember that the agency of this transfer was unknown. It was merely known that a transfer occurred.

Fracastoro's writing are mainly philosophical and he attempts to define the subject in terms of the ideas of the day. Even though his discussions seems crude by current standards...[they come] close...to hitting the nail on the head...

This paper was written in Latin. It is interesting that Fracastoro uses a word for the infectious or contagious principle which can best be translated in English as "germ."...His statement that these germs generate and propagate other germs is prophetic although not based on direct observation. Finally, his attempt to find a similarity between putrefaction and contagion is noteworthy because it was this very similarity which led later workers, such as Henle, Lister, Pasteur, and Koch, to consider seriously the germ theory of disease. —Thomas Brock, editor and translator Milestones in Microbiology (Washington, D.C.: American Society for Microbiology, 1961), pp. 69–85.
What Is Contagion?

I shall now proceed to discuss Contagion, and shall begin with what seem to be its universal principles from which are derived its particular causes. As its name indicates, contagion is an infection that passes from one thing to another. The infection is precisely similar in both the carrier and the receiver of the contagion; we say that contagion has occurred when a certain similar taint has affected them both. So, when persons die of drinking poison, we say perhaps that they were infected, but not that they suffered contagion; and in the case of things that naturally go bad when exposed to the air, such as milk, meat, etc., we say that they have become corrupt, but not that they have suffered contagion.

Everything that happens, whether actively or passively, affects the essential substance of bodies or their non-essential parts. When someone has been heated or sullied by something, we do not say, except by metaphor, that he has suffered a contagion; because contagion is precisely a similar infection of the actual cause. Now when a house catches fire from the burning of a neighboring house, are we to call that contagion? No, certainly not, nor in general when a whole thing is destroyed primarily as a whole. The term is more correctly used when infection originates in very small imperceptible particles, and begins with them, as the word “infection” implies; for we use the term “infected,” not of a something that is destroyed as a whole, but of a certain kind of destruction that affects its imperceptible particles. By the whole, I mean the actual composite, and by very small, imperceptible particles, I mean the particles of which the composite and mixture (combination) are composed. Now burning acts on the thing as a whole, whereas contagion acts on the component particles, though by them the whole thing itself may presently be corrupted and destroyed.

Contagion, then, seems to be a certain passive effect of elements in combination. But since such combinations can be corrupted and destroyed in two ways, either by the advent of a contrary element, owing to which the combination cannot retain its form or secondly by the dissolution of the combination, so happens when things have putrefied, we may perhaps hesitate to say whether contagion, when it is carried by the infection of the smallest particles, is produced in the former way or the latter. Moreover, what shall we say is the nature of this infection? Is it a corruption of those particles, or only an alteration? What, in short, happens to those particles? Hence it is hard to determine whether every contagion is a kind of putrefaction. All these problems will become clearer if we first investigate the fundamental differences of contagions and their causes. Meanwhile, if we allow ourselves to sketch a sort of tentative definition of contagion, we shall define it as: A certain precisely similar corruption which develops in the substance of a combination, passes from one thing to another, and is originally caused by infection of the imperceptible particles.
The Fundamental Difference in Contagions

There are, it seems, three fundamentally different types of contagion: the first infects by direct contact only; the second does the same, but in addition, leaves fomes, and this contagion may spread by means of these fomes, for instance scabies, phthisis [tuberculosis], bald spots, elephantiasis, and the like. By fomes, I mean clothes, wooden objects, and things of that sort, which though not themselves corrupted can, nevertheless, preserve the original germs of the contagion and infect by means of those; thirdly, there is a kind of contagion which is transmitted not only by direct contact or by fomes as intermediary, but also infects at a distance; for example, pestilent fevers, phthisis, certain kinds of ophthalmia, exanthemata of the kind called variolae [small pox], and the like. These different contagions seem to obey a certain law; for those which carry contagion to a distant object infect both by direct contact and by fomes; those that are contagious by means of fomes are equally so by direct contact; not all of them are contagious at a distance, but all are contagious by direct contact. Hence the most simple kind of contagion is that of direct contact only, and it is naturally the first in order. . . .

Contagion That Infects by Contact Only

An especially good instance of the contagion that infects by contact only is that which occurs in fruits, as when grape infects grape, or apple infects apple; so we must try to discover the principle of this infection. It is evident that they are infected because they touch; and that one fruit decays first, but what is the principle of the infection? Since the first fruit from which all infection passes to the rest has putrefied, we must suppose that the second has contracted a precisely similar putrefaction, seeing that we defined contagion as a precisely similar infection of one thing by another. Now putrefaction is a sort of dissolution of a combination due to evaporation of the innate warmth and moisture. The principle of that evaporation is always foreign heat, whether that heat be in the air or in the surrounding moisture; hence, in both fruits, the principle of contagion will be the same as the principle of putrefaction, namely extraneous heat; but this heat came to the first fruit either from the air or some other source; and we may not yet speak of contagion; but the heat has passed on to the second fruit by means of those imperceptible particles that evaporate from the first fruit, and now there is contagion, since there is a similar infection in both fruits; the heat that evaporates from the first fruit has power to produce in the second fruit what the air produced in the first, and to make it putrefy in a similar way, all the more because there is analogy. Now some of the particles that evaporate from the first fruit are hot and dry, either independently or when in combination. Those that are hot and dry are more apt to burn the fruit, whereas those that are hot and moist are more apt to produce putrefaction.
and less apt to burn. For the moisture softens and relaxes the parts of the fruit that it touches, and makes them easily separable, while the heat lifts them up and separates them. Hence when heat and moisture are produced within and evaporate, the result is dissolution of the combination, and this was our definition of putrefaction. We must therefore suppose that the hot moist particles—moist either independently or in combination—that evaporate from the first fruit, are the principle and germ of the putrefaction that occurs in the second fruit. I use the term "moist in combination," because, in evaporations that occur in putrescent bodies, it nearly always happens that very small particles are intermingled, and thus become principles of certain generations and of new corruptions; and this combination of hot and moist particles is most apt to convey putrefaction and contagions. We must therefore suppose that it is by means of these principles that contagion occurs in fruits. But in all other bodies also that are in contact and putrefy, if they are analogous to one another, it is reasonable to suppose that the same thing happens, and by means of the same principle. Now the principle is those imperceptible particles, which are hot and sharp when they evaporate, but are moist in combination. In what follows, they are called Germs of Contagion.

Contagion That Infects by Fomes

Now it is at once obvious that the germs that transmit contagion by means of fomes are produced in the same manner and by the same principle as that above described, for the principle that exists in fomes seems to be of a different nature, inasmuch as, when it has retired into the fomes from the body originally infected, it may last there for a very long time without any alteration. Things that have been touched by persons suffering from phthisis or the plague are the most amazing examples of this. I have often observed that in them this virus has been preserved for two or three years; whereas particles that evaporate from putrefying bodies never seem to have the power to last as long as that. Nevertheless no one ought to think that the principle of contagion that is in the fomes is not the same as the principles that infect by contact only, because the very same particles that evaporate from the body originally infected, after being thus preserved, can produce the same effect as they would have done when they evaporated from the original body. . . . Now a combination is strong and lasting in virtue of two qualities; first, it must have the kind of hardness possessed by iron, stones, and the like, whose very small, imperceptible particles last for many years; secondly there must be present a certain viscosity, and the mixing process must be thoroughly elaborated. So that even when the germs of contagion are not hard, they be viscous and elaborated. By an elaborated combination I mean one composed of very small particles well shaken together. . . . Combinations of this sort are produced by evaporations that
are closely confined, where what evaporates is not dispersed, but is vio-
lently shaken, and hence is very finely and minutely mixed. Now if viscosi-
be added, the resulting combination is strong and suitable for its preserva-
tion in fomes. A proof of this is that all germs that infect by means of fomes
are without exception viscous and sticky, and only when they have this
quality can they occupy fomes. . . .

Contagion at a Distance

Even more surprising and hard to explain are those diseases that cause
contagion, not by direct contact only or by fomes only, but also at a distance.
There is a kind of ophthalmia with which the sufferer infects everyone who
looks at him. It is well-known that pestiferous fevers, phthisis, and many other
diseases infect those who live with the sufferer, even though there is no actual
contact. It is far from certain what is the nature of these diseases, and how the
taint is propagated. We must therefore study these problems with the greatest
care, since of this sort are the majority of the diseases we are investigating.

