ENGLISH FOR SCIENCE AND TECHNOLOGY A Handbook for Nonnative Speakers

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WRITING PARAGRAPHS

Unlike readers in the academic world, most readers in the "real world" read *selectively:* rather than thoroughly digesting a piece of writing, they skim-read most of it, skipping from one main idea to another until they come to something that particularly interests them. Such readers are forced to read this way. They are overwhelmed with reading material and simply don't have the time to read everything carefully.

As a writer, therefore, you should do everything possible to ease this kind of reader's burden; in particular, you should make your writing *easy to skim-read.* One of the best ways to do this is to write good paragraphs. What makes for a good paragraph in scientific/technical writing? First of all, a good paragraph has *unity:* it focuses on a single idea or theme. Secondly, a good paragraph has *coherence:* one sentence leads to the next in some kind of logical sequence. Finally, a good paragraph has *adequate content:* it has an appropriate selection and number of details to support the main idea of the paragraph. Readers expect to find these qualities in paragraphs, and you as writer should take care not to frustrate their expectations.

There are two principal tools you can use to invest your paragraphs with the qualities just described: (1) a good topic statement and (2) an appropriate pattern of organization.

2.1
WRITE A GOOD TOPIC STATEMENT

The topic of a paragraph is its main idea or theme, i.e., what the paragraph is about. As with a larger piece of writing, readers of a paragraph want to know right away what the topic is. They also like to have some idea of how this topic will be developed. In other words, readers will use whatever cues they can to quickly generate expectations about the paragraph as a whole. This strategy serves two purposes: (1) it allows readers to guess what's coming and thus digest it more easily and (2) it allows them to avoid reading the paragraph altogether if the subject matter holds no interest for them.

You can help your readers, therefore, by providing a good topic statement right at the beginning of the paragraph. It does not have to be confined to a single sentence: often a topic statement is extended over the first two sentences of a paragraph. It should, however, always contain one or more key words directly related to the topic, and it should be as complete a statement of the main idea as possible, without getting into too much detail and

making the sentence(s) forbiddingly long. In addition, if possible, it should suggest how the topic will be developed (by comparison and contrast, by cause-and-effect analysis, etc.).

Here is an example of an effective topic statement.

> *Unlike gasohol-powered cars, the fuel cell alternative is virtually pollution-free.* A methanol fuel cell system works through chemical reactions that leave the air clean. A fuel processor breaks the methanol down into carbon dioxide and hydrogen; the hydrogen is then pumped to the cell itself, where it combines with oxygen to form water. Current is then produced when the electrons traded between molecules in this reaction travel through an external circuit. The net products are carbon dioxide, water, and electricity. By contrast, when gasohol is burned in an internal combustion engine, it produces the same nitrous oxides that gasoline does.[1] [italics added]

This topic statement is a good one because it tells the reader immediately what the theme of the paragraph is (fuel cell cars don't pollute) and because it's consistent with how the rest of the paragraph is developed (as a cause-and-effect description of how the fuel cell process works). Notice how the writer has used the key term *fuel cell* in the most important position in the sentence, the main-clause subject position, thus establishing it as the paragraph topic, i.e., what the paragraph is about.

For an example of what *not* to do, here is a paragraph from a student report on whether to use an argon recovery process or a hydrogen recovery process in a proposed ammonia plant:

> **NEGATIVE EXAMPLE**
> Utility costs for the argon process are 75 percent greater than for the proposed hydrogen process. Initial capital cost is $5.4 million, roughly three times the hydrogen process cost. However, annual income from the sale of argon, increased ammonia production, and reduced natural gas requirements elsewhere in the plant is 160 percent higher than that generated by the hydrogen process. Present worth analysis shows that the argon process is the better investment. The present worth of the argon process is $10.25 million. The present worth of the hydrogen process is $4.14 million.

Most readers will quickly conclude, on the basis of the first two sentences of this paragraph, that the argon process is more costly than the hydrogen one and should therefore not be chosen. But this is just the opposite of what the writer wants them to understand! For later on—buried near the bottom of the paragraph—the report states that "the argon process is the better investment." This statement is actually the topic statement of the paragraph. By "burying" it, the writer is running a serious risk of having the readers—especially those busy *important* readers!—completely overlook it.