How the Germs of Contagion Are Carried to a Distant Object and in
a Circle

Let us first enquire by what sort of movement these germs of contagion are
impelled, since it is clear that they are carried far and to persons far distant,
a fact that many people find astonishing. . . . Now the principle of movement
in these small bodies, in all directions, is in part independent, in part given
by something else. All the evaporation independently rises upwards, as
may be seen in smoke and many other things, for everyone knows that all
evaporation is warm; but the movement may be derived from something
else, and then the thrust is sideways and finally downwards. This is due to
two main causes, one being the resistance of the air or of the floors, the
things of that sort on which the particles that are first exhaled; when these
particles cannot be carried further, they are thrust sideways by the particles
that follow them, and these by others, till the whole surrounding space is
filled. The second cause is the air itself which divides into its small and
indivisible parts all evaporation that is tenuous and easily soluble. For it is
the nature of elements and of all liquids that they seek, so far as it is possible,
a suitable position; and a position is most suitable when the parts are
continuous, or if not continuous, are the least possible distance apart from
one another; for thus they are less exposed to violence . . . Hence the air
keeps on dividing the evaporation more and more, until it arrives at those
parts which cannot be further divided and separated. Then when this
countless division has been made, much of the air is filled and mingled with
the evaporation all round and about, as is most evident in the case of smoke.
These then are the reasons why the evaporations that occur in contagions
are also carried around and about, and occupy a great volume in the air. . . .
Thus it is that these germs may infect also those who live with persons infected, and the germs can be preserved for a certain time, not only in fomes but also in the air, though no longer in fomes.

But how does it happen that germs whose bulk is so small do not suffer alteration, when thus exposed to the air? That is the first question. What must be the strength of the combination in so small a particle, especially when those particles have not the quality of hardness that they can last so long in the air? It is those that are viscous and sticky. However small that they may be, they can live, if not quite so long as the hard ones, still nearly as long.

The hard particles offer most resistance to alterations, because of three properties. First, in a small bulk they have more substance; secondly, they are colder, on account of their earthy elements; thirdly, by reason of their density, their parts cannot be easily volatilised and rarefied as ought to happen when heat is introduced. . . . [H]ard but also viscous bodies, defend themselves from many alterations, if only these are moderate; but they cannot endure violent alterations. Hence the germs of all contagions are consumed by fire, and are broken up by very cold water also. . . .

Of such sort are the germs of contagions also, for they are all per se acute, although constituted in viscosity, and they become active when the animal heat vaporises that combination and brings together the similar parts. Now germs of this kind have great power over the humors and spirits, so that they can even cause death in a few hours if they are analogous with the spirits, but about this I will say more later. These same germs can be shot forth from sore eyes into the eyes of another and carry in a precisely similar infection, and this is not a visual image but a taint in the eye. It is not surprising, if one considers the method by which they attack, that they penetrate into the animal, and some of them very quickly, for they attack and enter from the small pores, veins, and arteries into the larger, and from these to others and often reach to the heart.

One method of penetration is by propagation, and so to speak, progeny. For the original germs, which have adhered to the neighboring humors with which they are analogous, generate and propagate other germs precisely like themselves, and these in turn propagate others, until the whole mass and bulk of humors is infected by them. A second method of penetration is by attraction, which works inwardly, partly through the breath of inspiration, partly by the dilation of blood vessels. For along with the air that is drawn in, there enter, mixed with it, germs of contagions, and when once these have been introduced, they do not retire as easily by expiration as they entered by inspiration; for they adhere closely to the humors and organs, and some of them even to the spirits, which retreat from the image of their contrary, and carry their enemy with them even to the heart. . . .

The Analogy of Contagions

Contagions have manifold and very surprising analogies [selective prop-
properties. For instance, there is a certain pest which attacks trees and crops, but harms no sort of animal; again there is a pest which attacks certain animals but spares trees and crops. In the animal world, one pest will attack man, another cattle, another horses and so on. . . . Some pests work promiscuously, so that some persons are infected, others not; some persons can associate with the plague-stricken and take no hurt, others can not. The organs of the body also have their own analogy (affinity), for ophthalmia harms no organ save the eyes, while phthisis does not affect the eyes, though they are so delicate, but does affect the lungs. . . .

Is Every Contagion a Kind of Putrefaction?

Now let us enquire whether every kind of contagion is a kind of putrefaction, and whether every putrefaction is contagious. It seems that every putrefaction is contagious, either absolutely, or at least contagious to a contiguous part, but not every putrefaction is contagious for another body, since, in order that it may act, many factors are required, as I have said. Perhaps one may doubt whether every contagion consists in putrefaction of some sort; since rabies seems to be contagion of a sort, but not putrefaction. Likewise, when wine turns to vinegar, it seems to suffer a sort of contagion by something else, but not to suffer putrefaction. For when it putrefies it has a bad smell and is unfit to drink, whereas vinegar is pleasant to taste and even opposes putrefaction. Yet these cases must also be regarded as putrefactions of a sort. . . .

Now all putrefactions have the power to convey precisely similar putrefaction, at least to a continuous part; hence, if every contagion is putrefaction, it seems that contagion, simply and generally speaking, might be defined as: A certain precisely similar putrefaction which passes from one thing to another, whether that other be continuous with the original thing or separated from it. Yet this is not contagion strictly so called, for true contagion occurs between two different bodies. But if we wish to consider, above all and by itself, that contagion which is observed in diseases and does not affect by direct contact only, then we shall define contagion as: A precisely similar putrefaction which passes from one thing to another; its germs have great activity; they are made up of a strong and viscous combination; and they have not only material but also a spiritual antipathy to the animal organism. This definition will give us the key to all the phenomena that are observed in contagion.

Exercises

1. Definition

Look up the word germ. Where does Fracastoro get the term? Write an extended definition of this term. Go beyond this essay in your definition.
2. Stipulative Definition

Write a sentence definition for contagion, and use that as the basis to write a stipulative definition of the term. For this assignment, you should stay entirely within the text of this essay.

3. Comparison/Contrast

Write an essay that compares/contrasts infection and putrefaction. You may do further research into the historical background of these terms.

4. Analysis

Using both Hippocrates' and Thucydides' writing as a point of contrast, discuss the significance of a germ theory of disease.
A *Contagium vivum fluidum* as the Cause of the Mosaic Diseases of Tobacco Leaves

Martinus W. Beijerinck
(1899)

The general term for a living infectious agent which had been used for years was "virus." Any infectious agent was described with this word. Although many infectious diseases were easily shown to be caused by bacteria, it was not always possible to do so. Sometimes it was possible to transmit a disease from host to host even after the infectious fluid was filtered through pores so small that all bacteria were removed. When it could be shown that this agent could pass through a filter, then reproduce in a new host, and, after being filtered again, infect another host, it was obvious that here was a living agent. Beijerinck called this a "liquid" (or fluid, that is non-particulate) living agent of disease. Others called these "Filterable viruses." Gradually the word "virus" became restricted to filterable viruses, so that now that adjective filterable has been dropped. We know now that these viruses are particulate, and since [Wendell] Stanley succeeded in crystallizing one, we know that they are quite unlike other living organisms, so that many refused to consider them living. —Thomas Brock, editor and translator, *Milestones in Microbiology* (Washington, D.C.: American Society for Microbiology, 1961), p. 6.

Although Beijerinck was wrong about the diffusibility of the tobacco mosaic virus, the rest of his observations are quite valid. He describes an agent which can pass through the smallest filters, can apparently reproduce only in the living plant and seems quite stable. In attempting to explain these observations, he finds himself in a dilemma since the physiological and biochemical facts of cell function were not yet available for him to use in explaining his observations. It is interesting that he comes as close to hitting the nail on the head as he does. His postulate that the virus becomes incorporated through living protoplasm of the host plant is one which is about as close to current thinking on virus multiplication as it would be possible to get in 1899. . . . He shows that the amount of virus...
in a filtrate could be crudely quantitated. This is an important area in virus research, since it is necessary to have some idea of how much infectious material is present in a sample. (Comment on Beijerinck, *Milestones in Microbiology*, p. 157.)