A few simple changes can easily remedy the situation: (1) promoting the topic statement to initial position in the paragraph, (2) combining the next two sentences and subordinating them to the next one, (3) combining the last two sentences, and (4) adding a few words for emphasis:

> The argon process is clearly a better investment than the hydrogen process. Although it has higher utility costs (by 75%) and a higher initial capital cost (by 300%), it generates annual income—from the sale of argon, from increased ammonia production, and from reduced natural gas requirements elsewhere in the plant—that is 160% greater than that generated by the hydrogen process. Present worth analysis shows that the argon process is valued at $10.25 million whereas the hydrogen process is valued at only $4.14 million.

Notice how much more readable the rewritten version is. The topic statement serves to establish the main point and also to suggest how the rest of the paragraph will be developed (as a comparison-and-contrast pattern). The key term *argon process* (or its pronoun equivalent *it*) is used repeatedly in sentence-subject or clause-subject positions, thus keeping the reader's mind focused on it; all reference to the hydrogen process, by contrast, is deliberately subordinated.

The basic principle behind a well-written topic statement is this: by the time a reader has finished reading the first sentence or two of a paragraph, he or she should be able to predict what the rest of the paragraph is generally about and how it will probably be developed. Suppose, for example, you were reading an article on transport across membranes in a popular-science magazine and began reading this paragraph opening:

> The human body is made up of millions and billions of cells, each of which contains, among other substances, millions and billions of protein molecules. . . .[2]

How do you think the rest of the paragraph will go? What will it be about? Do you expect it to elaborate on other substances, on cells, on the human body generally? Probably not. Instead, there seems to be a narrowing down of focus to the term *protein molecules;* this is probably what the paragraph is about. How will this topic be developed? Well, the pattern of development used in this opening sentence is one of classification-division. Perhaps that pattern will be continued. Or maybe the writer has used some other pattern—a general-to-particular ordering of details, say, or a comparison of protein molecules with other kinds of molecules. Maybe the writer has used two patterns together. Of all the possibilities, though, you'd probably expect the classification-division pattern to be continued. It's a general fact about human nature that once we perceive a pattern in something, we expect it to continue—unless, of course, it's explicitly broken. Let's see what happens with

this paragraph:

> . . . An average cell contains hundreds of different kinds of proteins, and all of the cells of the human body contain, among them, as many as 100,000 different kinds of proteins. These proteins can perform millions of different functions, a versatility which is largely responsible for the phenomenon called "life."[2]

The writer has indeed continued with the classification-division pattern set up in the first sentence. Notice, too, how the pattern proceeds from general to particular; the grammatical subjects of the three sentences show this progression quite clearly: *The human body. . . . An average cell. . . . These proteins. . . .*

Though paragraphs sometimes exist in isolation, they are usually linked to other paragraphs, forming larger conceptual units. In such cases, either the topic and pattern set up in one paragraph may be carried on to the next or the break between paragraphs can be used to switch to a new topic and/or a new pattern. In any event, it is usually desirable to maintain some kind of continuity when moving from one paragraph to the next. This is most often done by incorporating a key word or term from one paragraph into the first sentence of the next. In the membrane transport article, for example, the first sentence of the next paragraph begins as follows:

> The proteins derive their versatility from their structure—they are made up of chains of molecules of amino acids, substances of which there are 20 different ones in the human organism. . . .[2]

Notice how the writer has picked up on the key word *versatility* from the last sentence of the first paragraph and used it as a transition to the subject matter of the second paragraph.

And what *is* the subject matter of this new paragraph? If the topic statement (above) is a good one, you should be able to predict with some assurance what it is. First of all, two new words appear prominently in this statement: *structure* and *amino acids.* We might suppose, therefore, that the theme of this paragraph is the structure of amino acids. Furthermore, since the writer has begun discussing amino acids by saying that there are 20 different types of them, we might expect the rest of the paragraph to be a discussion of the structural variety of amino acids, perhaps according to a classification-division pattern, a comparison-contrast pattern, or a general-to-particular ordering of details. Let's see how it actually does continue:

> An average protein molecule consists of about 500 molecules of amino acids of different kinds (seldom all 20), arranged in some particular sequence. A sequence of 500 amino acids composed of all the 20 different ones would have as many as 1×10^{60} (1 followed by 60 zeros) possible arrangements,

each arrangement having particular chemical properties and therefore chemical capabilities. From these few facts alone, we can readily appreciate how important the study of the amino acids is to our understanding of proteins, of the cell, and of life.[2]

As you can see, the paragraph as a whole *does* satisfy the expectations raised by the topic statement. It *is* about the structural variety of amino acids, and it *does* follow a general-to-particular pattern of development.

EXERCISE 2-1 For each of the following paragraphs, circle an appropriate topic statement from among the three possibilities given. Be prepared to defend your choices.

A i Many researchers believe that the cost of platinum will level off in the not-too-distant future.

ii Fuel cell cars may someday be designed to operate with a catalyst different from the one being used today.

iii Further development of fuel cell cars, despite their advantages, awaits more compelling economics.

While the soaring price of oil might have made the fuel cell car economically attractive, the rising value of precious metals has had the opposite effect. Fuel cells designed to run on methanol use platinum as a catalyst, and the price of that metal quadrupled during 1979. The cost of platinum alone could add a few thousand dollars to the price of a fuel cell car. Researchers have been trying to decrease the amount of platinum needed in the cells or to substitute a different, cheaper catalyst.[1]

B i The quantity of coal left in the earth is impressive.

ii Coal is a more viable source of energy than petroleum.

iii The mining of coal entails a number of difficulties.

There are known to be 198 billion tons of coal at a depth of less than 1000 feet and lying in beds at least 3.5 feet deep for bituminous coal and at least 10 feet thick for beds of lower grade coal. An equal quantity of coal of the same accessibility is identified as "undiscovered recoverable reserves." In addition, there are even larger quantities of marginally available coal resources, amounting to 1 trillion, 400 billion tons. At 35 million Btu's per ton, coal can provide a great deal of energy for many years to come.[3]

C
i Many molecular biologists are now convinced that the discovery of movable genetic elements holds the key to the solution of several long-standing mysteries.

ii It has become evident that in eucaryotes, unlike procaryotes, the genes coding for protein production do not exist as one continuous stretch of DNA.

iii Wrapping of the DNA on the enzyme with a positive superhelical sense ensures that the reaction will produce negative supercoiling once the wrapped segment is translocated.

It seems to go a long way, for instance, toward explaining how the human body is able to synthesize a million and more different molecular antibody species, each tailor-made to grapple with a specific antigen. Movable elements may help answer the age-old question of differentiation: how a fertilized egg divides and ultimately becomes, in the course of embryonic development, many different kinds of tissue cells. Jumping genes may also provide a mechanism for satisfying scientists who have been arguing that point mutations alone were far from enough to account for the story of evolution.[4]

EXERCISE 2-2 Each of the following sentences has been taken from an original text where it serves as an effective topic statement for a well-written paragraph. See if you can guess roughly how each paragraph is developed beyond the topic statement: what the key words are, what the pattern of organization is.

A The first modular home to be tested by government engineers for durability exceeded the criteria for the National Bureau of Standards.[5]

B At the time of its explosion, Mount St. Helens was probably the most closely watched volcano in the world.[6]

C The production of an important heavy chemical, nitric acid (HNO_3), requires large quantities of ammonia.[7]

D Until 1922, no one knew how a signal crosses the junction between one nerve cell and another.[8]

E The basic property of gyroscopic action is that the gyroscope stays spinning in exactly the same direction in space over both short and long periods of time.[9]

2.2
DEVELOP A CLEAR PATTERN OF ORGANIZATION

Once you have written a satisfactory topic statement, you'll want to follow it up with a number of supporting statements. These statements should follow a consistent pattern of organization, one that flows naturally or even predictably from the topic statement. That way, you'll satisfy the reader's expectations and allow her or him to process the paragraph as a unified whole.

Some of the most commonly used patterns of organization in scientific and technical writing are chronological description, cause-and-effect analysis, comparison and contrast, listing, and general-to-particular ordering of details. Each of these patterns has certain characteristic features, and by using these features you can make it easier for the reader to perceive which pattern you're using.

Chronological Description

The use of a time frame to tie sentences together is a well-known pattern of organization which you have no doubt used many times in your writing. It is commonly used, for example, to either describe or prescribe a step-by-step procedure: *First connect the vacuum tube . . . then return the plate . . . finally, close the contact key. . . .* It is used to recount a sequence of past events, as when you want to bring a reader up to date, e.g., in a progress report or in the Review of Literature section of a journal article.