The leaf spot disease of tobacco, also called the mosaic disease, is manifested first as a bleaching of the chlorophyll, occurring in spots over the leaf blade. This is followed later by the death of a part or all of the tissue of the spots. The discoloration appears first right next to the leaf veins and it is manifested then by a strong increase in the amount of chlorophyll. Later the spaces between the spots become bleached usually to a yellow color, but in isolated cases, they become completely albino. The dark green patches grow at the beginning more rapidly than the other parts of the leaf, leading to wart-like growths which arise from the upper surface of the leaf. However, this phenomenon is observed more often in artificial infections than in tobacco fields, where the diseased leaves usually remain completely flat.

The third phase of the disease consists of localized death of the hundred or thousand small spores which are distributed randomly over the leaf. These then assume a brown color and become very fragile, so that the holes are formed easily during the harvest of the leaves. These spots are the fear of the Dutch tobacco farmer, because they make the leaf worthless for cigar wrappers.

Herr Adolf Mayer showed in 1887 that this disease was contagious. He expressed the sap from sick plants, placed it in capillary tubes and stuck these in healthy plants. He found that after 2-3 weeks, the latter plants became diseased.

In 1887 I attempted to discover if there was not a parasite which could be demonstrated to be the cause of the disease. Since microscopic studies were completely negative, the only type of bacteria that could be considered were those which could not be observed directly. But culture procedures showed that aerobic bacteria were completely absent, either from the healthy or the diseased plants. I later showed that anaerobic bacteria were also absent.

It seemed certain, therefore, that we were dealing here with a disease which was caused by a *contagium* which was not a *contagium fixum* in the usual sense of the words. This encouraged me to carry out new experimental infections in 1897 and 1898, in order to understand the properties of the *contagium* better. I would like to present here briefly the main results which were obtained from these studies.

It was first shown that the juice expressed from sick plants did not lose its virulence even after being filtered through a porcelain filter so fine that it rendered the juice completely sterile. This filtrate was tested for the
presence of both aerobes and anaerobes, so that the experiment was com-
pletely unobjectionable. This filtrate was kept three months and remained 
completely bacterial free during this time but was repeatedly shown to 
induce the identical mosaic when inoculated into plants. I do not know how 
long the virulence of this filtrate can be maintained.

The following experiments were designed to answer the question as to 
whether the virus should be considered particulate or soluble.

Pulverized tissue of diseased leaves was spread on thick agar plates 
and diffusion allowed to occur. A virus which was particulate would remain 
on the surface of the agar since it could not diffuse into the molecule-sized 
pores of the agar plate. The deep layers of the agar would thereupon become 
virulent. But a water soluble virus ought to be able to penetrate to a certain 
depth in the agar plate. The experiment was discontinued after a diffusion 
time of about ten days, what would be considered to be long enough, since 
I knew that diptase trypsin would diffuse in a considerable extent in this 
time. The upper surface of the plate was first washed with water and then 
with a strong solution of mercuric bichloride. After this, a sharp platinum 
needle was useful to remove part of the agar, so that the inner layers could 
be reached, care being taken not to disturb the upper surface. Healthy plants 
were then infected with agar from these deep layers. The infection was just 
as extensive with this material as when the sterile filtrate was used. It can 
hardly be doubted, therefore, that the contagium must be considered to be 
fluid, or more accurately, water soluble.

The experimental infections using plant juices were performed using 
the hypodermic needle of Pravaz. The most suitable place to infect is the 
youngest part of the stem which can be manipulated easily without causing 
extensive damage, since the closer the infection is to the meristem of the 
terminal bud, the earlier the results are seen. It has been shown that the 
virus moves slowly through the plant, and further, that only the portions 
of the young leaves that are undergoing cell division are sensitive to the 
infection. Both the mature leaves as well as the young leaves in which the 
cells have already stopped dividing are completely insensitive to the virus, 
even though they are able to transport it towards the meristematic regions. 
If stem internodes that are enlarging are infected, after 10–12 days the first 
symptoms of the disease can be observed in the young leaves which are 
coming out of the apical meristem. However, if an infection is carefully 
made as close as possible to the apical meristem, even after 3–4 days, yellow 
spots and crisp distorted areas can be observed in the youngest little leaves 
that are still within the bud.

The amount of virus which is sufficient to infect a large number of 
leaves is quite small. It is then possible to obtain material from these 
diseased leaves which can be used to infect unlimited numbers of new 
plants. It is therefore quite clear that the virus is reproducing within the 
plant. From the above, it is clear that this reproduction is not in the mature 
plant cells but in those tissues where cell division is occurring.
Although the virus can exist outside the tobacco plant, it cannot reproduce under these conditions. I conclude this from the following fact: If a sterile filtrate of virus is mixed with a healthy tobacco plants, it can be determined by experimental infections that no reproduction of the virus is obtained. Instead the virus is diluted in the same way as if pure water had been used instead of plant sap.

It is not difficult to determine the accuracy of this statement, since the amount of virus used to infect plants has been a great influence on the development of the symptoms of the mosaic disease. With a small amount of virus, the usual results are obtained as described above. With large amounts of virus, highly-deformed leaves of characteristic shapes are obtained. In order to obtain these deformed leaves, it is necessary to inject much more of a diluted virus than of one not diluted. In this way, it is easy to tell whether the virus has reproduced or stayed the same in any type of fluid. As mentioned above, I have not observed reproduction under artificial conditions, so that I believe the only model of reproduction of the virus is in the cells of the plants that are dividing.

The ability of the virus to reproduce only when combined with living protoplasm of the host plant maybe related to its soluble or liquid nature. It is not easy to understand why a *contagium fixum*, even if so small that it could not be seen by direct microscopic examination, could not still reproduce away from the host, like ordinary parasitic bacteria. In addition, it would seem probable that a microscopically invisible *contagium*, if particulate, could develop into macroscopically visible colonies on gelatin plates.

A soluble and diffusible virus, such as the mosaic virus, should bring about some coloration or change in refractive index of a gelatin or sugar medium, if the chemical nature of the medium were altered when used as a nutrient by a reproducing virus. Such changes could not be seen when the virus was seeded onto malt extract gelatin or onto plates containing 10 per cent gelatin dissolved in a plant decoction containing 2 per cent cane-sugar, both excellent media in my hands for the growth of parasitic and saprophytic plant bacteria. It also seems to me that reproduction or growth of a soluble body is not inconceivable, although difficult to imagine. It would not seem wise to assume a division process of molecules which would lead to their reproduction, and the idea of molecules which feed themselves, which much be assumed to explain this, seems to me an unclear concept, if not actually contrary to nature.

A partial explanation would be the view that the *contagium* must be incorporated into the living protoplasm of the cell in order to reproduce, and its reproduction is so to speak passively brought about with the reproduction of the cell. But this would then leave us with one mystery instead of two, since the incorporation of a virus into living protoplasm, even if it is shown to be a fact, can in no way be viewed as an understandable process.

If the soil in which a tobacco plant is growing is infected with the virus,
after a time the disease is seen to appear in the apical bud. The length of
time for its appearance is primarily dependent on the size of the plant. In
young plants, I saw the first symptoms in two weeks, while in larger and
older individuals, 4–6 weeks occurred before the symptoms appeared in
the newly formed leaves of the terminal meristem. Therefore the roots and
stem must be able to transmit the virus considerable distances.

It is possible to infect the plants through the roots only when they are
two or more decimeters high. It is uncertain whether wounds in the roots
are necessary, or whether the uptake of the virus can occur through surface
contact at the root. Since the *controagium* can only attack the leaves that form
after the infection begins, the number of healthy leaves below the infected
ones can be used to approximate the time of infection in plants growing
naturally which have taken up the virus through their roots.

The virus can be dried without a change in its virulence. It could
therefore overwinter in soil, where it perhaps would be partially destroyed
like so many bacteria and yeast.

An alcohol precipitate of virulent plant juice, dried at 40 degrees C.,
retained its virulence.

The virulence is also maintained in dried leaves, so that two-year old
herbarium leaves are still suitable for experimental infections. Therefore the
dried dust which forms easily during the harvest from the broken dead
tissue of the leaf spots must undoubtedly be able to spread the disease.

As expected in a moist environment, the virus was inactivated by
boiling water, as well as at 90 degrees C. I have not determined the lowest
temperature at which activation would occur but would expect it would
between 70 and 80 degrees C.

It is possible that there are a whole series of plant diseases which are
caused by *controagium fluidum*, in a similar manner to the mosaic disease of
tobacco plants. The diseases of peach trees described in America by Erwin
Smith sometime in 1894 under the names peach yellows and peach rosette
seem, from his description, undoubtedly to belong here, although it is not
yet certain if these diseases can be transmitted only through budding and
grafting, as he describes, or, what is more likely, they can also be transmitted
through the juice of the dead tissues.