The most characteristic features of chronological description are:

time adverbs and phrases	in 1980, last week, at 10:15, first, second, finally, soon after the project began
verb tense sequencing	Originally we ***wanted*** to. . . . More recently we ***have attempted*** to. . . . Now we ***are trying*** to. . . . In the future we ***shall try*** to. . . .
grammatical parallelism	***Mount*** the grating near the end. . . . ***Locate*** a rider on the scale. . . . ***Adjust*** the grating. . . . ***Read*** the distances on the scale. . . .

Not all of these features are likely to be found in any one type of chronological description. For example, descriptions of standard procedures (e.g., test procedures, experimental procedures, assembly instructions) strongly favor the use of parallelism over the other features. Descriptions of past events, on the other hand, tend to rely more on time adverbs and phrases and on different verb tenses.

The following is a well-written paragraph using chronological ordering as its basic pattern of organization:

> Total U.S. research and development spending *is projected* to reach a current-dollar level of $66.7 billion *in 1981,* an increase of 10 percent over *the 1980 projected level* and nearly double the amount spent on these activities *in 1975.* Even in constant dollars, and despite the reductions in R&D programs contained in the Federal *1980* and *1981* budgets, U.S. R&D spending *in 1981 is expected to follow* the growth trend of *the past five years, when* R&D funding *grew* at an average annual rate of better than 3 percent. That growth *resulted* in large part from increased emphasis on searching for means to resolve energy and environmental problems and a resurgence of defense R&D activity. *Between 1975 and 1978,* the last year for which survey data are available, energy *accounted for* one third of the R&D spending increase while, at the same time, amounting to 10 percent of the national R&D effort.[10] [italics added]

This paragraph contains a great deal of information, and it would probably be quite confusing were it not so well structured. Notice how the topic statement provides a clear overview of the paragraph as a whole: it tells you not only what the main theme is (that U.S. R&D spending is continuing to follow a significant growth trend) but also how this theme will be developed (by chronological order, featuring the years 1981, 1980, and 1975). The remainder of the paragraph is then devoted to fulfilling these expectations. Notice how the writer not only has repeated the key dates but also has taken care to use correct verb tense forms when referring to them.

Cause-and-Effect Analysis

This pattern of organization is used in scientific and technical writing for a number of purposes, including (1) making a logical argument, (2) describing a process, (3) explaining why something happened the way it did, and (4) predicting some future sequence of events. Whenever you are describing causes and effects, it is usually best to describe them in straight chronological order: causes *before* effects. That way, you can minimize the number of "traffic signals" you need. Even when the description is clearly one of causes followed by effects, however, your readers will appreciate it if you occasionally insert such signals. The characteristic signals of cause-and-effect analysis include:

connective words and phrases	therefore, thus, consequently, accordingly, as a result, so
subordinate clauses	since, because (of), due to
causative verbs	causes, results in, gives rise to, affects, requires, produces

conditional constructions	when ozone reacts with nitric oxide, the ozone is destroyed and NO_2 is formed.

In addition, when causes and effects are described in chronological order, the features associated with chronological description can be used.

A good example of cause-and-effect patterning is this paragraph from a physics text explaining what surface tension is:

> One of the most important properties of a liquid is that its surface behaves like an elastic covering that is continually trying to decrease its area. *A result* of this tendency for the surface to contract is the formation of liquids into droplets as spherical as possible considering the constraint of the ever-present gravity force. Surface tension *arises because* the elastic attractive forces between molecules inside a liquid are symmetrical; molecules situated near the surface are attracted from the inside but not the outside. The surface molecules experience a net inward force; and *consequently,* moving a surface molecule out of the surface *requires* energy. The energy E required to remove all surface molecules out of range of the forces of the remaining liquid is proportional to the surface area; *therefore,*
>
> $E = \sigma A$
>
> where σ, the proportionality factor, is called the surface tension,
>
> $\sigma = E/A$
>
> and is measured in joules/m^2. [italics added][11]

Notice how, in addition to using signal words such as *consequently* and *therefore,* the writer has linked the sentences together in a steplike sequence. This has been accomplished mainly through the following technique: after introducing and discussing a new term in one sentence, the writer then uses it in the next sentence as part of the framework for introducing and discussing the next new term:

Surface tension . . . *molecules situated near the surface.* . . .

The surface molecules . . . requires energy.

The energy E required . . . is *proportional* to . . .

the *proportionality* factor . . . is measured in joules/m^2.