Exercises

1. Describe the phases of the tobacco mosaic disease.
2. Though not phrased as a question, define the research question which directs
   the formulation of Beijerinck's hypotheses.
3. Identify the hypotheses.
4. Describe the series of experiments. Distinguish between Beijerinck's descriptions
   of past research and present research. Make a clear statement about how the
   experiments are connected as whole.
5. Identity conclusive results. How does Beijerinck explain his results?

Notes

Molecular Structure of Nucleic Acids
A Structure for Deoxyribose Nucleic Acid*

J. D. Watson and F. H. Crick

We wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey. They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons: (1) We believe the material which gives the X-ray diagrams is the salt, not the free acid. Without the acidic hydrogen atoms it is not clear what forces hold the structure together, especially as the negatively charged phosphates near the axis will repel each other. (2) Some of the van der Waals distances appear to be too small.

Another three-chain structure has been suggested by Fraser (in the press). In his model, the phosphates are on the outside and the bases on the inside, linked together by hydrogen bonds. This structure as described is rather ill-defined, and for this reason, we shall not comment on it.

We wish to put forward a radically different structure of the salt of deoxyribose nucleic acid. This structure has two round helical chains each coiled round the same axis (see diagram).

We have made the usual chemical assumptions, namely, that each chain consists of phosphate diester groups joining β-D-deoxyribofuranose residues

The DNA molecule: (A) diagrammatic model of the double helix showing the pairing of A in one strand with T in the other and of G in one strand with C in the other; (b) space-filling model of the DNA double helix. Each DNA strand winds around the other with the base pairs bridging between the strands.

with 3', 5' linkages. These two chains (but not their bases) are related by a dyad perpendicular to the fibre axis. Both chains follow right-handed helices, but owing to the dyad, the sequences of the atoms in the two chains run in opposite directions. Each chain loosely resembles Furbeg's model No. 1; that is, the bases are on the inside of the helix and the phosphates on the outside. The configuration of the sugar and the atoms near it close to Furbeg's 'standard configuration,' the sugar being roughly perpendicular to the attached base. There is a residue on every chain every 3-4 Å in the z-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats itself after 10 residues on each chain, that is, after 34 Å. The distance of a phosphorus atom from the fibre axis is 10 Å. As the phosphates are on the outside, cations have easy access to them.
The structure is an open one, and its water content is rather high. At lower water contents, we would expect bases to tilt so that the structure could become more compact.

The novel feature of the structure is the manner in which the two chains are held together by purine and pyrimidine bases. The places of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical z-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows: purine position 1 to pyrimidine position 1; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can be bound together. These pairs are: adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine).

In other words, if an adenine forms one member of a pair, on either chain, then on these assumptions the other member must be thymine; similarly for a guanine and cytosine. The sequence of bases on a single chain does not appear to be restricted in any way. However, if only specific pairs of bases can be formed, it follows that if the sequence of bases on one chain is given, then the sequence on the other chain is automatically determined.

It has been found experimentally that the ratio of the amounts of adenine to thymine, and the ration of guanine to cytosine, are always very close to unity for deoxyribose nucleic acid.

It is probably impossible to build this structure with a ribose sugar in place of the deoxyribose, as the extra oxygen atom would make too close a van der Waals contact.

The previously published X-ray data on deoxyribose nucleic acid are insufficient for a rigorous test of our structure. So far as we can tell, it is roughly compatible with the experimental data, but it must be regarded as unproved until it has been checked against more exact results. Some of these are given in the following communications. We were not aware of the details of the results presented there when we devised our structure, which rests mainly though not entirely on published experimental data and stereochemical arguments.

It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.

Full details of the structure, including the conditions assumed in building it, together with a set of co-ordinates for the atoms, will be published elsewhere.

We are much indebted to Dr. Jerry Donohue for constant advice and criticism, especially on interatomic distances. We have also been stimulated by a knowledge of the general nature of the unpublished experimental
results and ideas of Dr. M. H. F. Wilkins, Dr. R. E. Franklin, and their co-workers at King's College, London. One of us (J.D.W.) has been aided by a fellowship from the National Foundation for Infantile Paralysis.

J. D. Watson and F. H. Crick  
Medical Research Council Unit for the Study of  
the Molecular Structure of Biological Systems  
Cavendish Laboratory  
Cambridge  
April 2

Notes


Exercises

1. Order of Description  
   Analyze the ordering of the description of the DNA molecule.

2. Significance  
   This essay was one of the most important of our time, yet it does not announce its own importance with a great deal of fanfare. How could you know the significance of this information? Hint: analyze this paper for its targeted audience.

3. Scientific Method  
   Analyze Crick and Watson's model for its explanatory value. Is this model presented hypothetically? Must further testing be conducted to validate its efficacy? Locate this paper in the process of scientific reasoning.
Appendices
Appendix I

Writing Grant Proposals

A grant proposal is a formal, written request for money, equipment, library, or computer access. Whether proposals run to a few pages or to a hundred pages, they require a statement of the request, an explanation/justification for the request, a budget, and a specific plan of implementation. As a written form, the grant is explicit and straightforward, but grant-writing is time consuming and labor intensive because in addition to describing your project in a written text, you must fill out forms, devise a budget, and in many cases collect the curricula vitae of the members of the research team. If your budget lists travel costs, you will have to call airlines for ticket estimates or consult sources for mileage. If the budget lists equipment costs, you will have to solicit estimates. These logistical efforts require time and organization.

Budget your time, not only to accommodate the logistics, but also to allow for several revisions of the proposal. Soliciting readings by your colleagues will provide you valuable feedback on all aspects. Soliciting a reading from a person outside the field can provide you with feedback on the general intelligibility of your grant. Published deadlines—postmark deadlines or receipt-of-materials—are taken seriously. Check your deadline.

In the sciences, a proposal will be composed of the following parts: an introduction, abstract, statement of the research problem, methodology used to implement the research program, and anticipated results. In structure, a proposal is analogous to a science paper with anticipated results taking the place of actual results. Some granting institutions will ask you to submit a schedule for carrying out the research program.

If you are asked to submit a schedule of research, and contingencies make you tentative about timing, estimate. Put some thought into planning this. When it comes time to actually implement your research plan, you may find yourself turning to those timing guidelines in order to fulfill them.

Evaluation Criteria

Granting agencies make explicit the criteria by which a grant is evaluated.
No privileged information is withheld from you. As you formulate the argument for your proposal, write with the evaluation criteria in mind. Because proposal format and evaluation criteria differ, make sure that you respond to the specific requirements of the granting institution.

A science proposal is evaluated roughly on two sets of criteria: (1) scientific merit and (2) implementation. By scientific merit is meant that the solution to your research problem should produce a substantive contribution to your area of study or to the public. Some granting agencies look more favorably upon projects which engage in applied science research rather than theoretical research. Some agencies may value applied and theoretical work equally. Make sure that your project is directed to the institution which funds the kind of research you propose.

The grant is assessed by a number of factors. Your ability to carry out the goals of the proposal is determined by your experience and that of your staff, evaluated in part through the curricula vitae you are asked to supply. Your institution's ability to support the research is also a factor weighed by the review board; if you need a supercollider to conduct research at a facility which has no supercollider, your proposal is obviously at a disadvantage. In addition, the project must be planned and implemented to conform with your institution's policy and procedures regulations. Those regulations may limit the use or nature of research subjects or materials; they may restrict the way you spend grant funds. The research must conform to national policies or protocols regulating the use of subjects, materials and so on.

The following extract from the National Science Foundation, Grant Proposal Guide [(NSF 94-2), January 1994] defines the selection criteria for grants.

Four criteria for the selection of research projects by the National Science Foundation are listed below, together with the elements that constitute each criterion.

1. **Research performance competence**—This criterion relates to the capability of the investigator(s), the soundness of the proposed approach, and the adequacy of the institutional resources available.

2. **Intrinsic merit of the research**—This criterion is used to assess the likelihood that the research will lead to new discoveries or significant advances within the field of science or engineering, or have a substantial impact on progress in that field or in other scientific and engineering fields.

3. **Utility or relevance of the research**—This criterion is used to assess the likelihood that the research can contribute to achievement of a goal that is extrinsic or in addition to that of the research field itself, and thereby serve as the basis for new or improved technology or assist in the solution of society problems.

4. **Effect of the research on the infrastructure of science and engineering**—This criterion relates to the potential of the proposed research to contribute to the better understanding or improvement of the quality,
distribution, or effectiveness of the Nation's scientific and engineering research, education, and manpower base.

The Review Process

Your grant may pass through several levels of review. When your grant is received by the granting institution, it may be sent to readers knowledgeable in the field. In some cases, the reviewer may offer recommendations without convening as a group. The NIH (National Institutes of Health) for example has a two-tiered review process, the members of which serve only in an advisory capacity; they make recommendations but do not ultimately make decisions. In the first tier, the proposal is sent to experts in the field who assign a priority to your work based on scientific merit; they do not, however, set policy.

The second tier of review goes over the first-tier recommendations and assesses the applications against the program's priorities; this level of review is composed of members who are inside and outside the science field. Ultimately decisions rest with a third group, the Division of Research Grants (DRG), which considers the recommendations made by the tiers.

The tiered review process puts your proposal among diverse readers. To which audience do you write? Your writing must be intelligible to all your readers and, as such, must be concise, clear, and to the point. Avoid overly technical language. Bear in mind that reviewers have other proposals besides yours to read in addition to the daily concerns of working, raising a family, or maintaining their own professional profiles. Do not make your reader work too hard. Your proposal should stand out by its merit, by the soundness of its procedural design, and by the clarity of its writing.

The review board at any level makes one of three decisions: approved, declined, deferred. A deferral is granted to those proposers who need to provide further information before action can be taken. Approval means that the board has found your proposal satisfactory in scientific merit and implementation strategies. Even though your proposal may secure approval at one or two levels in the tier-process, it still remains in competition with other grants which have likewise secured approval and will hence be ranked against them. If the proposal is declined, it is knocked out outright. Deferral means that a decision has been put off pending the submission of further materials by the applicant or pending a site visit. The purpose of a site visit is to assess the capabilities of the institution to implement the research project.

Budgets

Budgets are usually accompanied with a narrative which explains the costs.
Use headings if your budget narrative has many subsections. In planning travel, solicit estimates for business class. If your grant originates under the auspices of your university, your university will probably prohibit such items as first-class travel, monies for entertainment and liquor. Direct costs refer to the actual cost of the project; indirect costs, usually expressed as a percentage, refer to the grant funds which go to the institution to cover overhead costs like electricity, laboratory or office space, and equipment. Indirect costs may run as high as 50 percent of the grant award.

**Headings**

Use headings to divide the parts of your proposal. The grant specifications spell out particular divisions. Derive headings from these categories; use sub-headings as necessary.

**Proposal Specification: NIH**

The following specifications are taken from the application package for a Public Health Service Grant issued by the U. S. Department of Health and Human Services, Grant Application form PHS 398 and explanations (6/30/94). They are intended to illustrate the prescriptive nature of grant proposals.

**Research Plan.** Organize Items 1-4, to answer these questions: (1) What do you intend to do? (2) Why is the work important? (3) What has already been done? (4) How are you going to do the work? **Do not exceed 25 pages for Items 1-4.** All tables and graphs must be included within the 25 page limit of Items 1-4. Full-sized glossy photographs of material such as electron micrographs or gels may be included in the Appendix; however, a copy of any photograph must also be included within the Research Plan and within the page limitations (See Appendix for further instructions). **Twenty five pages is the absolute maximum and will be strictly enforced.** Applications that exceed this limit, or that exceed the type size limitations (see page 10), will be returned without review. You may use any page distribution within this overall limitation; however, the PHS recommends the following format and distribution:

1. **Specific Aims.** State the broad, long-term objectives and describe concisely and realistically what the specific research described in this application is intended to accomplish and any hypotheses to be tested. **One page is recommended.**

2. **Background and Significance.** Briefly sketch the background to the present proposal, critically evaluate existing knowledge, and specifically identify the gaps which the project is intended to fill. State concisely the importance of the research described in this application by relating the specific aims to the broad, long-term objective. **Two to three pages are recommended.**

3. **Progress Report/Preliminary Studies.** A progress report is required for Competing Continuation and Supplemental applications; for
Writing Grant Proposals 243

New applications, a report of the principle investigator/program director’s preliminary studies is recommended.

For COMPETING CONTINUATION and SUPPLEMENTAL applications, give the beginning and ending dates for the period covered since the project was last reviewed competitively. List all personnel who have worked on the project during this period, their titles, birth dates, Social Security Numbers, dates of service and percentages of their appointments devoted to this project. Summarize the previous application’s specific aims and provide a succinct account of published and unpublished results indicating the progress toward their achievement. Summarize the importance of the findings. Discuss any changes in the specific aims since the project was reviewed competitively. List the titles and complete references to all publications, manuscripts submitted or accepted for publication, patents, invention reports, and other printed materials that have resulted from the project since it was last reviewed competitively. Note that this list is excluded from the 25 page limit. Submit five collated sets of no more than ten such items as an Appendix.

New applications may use this section to provide an account of the principle investigator/program director’s preliminary studies pertinent to the application and/or any other information that will help to establish the experience and competence of the investigator to pursue the proposed project. The titles and complete references to appropriate publications and manuscripts submitted or accepted for publication may be listed, and five collated sets of no more than ten such items of background material may be submitted as an Appendix. Six to eight pages are recommended for the narrative portion of the Progress Report/Preliminary Studies, excluding the list of materials resulting from the project since it was last reviewed competitively.

4. Research Design and Methods. Outline the research design and the procedures to be used to accomplish the specific aims of the project. Include the means by which the data will be collected, analyzed, and interpreted. Describe any new methodology and its advantages over existing methodologies. Discuss the potential difficulties and limitations of the proposed procedures and alternative approaches to achieve the aims. Provide a tentative sequence or timetable for the investigation. Point out any procedures, situations, or materials that may be hazardous to personnel and the precautions to be exercised. Although no specific number of pages is recommended for this section of the application, the total for Sections 1–4 may not exceed 25 pages, including all tables and figures.

Discussion

1. Specific aims asks for the definition of long-term objectives. (See Chapter 8, “Definition”), and a description of the goals of your research project. The discussion of causality in Chapter 12 may be useful to this section. The proposed research is posited as a cause for which you must anticipate effects. In what position of causality do you see your work? Do your long-term objectives represent your project as a remote cause able to influence or contribute to a general knowledge base? Do your long-term objectives represent your project as a proximate cause with direct and clear
cut ends? Will it influence, contribute, modify other aspects of science? Is your project the first step in a series of projects, perhaps the initial research in what may be your life's work?

2. The background survey parallels the background information which serves as an introduction to a science paper. Notice that you have two pages to represent both the major contributions to the field and whatever commentary you have on them. While your research on the background must be comprehensive, you are not in a position to mention every title. This means that you must classify your research into patterns. Assess what the general consensus is, who the most significant proponents of that view are, who the exceptions are. Mention the notable researchers.

This section sets up a comparison/contrast mode as a means to defining the significance of your project. By explaining the status of the field (definition), and explaining how your work fills in the gap (comparison/contrast), you arrive at an explanation as to why your work is important. This argument from definition was introduced in Chapter 10 under the heading "Essay Exam." A further demarcation of significance can be structured through a comparison/contrast between your immediate and long-term research objectives.

Make sure that your mention of long-term objectives as stated in section 1 corresponds to the long-term objectives you discuss in section 2.

Section 3 asks for the researcher's credentials. What information about the person will contribute to the credibility of the researcher's plan? Credentials are established by past publications or past experience which demonstrate a record of achievement and which display expertise in the area.

Section 4 calls for an outline of methodology. An outline refers to a more schematic discussion that you would normally supply in a science paper. Since experts will be among the review board, gear this segment more towards that audience.

What to Do If Your Project Fails to Get Funded

Do not lose heart if you do not acquire all the support you requested or if your proposal is declined. If you receive a summary statement which represents the reviewer's remarks, read it carefully to assess the limitations of your proposal. Determine if the limitation to your grant came from unclear writing: if you didn't get your point across, while the original project had merit, your manner of presentation hindered its success. Rewrite to clarify and resubmit.