If this kind of step-by-step linking is done properly, it reduces the need to insert many signal words and markers of subordination. (See Chapter 14 for further discussion of this technique.)

Comparison and Contrast

Often, in technical writing especially, you will find it necessary to compare two or more things that are similar in some ways but different in others. This is particularly common in business and industry, where one is constantly wrestling with cost-benefit trade-offs and other choices that must be made from among various alternatives under various constraints.

In writing a comparison-and-contrast paragraph, *try to avoid jumping back and forth from one alternative to another.* Suppose, for example, that you are comparing items X and Y and are using criteria A, B, C, and D to compare them; suppose further that the first three criteria favor X and the fourth favors Y. In such a case, you should present the comparison in terms of these two criteria groupings: first A through C, then D. This will make it easier for the reader to see that product X wins out over product Y in three of the four criteria. And that's what the reader will most likely want to know—the proverbial bottom line. (If you think the reader will be more interested in the details of the comparison, provide a table.)

Characteristic features of comparison-and-contrast paragraphs include:

connective words and phrases	however, on the other hand, conversely, similarly, likewise, in contrast to
comparative constructions	more than, -er, than, less than, as . . . as, rather than, is different from
modal verbs	program X ***will*** be easy to implement, whereas program Y ***would*** entail a number of complications . . .
subordinate clauses	while, whereas, but
parallelism	model X is reliable and efficient, whereas model Y is unreliable and relatively inefficient . . .

One final principle of comparison-and-contrast writing is this: *phrase your words so as to reveal your own preference in the comparison.* In other words, don't just make a simple comparison as if you were a neutral observer. Instead, allow your own interpretation of the facts to color your description. Don't say, "Item X weighs 3.2 pounds, and item Y weighs 2.7 pounds"; say, "Item X weighs 3.2 pounds, whereas item Y weighs only 2.7 pounds." After all, *you* are the one who has made the study, and so *you* know what the facts of the matter are. Using some of the features listed above will enable you to let your reader know what your choice is.

Below is a model comparison-and-contrast paragraph. Note how it uses some of the features listed above.

> A one-million-fold increase in speed characterizes the development of machine computation over the past thirty years. The increase results from improvements in computer hardware. In the 1940's ENIAC, an early electronic computer, filled a room with its banks of vacuum tubes and miles of wiring. Today one can hold in the hand a computing device costing about $200 that is twenty times faster than ENIAC, has more components and a larger memory, is thousands of times more reliable, costs 1/10,000 the price, and consumes the power of a light bulb rather than that of a locomotive.[12]

Listing

Scientific and technical writing presents frequent opportunities to put information in the form of lists. If you are describing an experiment, for example, you will probably want to make a list of the equipment used. If you are writing a progress report, you may want to make a list of things already done and another list of things still to do. If you're writing a report recommending the development or purchase of some new product, you may want to list its outstanding features or the reasons you're recommending it.

Lists may be either formatted or unformatted. Formatted lists are set off from the rest of the paragraph by means of indentation and/or numbering or lettering. Unformatted lists do not have such visual cues. In both cases, *all items in a list should be cast in parallel grammatical form.* This principle is especially important in the case of unformatted lists, since it can be quite difficult otherwise for the reader to detect the presence of the list. (Parallelism is important not only in lists but also in comparative constructions, in descriptions of procedures, and in other rhetorical patterns; see Chapter 3 for further discussion.)

A second important principle to follow when constructing lists is this: *if the items in a list are not equally important, they should be arranged in descending order of importance.* A list, by definition, is a set of items all of which have something in common and yet are independent of each other. Thus, in principle, these items can be arranged or rearranged any way at all. You can take advantage of this freedom by arranging them with the most important item in the most prominent position, namely, on top. Here is an example:

> In addition to coal and nuclear energy, a wide variety of other power sources are also frequently discussed in the news and in scientific literature; unfortunately, most are not yet ready for practical use. Geothermal energy is one of the more practical of proposed new sources. It is already in use in Italy, Iceland, and northern California but is not yet meeting all expectations for it. Solar energy seems an elegant idea because it is inexhaustible and adds no net heat or carbon dioxide to the global environment. Yet present methods of exploiting it make solar energy hopelessly inadequate as a major power source in the next few decades. Sophisticated windmills to generate electricity are also under study by some. Biomass conversion is also getting under way. Some of these

> sources of energy, which we now generally regard as esoteric, may well prove themselves and make a substantial contribution over the long run if their costs can be brought within reason.[3]

The different power sources discussed in this paragraph constitute an unformatted list:

> Geothermal energy . . .
>
> Solar energy . . .
>
> Sophisticated windmills . . .
>
> Biomass conversion . . .