If your grant was declined because you did not provide a realistic plan of implementation, spend more time on fleshing out the plan and resubmit. If your science project is construed to be without scientific merit, reconceive your project.
References


______. *Writing a Successful Grant Application*. Jones and Bartlett, 1989.
The Deep Six

The "Deep Six" are six grammar/punctuation errors. They are called the deep six because they are the most frequently made obfuscating errors; they sink your prose into meaningless oblivion, interfering with the meaning of the writing by making a point difficult or impossible to follow. While such obstacles to communication, if infrequent or few, may be as innocent as "white noise," more often they will confuse the reader about your point.

The "Deep Six" are not the only grammar/punctuation errors but they are the most common and therefore the most necessary to correct. Read the following descriptions. If you do not understand what the errors are or how you can fix them, turn to the appropriate section in the grammar unit which follows.

1. Sentence Fragment: A sentence fragment is a group of words written as a sentence that fail to function as a grammatically complete sentence. A sentence conveys a complete idea. It should have a subject and a finite verb in a grammatically independent predication.

   Fault: Me Tarzan—you Jane.
   Correction: I am Tarzan. You are Jane
   Fault: Being that he was late.
   Correction: He was late.
   See verbals and clauses.

2. Comma Splice: A comma splice results when two independent clauses are run together with a comma. Comma splices, like repeated sentence fragments, suggest that the writer is unable to recognize complete ideas. Two independent clauses can be joined in two ways: (1) with a comma and a coordinating conjunction (and, or, but, nor, for); (2) with a semicolon.
Alternatively, (3) two independent clauses could be written as two separate sentences, or (4) one independent clause could be subordinated to the other.

Fault: We canceled the picnic, it rained.

Corrections:
(1) comma + conjunction  
   We canceled the picnic, and it rained.
(2) semicolon  
   We canceled the picnic; it rained.
(3) two independent clauses  
   We canceled the picnic. It rained.
(4) subordination  
   We canceled the picnic because it rained

See clauses.

3. Run-on and Fused Sentences: The fused sentence jams together two independent clauses with no punctuation at all. A series of fused sentences or a combination of fused sentences and correctly punctuated sentences creates a run-on sentence.

Fused Sentence Fault: We canceled the picnic it rained that day and my car broke down.

Correction: We canceled the picnic because it rained that day. Then my car broke down.

In contrast to a fused sentence, which can be identified by the absence of punctuation, a run-on sentence cannot be defined precisely. In general terms, a run-on goes on too long. But how long is too long? Use your best judgement. Consider the context. There is no absolute rule which defines too long.

To correct a run-on sentence, break it into smaller sentences.

See clauses.

4. Agreement of Pronouns: Pronouns agree with their antecedents in person, number, and gender. To agree means to correspond in form.

Fault: Jones, Newton, and Perez noted positive correlation of results; in particular, his studies showed . . . [whose?] (Plural antecedent, singular pronoun)

Correction: Jones, Newton, and Perez noted positive correlation with their results; in particular, Newton's studies showed . . .

See Pronouns.

5. Agreement of Verbs: A verb agrees with its subject in person and in number, no matter what the subject is and wherever the subject is located in the sentence.

Fault: Many varieties of plankton lives in the sea.
Correction: Many varieties of plankton live in the sea.

[Varieties, not plankton, is the subject of the verb live.]

See Verbs.
6. Dangling Modifiers: Dangling modifiers are verbal clusters or elliptical adverbial clauses which are incorrectly positioned apart from what they modify, or which possess nothing in the sentence to modify. Dangling modifiers are especially prevalent in sentences beginning with -ing words (participles) which do not refer to the subject of the main clause of the sentence.

Rule: The phrase must modify the word it is attached to.

Fault: *Having received your proposal this morning, it is expected that the Director will have time to review it later today.*

Correction: *Having received your proposal this morning, we expect that the Director will have time to review it later today.*

See Subordination.

Grammar and Mechanics

In the following section, the elements of grammar will be outlined, starting with the most basic concepts. If you already understand what a complete sentence or a subordinate clause is, turn directly to the heading which pertains to your problem. If you need more briefing on general language terms, continue reading.

There are two ways to classify words: by identity and by function.

Identity, identification, identify, id—all these words come from the same root.

Identity: the collective aspect of the set of characteristics by which a thing is definitively recognized or known.

Words have an identity—what they are. You might remember from grade school that you learned the parts of speech. The parts of speech—noun, pronoun, verb, adverb, adjective, preposition, conjunction—name the identities of words.

However, though words possess fixed identities, they can function in different ways in a sentence. Function refers to the way a word behaves in a sentence: what role it takes, what semantic position it occupies. Subject, predicate, and object name some of the functions a word can have.

Sometimes the identity and the function are the same. An adjective is always an adjective. No matter how you uses the word red, it must always function as an attribute describing a substance: a red table, a red sky, red blood. It is born an adjective, will die an adjective, and may in its lifetime hope to be part of a compound adjective—red-blooded person—and to describe many nouns.

Sometimes the identity and the function differ. A verb can sometimes behave as a noun. Take swimming. In the sentence, "Swimming is my favorite sport," swimming functions as a noun in the subject of the sentence.
In the sentence, "He is swimming across the pool," *swimming* is a verb. The word has an identity but its function can change.

For practical purposes, we will divide the identity of the word—*what it is*—from its function—*what it does*.

<table>
<thead>
<tr>
<th>What It Is</th>
<th>What It Does</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noun/Pronoun</td>
<td>Subject, Direct Object, Indirect Object, Object of Preposition</td>
</tr>
<tr>
<td>Verb</td>
<td>Predicate</td>
</tr>
<tr>
<td>Adjective</td>
<td>Adjective</td>
</tr>
<tr>
<td>Adverb</td>
<td>Adverb</td>
</tr>
<tr>
<td>Preposition</td>
<td>Preposition</td>
</tr>
<tr>
<td>Conjunction</td>
<td>Conjunction</td>
</tr>
<tr>
<td>Interjection</td>
<td>Interjection</td>
</tr>
</tbody>
</table>

**NOUN**

A *noun* is a word that names a person, place, thing, or abstraction. An abstraction can include an emotion, idea, concept, wish, passion, or quality.

*Person*: scientist, golfer, poet, gossip, rogue, zealot.

*Place*: house, laboratory, cellar, attic, patio, rotunda.

*Thing*: pipet, cigar, wrench, paradox, nosebleed, ice.

*Abstractions*: realism, truth, attraction, beauty, ethos.

There are two sub-classes of nouns: proper nouns and common nouns. *Proper nouns* name a particular person, place, thing or idea: Oedipus, Marie Curie, Socrates, Columbia, Gabriel Garcia Marquez. Proper nouns are always capitalized. A *common noun* names a thing in general: microscope, accordion, moose, nucleus.

A *collective noun*, a subset of common nouns, names a group of things: orchestra, gang, troop, galaxy, squad, cluster, coven, bevy, tribe, audience.

**Function**

A noun, like a pronoun, may function as the subject of a sentence, the direct object, the indirect object, or the object of a preposition.

*Subject*: The *chair* is in the room.

*Direct Object*: He put the *chair* in the living room.

*Indirect Object*: He gave (to) the *chair* a new paint job.

*Object of Preposition*: He put the book on the *chair*.

**PRONOUN**

A pronoun takes the place of a noun. It must agree with the noun in person, number, and gender.

I (first person, singular) me, mine, my

we (first person, plural) us, ours, our

you (second person, singular) you, yours, your
Mechanics and Style

you (second person, plural) you, yours, your
he/she (third person, singular) him, her, it; his, hers, its; his her, it
they (third person, plural) them, theirs, their
who, whom, whose, whose

The pronoun is inflected in its use.

I have a book. subject
It belongs to me. object
It is mine. predicate adjective
It is my book. possessive

More Complicated Cases. The first instance applies to subject-verb agreement as well.

(1) Agreement with Groups. Some nouns can take either a singular or plural verb and pronoun. For instance, when the noun is a collective noun, it may act either as an individual or as a group. Such words, which are single words, refer to a group. A word like colony refers to one unit composed of many individual parts. Other words like this include the following: team, colony, United States, pair, scissors, group, class, committee, company, board [of directors], etc.

To determine agreement, look at the meaning of the sentence: If the group functions as one unit, it is singular. If the sentence emphasizes the individual members of the group, it is plural.

The baseball team that participated in the parade were the California Angels; they won the game.

The baseball team was the California Angels; it was coached by Alexander the Great.

(2) The Universal Subject. Traditionally the rule in English has been to use the third person masculine pronoun as the universal subject in cases when you do not know the gender or in cases when the gender is mixed. For example, this rule would say, "Everyone in the class has his book," even if the group were mixed in gender. Because the masculine pronoun is no longer universally accepted as the common gender, people very frequently try to avoid this phrasing. The most common correction of this problem has been to phrase the sentence as "Everyone in the class has their book." Unfortunately, this correction substitutes one error for another because the subject of the sentence, everyone, is singular [every one]; it must agree with the pronoun in number but their is plural. This phrasing would, however, be correct if the sentence referred to a situation in which the class owns one book and their book shows collective ownership: one book owned by a class.

You have four options in cases such as these: (1) rephrase the sentence entirely: The class brought their books; (2) use both pronouns: Everyone has his and her book; (3) use the traditional universal subject; (4) make the feminine the universal subject.
VERBS

A verb is a word which describes an action or a state of being.

"Be" Verbs: The follow verbs denote a state of being: am, is, are, was, were, appear, tastes, seems.

Transitive Verbs: Some verbs convey action. The action passes through the verb to an object. These are called TRANSitive verbs because the action is transmitted THROUGH the verb into the object. In the example

Joe kicked the ball.

the action of kicking starts with Joe, passes through kick and lands on the ball.

Intransitive Verbs: Some verbs convey action but cannot be forced under any conditions to relate to an object.

Example: I sit down. I stand up.

Such verbs of self-propelled action do not carry an action through a verb. They have no object. Lie (as in I lie down) is intransitive. It is conjugated as lie, lay, lain. In contrast lay is a transitive verb, because it is possible to lay an object down, as in, "I lay my book on the table." Lay is conjugated lay, laid, laid. (The verb "to lie" as in to place differs from "to lie" as in to tell a falsehood. This form of lie is conjugated as lie, lied, lied.)

Tense

All verbs have two attributes: tense and voice. Tense denotes time.

Present

Joe kicks the ball

Present continuous

Joe is kicking the ball.

Past

Joe kicked the ball.

Present Perfect

Joe has kicked the ball.

Present Perfect Continuous

Joe has been kicking the ball.

Past Perfect

Joe had kicked the ball.

Past Perfect Continuous

Joe had been kicking the ball.

Future

Joe will kick the ball.

Future Perfect

Joe will have kicked the ball.

Future Continuous

Joe will be kicking the ball.

Future Perfect Continuous

Joe will have been kicking the ball.

Voice

Transitive verbs also possess voice. There are two voices, active and passive. In the active voice, the subject transmits an action through the verb to the object; in the passive voice, the subject receives the action transmitted through the verb.

Compare the active to the passive:

Active: Joe kicked the ball.

Passive: The ball was kicked by Joe.

Notice that the passive takes more words than the active voice to say the same thing. The active voice requires four words; the passive voice
requires six words. Sometimes the passive is said to be wordy because it takes more words in the sentence.

In English, it is appropriate to delete the agent of the passive voice.

Passive with agent deleted: The ball was kicked (by Joe).
The sample was measured (by me).

Because the agent is implied but deleted, in some cases the passive voice may be vague. This means that the audience cannot tell what or who the agent is. The passive voice is appropriate, even desirable, for use in lab reports which describe a process in which the human agent is not the focus of the writing even though it reports what the agent did.

VERBALS

A verbal is a word which is made from a verb but which behaves like a noun or an adjective. There are three kinds of verbals: participials, gerunds, and infinitives.

Participials. A Participial is made from a verb but acts like an adjective. It is made from the participle form of the verb. (Notice the difference between the two words: participle and participial. Participle is the name of the verb form; participial is the term given to what you make of that verb form.) Verb participles come in two forms, the past and the present.

(1) Past participle of the verb (-ed for regular verbs): received, completed.

Example: I have completed my homework.

(2) Present participle of the verb (-ing form): freezing, smoking.

Example: Paul is smoking ham for Easter.

When you take the participle form of the verb and transform it into a adjective, you have a participial.

Put your completed essays on my desk. [The participial completed modifies essays.]

Contrast with the verb form: I completed the essays.

The received truth about this issue is written here. [The participial received modifies truth.]

Verb: I received a telegram.

The freezing rain made the roads dangerous. [The participial freezing modifies rain.]

Verb: I froze lemonade in the freezer.

She left the smoking gun behind. [The participial smoking modifies gun.]

Verb: He smoked three cigarettes.

Gerunds. A gerund is word derived from the participle of the verb but it functions as a noun.
Example: Ann loves swimming.

*Swimming* is derived from the present participle of the verb “to swim” as in the example, “She is swimming across the pool.” In the example, *swimming* behaves as a noun and, in the sentence, it occupies the place of the direct object.

**Studying** always bored Michael.

*Studying* is derived from the present participle of the verb “to study” as in the example, “Michael is studying in the library.” In the example, *studying* behaves as a noun, and in the sentence, it takes the position of the subject.

**Infinitives:** An infinitive is the “to” form of the verb. The infinitive may function as noun, adjective, or adverb.

- He plans to go.
- He is the man to elect.
- Some problems are difficult to solve.

**NOTE:** You may have encountered this grammatical rule about the infinitive: *Never split an infinitive.* A split infinitive is one in which another word or phrase separates the “to” from the verb.

- Example: I wanted to quickly finish my homework.
- Example: He wanted to not eat.

**Explanation:** quickly and not split up the infinitive because they come between “to” and the verb.

While the rule prohibiting the split infinitive is fading into disuse, some people view split infinitives as a social indecorum. The rule forbidding a split infinitive comes from the time when Latin was the universal language of the world. All scholarly, respectable writing was done in Latin. Scientists and scholars even took Latin names to show that they were learned. In Latin, infinitives appear as a single word. The rule which prohibits splitting an infinite shows deference to Latin and to the time when the rules which governed Latin grammar were applied to other languages.

For your purposes, you should decide on your own whether or not you will split an infinitive. On the one hand, it comes from an archaic and perhaps even absurd reasoning; on the other hand, some people judge the “proper” use of the infinitive as a mark of a person who is experienced in language use. The decision is yours.

**PREPOSITIONS**

A preposition is a word which denotes a position in space or time. An easy rule of thumb is this: a preposition is anything a plane can do to a cloud or anything that a sheep can do with a fence. Prepositions: among, around, before, beneath, between, in, on, on top of, through, under.
CONJUNCTIONS
Conjunctions function like hinges. They are words which link other words together. Conjunctions include and, or, but, nor, for, so, and yet.

ADVERBS
Adverbs are words that modify

— a verb. He ran quickly.
— an adjective. The surprise made me very happy.
— another adverb. He ran very quickly.

From Words to Sentences

Clauses

Definition
A clause is a unit of meaning which contains a subject and a predicate. The predicate is a verb; the subject may be a noun or a pronoun. No object is required to make a clause, but a clause could have one. There are two kinds of clauses:

(1) main (independent) clause
An independent clause contains a complete thought.
Example: I will leave.

(2) subordinate (dependent) clause
A dependent clause must be attached to a main clause to complete its meaning.
Example: When the time is right. . . .(what will happen?)

Clauses as Sentences

A sentence must express a complete thought and must contain a subject and a verb. “Close the door” is a sentence because, in the imperative, the subject “you” is implied.

Grammatical Error: A piece of a sentence does not express a complete thought. Pieces of sentences are called fragments. Do not write sentence fragments. One reason students write fragments is because they confuse a verbal with a verb.

Fragments: Being that it was time to go. The red painted pony.

Subject-Verb Agreement

1. The subject must agree with the verb in person and number. English
is an irregularly inflected language; the most common variation in the verb inflection is in the third person singular.

<table>
<thead>
<tr>
<th>Person</th>
<th>singular</th>
<th>plural</th>
</tr>
</thead>
<tbody>
<tr>
<td>first</td>
<td>I go</td>
<td>we go</td>
</tr>
<tr>
<td>second</td>
<td>you go</td>
<td>you go</td>
</tr>
<tr>
<td>third</td>
<td>he, she, or it goes</td>
<td>they go</td>
</tr>
</tbody>
</table>

2. Do not be misled by words or phrases that intervene between the subject and the verb. In your mind, cross out prepositional phrases which modify the subject to isolate it.

Incorrect: The cars in the lot looks broken-down.
Correct: The cars in the lot look broken-down.