Notice how the effective use of parallelism enables the reader to easily locate the four items making up the list, even though no visual formatting is used.

General-to-Particular Ordering of Details

A final rhetorical pattern commonly used in scientific and technical paragraphs is the ordering of supporting details from the more general to the more particular. Each sentence in this pattern focuses on a smaller frame of reference than the sentence before it.

Here is an example of such a pattern, taken from a discussion of the kinds of bearings needed in flywheel energy-storage systems:

> Magnetic bearings have been developed for aerospace applications, but only recently has their practicality been demonstrated as the heart of energy storage systems. The breakthrough is partly due to the recent development of stronger permanent magnets, such as those made from rare-earth cobalt compounds. Only ten pounds of such magnets could support two tons of rotor. Although the free suspension of a weight with permanent magnets is an unstable condition, an electromagnet servo loop has been used successfully to stabilize the rotor position.[13]

Notice how the topic of the first sentence (and of the paragraph as a whole), *magnetic bearings,* is developed in the second sentence by the writer's focusing on one component of such bearings, the *permanent magnets.* This subtopic is then discussed in even greater detail in the third sentence *(Only ten pounds of such magnets . . .).* Finally, the writer focuses on a subcomponent of these magnets, the *electromagnet servo loop.*

Other Patterns

The patterns of organization described above are not the only ones commonly used in scientific and technical writing. Others—such as classification-division, exemplification, extended definition, and analogy, to mention but

a few—are also used. (An example of paragraph development by classification-division, you may recall, was given earlier in this chapter.)

In addition, two or more patterns can often be used together. For example, you might want to give an *extended definition* of a process by describing it in terms of *causes and effects* or in terms of an *analogy* to some more familiar process. You might want to explain something by providing a *list* of *examples.* Or you might want to *divide* some subject into different classes and then *compare and contrast* these classes. Regardless of what kind of combination you elect to use, the important point is to establish at least one pattern of organization that runs through most if not all of the paragraph and thus provides a structural backbone for that paragraph.

EXERCISE 2-3 Each of the following paragraphs follows a particular pattern of organization. Identify the pattern, and point out as many of its features as you can.

A Flywheels appear to be the ideal energy storage element in solar electric or wind power systems. They can smooth the load on the generators by providing the energy to generate electricity when the sun is not shining or the wind is not blowing. And they can also provide peak power to an electrical load during periods when demand exceeds supply, such as during motor start-ups. Indeed, once spinning, flywheels can deliver energy rapidly for transient load conditions, which makes them especially useful in industrial and agricultural applications.[13]

Pattern: _____

Features: 1. _____
2. _____
3. _____

B *Scalar and Vector Quantities.* Every quantity requires a statement of at least two things: first, a numerical specification, or a magnitude, and, second, the appropriate unit. For one class of quantities the statement of a numeral and a unit is all that is necessary for a complete specification. For example, the quantity volume is completely specified when we say "25 cubic feet." On the other hand, for another class of quantities one must state, in addition, a direction in order to afford a complete specification. For example, the quantity force is completely specified when we say "10 pounds acting vertically upward." A quantity that involves, other than the statement of a unit, only the idea of magnitude is called a *scalar,* while a quantity that needs for its complete specification a direction as well as magnitude is called a *vector.* Quantities such as displacement, velocity, acceleration, force, weight, and torque

are vectors: each involves the idea of direction. Quantities such as speed, mass, and energy are scalars; none of these has associated with it a direction.[14]

Pattern: _____

Features: 1._____
2._____
3._____
4._____

C *The Vapor-Compression Refrigeration Cycle.* A simple vapor-compression refrigeration cycle is shown schematically in Fig. 2-1. The refrigerant enters the compressor as a slightly superheated vapor at a low pressure. It then leaves the compressor and enters the condenser as a vapor at some elevated pressure, where the refrigerant is condensed as a result of heat transfer to cooling water or to the surroundings. The refrigerant then leaves the condenser as a high-pressure liquid. The pressure of the liquid is decreased as it flows through the expansion valve, and, as a result, some of the liquid flashes into vapor. The remaining liquid, now at a low pressure, is vaporized in the evaporator as a result of heat transfer from the refrigerated space. This vapor then enters the compressor.[15]