3. Usually subjects joined by and are plural.
   Example: Oxygen and hydrogen are elements.
   Exception: When and is used to join words in a unit, the unit is singular.
   Example: Bacon and eggs is my favorite breakfast.

4. Each and every are singular: These words imply the meaning each (one) and every (one). Even when the subject is compound, with elements joined by and, the verb is singular:
   Example: Each nut and every bolt is tested for accuracy.

5. Singular subjects joined by either/or or neither/nor take a singular verb.
   Example: Neither José nor Maria is coming to the party.
   But if one subject is singular and one is plural, the verb agrees with the subject which is closest.
   Example: Neither the substance nor the conditions are changed.

6. Do not be misled by inverted word order (verb + subject) or (there + verb + subject).
   Examples: There was time to accomplish everything.
   There were winds from the east blowing through the hills.

7. A linking verb agrees with its subject, not with its complement.
   Example: His problem is frequent headaches.
   Example: Frequent headaches are his problem.

8. Nouns plural in form but singular in meaning take a singular verb.
   Example: News travels fast.
   Frequently used words in this category are news, mumps, measles, economics, electronics, physics.
Kinds of Clauses

Clauses can be arranged into four kinds of sentences.

1. *Simple Sentence* = one independent clause
   Typical paradigm: subject + verb + direct object
   The protozoan parasite causes Chagas' disease.

2. *Compound Sentence* = two or more independent clauses connected by a coordinating conjunction
   (The protozoan parasite causes Chagas' disease)
   and
   (it creates a health hazard affecting 20 million people in Central and South America).

3. *Complex Sentence* = one independent clause + one or more dependent clauses connected by a coordinating conjunction
   independent (The failure to control the spread of the infection has been attributed to the parasite's life cycle)
   dependent (which has different morphological forms in both the insect vector and the vertebrate host.)

4. *Compound-Complex Sentences* = at least two independent clauses (the compound part) + one or more dependent clauses (the complex part)
   independent (Upon transmission to mammalian host, the infective parasite circulates in the bloodstream as a nondividing form of parasite,)
   dependent (until infection is established by invasion in host cells);
   adverb (then)
   independent (a subsequent transformation to host the intracellular amastigote occurs.)

Use of Clauses

1. The audience needs will dictate the kind of sentences you make.
2. Vary the kind of sentences you use.
3. Avoid packing many dependent clauses into one sentence.

Significance

Sentence structure shows a relationship between ideas which are equal (compound) or hierarchical (complex and its forms). Complex sentences show a relationship of subordination; one concept is more important than another. The main idea takes the independent clause; the subordinate concept takes the dependent clause.
Coordinate means "being of equal structural rank."
Subordinate means "being of lower structural rank."

Coordination

1. Use coordination to give equal ideas equal emphasis.
   (The offer was tempting) but (I didn’t accept it.)
2. A compound sentence shows a stronger connection between ideas than does two separate sentences.
3. There are two ways to connect independent clauses.
   A. add a comma + coordinating conjunction (and, or, but, nor, for, so, yet)
   B. use a semicolon between independent clauses
      A semicolon always connects independent clauses with one exception.
      Exception: Use a semicolon to separate a series of items which contain commas.
      Example: The three scientists at the meeting were Dr. Eric Han, Kennedy Space Center; Dr. Hermes Trismigestus, Library of Alexandria; and Dr. Sheetal Kundalini, former director of the Rejkavi Institute of Applied Grammatology.

Grammatical Errors:
1. If you link two independent clauses with only a comma, you make a comma splice.
2. If you link two independent clauses together with no punctuation, you make a fused sentence.
3. Do not string main clauses together when some ideas should be subordinated.

   Awkward: I wanted to go to college, so I mowed and trimmed lawns all summer, and that way I could earn my tuition.
   Better: Because I wanted to go to college, I mowed and trimmed lawns to earn my tuition.

Subordination

1. Subordination signals to the reader that one point (expressed in the main clause) is more important than another (expressed in the dependent clause).
   The protozoan parasite, which causes Chagas’ disease, creates a major health hazard.
2. A subordinate clause always possesses a specific relationship to the main clauses. A subordinate clause specifies time, place, cause, concession, condition, exception, purpose or description. In the examples below, brackets surround the dependent clause.

**Time**

Everyone panicked [when the earthquake struck].

**Place**

Greenwich Time was set in London (where the Royal Society was founded).

**Cause**

[Because the tissue damage caused by free radicals is not limited to DNA,] defense mechanisms against free radicals will always be a subject of interest.

**Concession**

[Although past studies have shown this to be true,] our results suggest a more tentative approach is merited.

**Condition**

We cannot conduct this seminar [unless the university provides us with more computers].

**Exception**

[Except for innovative studies conducted at the Basel Institute for Applied Research,] no reports to date have shown this correlation.

**Purpose**

[In order to demonstrate the efficacy of new technology,] our collaborative group devised a new system of graphics.

**Description**

Professor Luis Villarreal, [who is famous for his work on pattern recognition,] made up this sentence.

3. Faulty subordination shows an error in reasoning. Avoid faulty subordination.

Put your main idea into the main clause.

**Awkward:** Jesus, who was hit by a car, wore a red hat.

**Which is more important—** Jesus wore a red hat or Jesus was hit by a car?

**Put the important point in the main clause position.**

Better: Jesus, who wore a red hat, was hit by a car.

Note: Use context to make a decision about what points are important in the sentence.

**Style**

When you revise your writing for stylistic purposes, you polish it up in
order to make your point as clearly and concisely as possible. Stylistic revision should be done when you have substantially completed your writing task and want to make it better.

1. Revise according to the need of your audience and purpose.

2. Avoid wordiness. Wordy means that you could accomplish the same meaning with fewer words. Some words or phrases are place holders like zero; they fill a place in a sentence but carry no semantic content. To avoid wordiness, reduce redundancy. Redundant means you do not need a word because you have expressed the point sufficiently already. In other words, you do not have to say the same thing twice. Example: In the phrase, completely eliminate, eliminate already contains the meaning of complete. Words like connect, collaborate, cooperate, or couple already imply a relationship between parts, so it would be redundant to say collaborate together. Other redundant expressions (in the brackets) include the following:

- yellow [in color]
- [basic] essentials
- return [back]
- [true] facts
- at 9:45 P.M. [that night]
- circular [in shape]
- small [-size] potatoes

3. Be concise. Do not use many words when a few will express the idea well.

Wordy: In the event that the grading system is changed, expect complaints on the part of the students.

Concise: If the grading system is changed, expect complaints on the part of the students.

Wordy: He spoke in a low and hard-to-hear voice.

Concise: He mumbled.

4. Make verbs do the work rather than nouns. "Sarah has communication with God" versus "Sarah communicates with God."

5. Use action verbs rather than "be" verbs.

Avoid using ("be" verb + adjective) when you could use an action verb instead: "There was a meeting" versus "They met."

Note: Sometimes you need to use "be" verbs to express states of being.

(is operative) can be expressed as operate
(is beneficial) benefits
(ae similar) resemble
(make contact with) contact

6. Place the most important idea in the most important syntactic positions (subject verb object).
"The departure of the fleet is thought to be necessarily conditional on the weather" versus "Bad weather may keep the fleet at anchor."

7. Avoid delaying phrases/non-referential pronouns. Some phrases are place holders; they usually delay the meaning of the sentence: *It is evident; It is obvious that; There is, are.*

8. Eliminate pointless elaborate prepositional phrases or connectives:
Wordy: This problem is *in the nature of* one encountered years ago.
Concise: This problem is *like* one encountered years ago.

Other wordy or redundant phrases include the following (the most concise version is inside the parenthesis):
- absolutely essential (essential)
- actual experience (experience)
- at the present time (at present, now)
- at this point in time (now, currently)
- completely eliminated (eliminated)
- collaborate together (collaborate)
- during the time that (while)
- few in number (few)
- in many cases (often)
- in most cases (usually)
- in this case (here)
- in all cases (always)
- involve the necessity of (necessitates, requires)
- in connection with (about)
- in the event of (if)
- in the neighborhood of (about)
- make application to (apply)
- make contact with (contact, see, meet)
- maintain cost control (control costs)
- on the part of (by)
- past history (history)
- range all the way from (range)
- red in color (red)
- stunted in growth (stunted)
- subsequent to (after)
- through the use of (by, with)
- true facts (facts)
- until such time as (until)
- with the object of (to)
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