Pattern: _____

Features: 1._____
2._____
3._____
4._____

D One of the newest branches of number theory is *analytic number theory.* A vast and intricate subject, it is largely a creation of the twentieth century. It has been called the science of approximation, for it is concerned mainly with determining the order (relative size) of the errors made when a calculation is approximate rather than exact. Its techniques have had an important impact on many departments of applied mathematics, including statistical mechanics and the kinetic theory of gases, where exact results are sometimes humanly unattainable.[16]

Pattern: _____

Features: 1._____
2._____

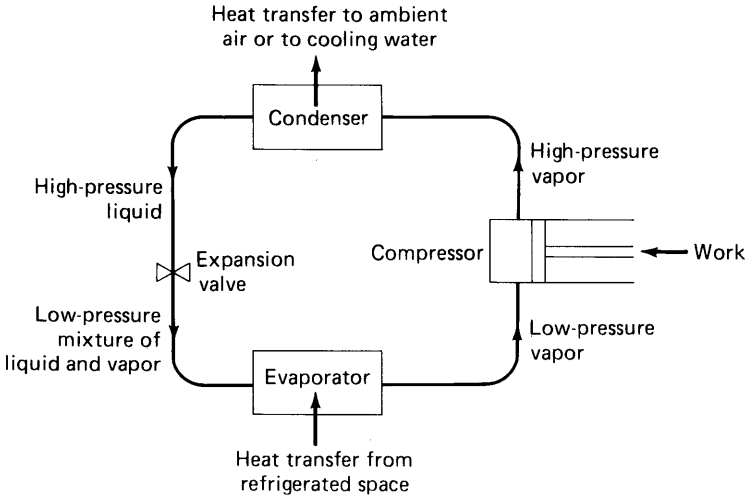

FIGURE 2-1 Schematic diagram of a simple refrigeration cycle.

EXERCISE 2-4 The following passage is taken from a popular-science journal article, where it was divided into seven paragraphs. Using your knowledge of topic statements and patterns of paragraph organization, see if you can determine where the six paragraph divisions should be.

We generally think of volcanoes as sizable mountains that belch lava and smoke from craters at their summits. But the essential element of a volcano is not its aboveground structure but the underground conduit that brings molten rock to the surface. The molten rock is known as magma as long as it is under the ground; after it erupts it is called lava. As the lava flows or explodes from a vent at the top of the conduit, it starts to build a volcanic edifice that may grow into a Vesuvius, a Mauna Loa, or a Mount St. Helens. Few people have witnessed the birth of a volcano, but Dionisio Pulido was present on February 20, 1943, when the Mexican volcano Paricutin made its first appearance in a cornfield on his small farm in the valley of Rancho Tepacua. Pulido, his wife and son, and a neighbor watched as smoke and ash began to rise from a small hole in the middle of the field. The smoke and ash were accompanied by rumbles, hisses, and hot particles of rock that set fire to nearby pine trees. By the next day, ash and rock debris had built a cone 10 meters high; in a week it had grown to 140 meters. By the time Paricutin finally quieted down in 1952, the cone towered 410 meters above the original level of Pulido's cornfield. Paricutin is an unusually large cinder cone, one of four basic types of volcanic edifices. Cinder cones, made up entirely of lava fragments, rarely rise more than 300 meters above their surroundings. They are the simplest type of volcano and are very common in western North America. A second type of volcano is the composite cone, or stratovolcano, built up of alternate layers of

lava and ash (lava particles). Mount St. Helens is a composite cone. So are many other spectacular volcanic peaks, including Mount Rainier and Mount Hood in the Cascades and Japan's Mount Fuji. The summits of many composite cones tower 1800 to 2400 meters above their bases. Shield volcanoes are built almost entirely of lava flows. They are broad, gently sloping structures that resemble a warrior's convex shield laid on the ground face up. Many of the world's largest mountains are shield volcanoes; clusters of them form the Hawaiian Islands. Mauna Loa, on the island of Hawaii, is the world's largest active volcano. Its base is more than 4500 meters below the surface of the ocean, and its crest is 4170 meters above the sea level—a total height of more than 8500 meters. Lava domes, the fourth type of volcano, are built up of thick, pasty lava that tends to pile up in a rough knob rather than to flow outward as it emerges from its vent. The main factors that determine whether lava will erupt in a smooth flow or a violent explosion are its chemical composition and the characteristics of the gases that are dissolved in it. Magma is a mixture of several oxides, mainly silicon dioxide. The rock can be principally basalt, andesite, dacite, or rhyolite, which are distinguished one from the other, among other things, by the fact that each has a larger proportion of silicon dioxide than the one before. Basaltic magmas usually erupt in a highly fluid state, and their dissolved gases escape easily, so that the lava flows freely. The more viscous rhyolites and dacites usually erupt explosively. Andesites may erupt in explosions or in flows that are not as smooth as those of basaltic lava.[17]

EXERCISE 2-5 The following passages (extracted from longer reports) were submitted as is by students. As you'll discover, they require very careful reading in order to be understood. Revise them—by rearranging or rewriting sentences, or perhaps by dividing them into two or more paragraphs—so that they can be more quickly and easily understood.

A ADVANTAGES AND DISADVANTAGES

The balance system is the simplest and cheapest system. However, it has drawn numerous complaints from users in California. The nozzles are heavy, hard to hold in place, and hard to remove due to the necessary airtight seal. The major problem has been that gasoline has been sucked out of the customer's tank back into the storage tank. This occurred when customers attempted to top off their tank and in the process overrode the automatic shutoff. The brands of the nozzles (OPW) were tested by the ARB in actual stations by inserting a small vial in the vapor return hose and checking for liquid in the vial after filling the vehicle. In the ARB tests the nozzles did not fail. However, in the MS test the nozzle failed. A $3\frac{1}{2}$-gallon container fitted with a standard auto filler pipe was used. The container had a mechanism to allow the inside pressure to be increased, and a 22.5% failure rate was reported. In one trial the container was filled to 15 gallons. The vacuum and assisted systems do not permit this overfilling, and no force is required to hold the nozzle. The prices of the three systems vary significantly. The balance system costs $\frac{1}{2}$ the amount of the assisted system, and the vacuum system is the most expensive.

B TECHNICAL DISCUSSION

The most important part of this modification program is the addition of a larger engine to the Corsair. The eighteen-cylinder Pratt & Whitney R-2800-CB-13 and three-bladed propeller that are the standard fit for an FG-1D are rated at 2500 hp, though there are cases where R-2800s have supplied up to 3300 hp (Greenamyer, 1969) in modified form. One possible alternative to the R-2800, a Curtiss-Wright R-3350-24 Cyclone 18, has been substituted for an R-2800 in an F8F-2 Bearcat. Rated at 2800 hp, this particular example has been pushed to 3800 hp (Shelton, 1971). Another alternative is the twenty-eight-cylinder Pratt & Whitney R-4360-4 Wasp Major. These were raced in the late 1940s on F2G Corsairs with four-bladed propellers. These engines were rated at 3000 hp, though in races they produced up to 4000 hp (Cleland, 1949). After some careful checking, I have chosen to recommend fitting a Pratt & Whitney R-4360-B-20 with a four-bladed propeller, to your Corsair. While rated at 3500 hp, I expect it to produce over 4000 hp after modification. One particular advantage in using the R-4360-B-20 is that it won't increase the aircraft's frontal area, being the same diameter as an R-2800. In contrast, an R-3350 would increase the frontal area by 11% because of its larger diameter. However, in fitting this larger engine, there will be a weight penalty of 1130 pounds. To keep the aircraft's center of gravity from moving too far forward, the firewall will have to be moved back at least a foot.

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3

PARALLELISM

All writing—whether of books, of reports, of articles, of sections of articles, of paragraphs, of sentences, etc.—consists of both form and content. Reading is made easier to the extent that the form *reflects* the content: we can then use formal features as cues to guide us as we try to absorb and interpret the content. Selective readers in particular depend on features of form to guide their reading. Such features are easy to spot and thus serve as signposts, allowing the reader to zero in on and quickly process those parts of a text that are of particular interest.

One way in which form reflects content is when we use grammatical parallelism in the writing of lists. If you write out a list, "Things To Do," that looks like this:

pick up mail

call Hazlitt

work on tailgate project

don't forget to ask RJ for $$

you're using parallelism because you've put each item on the list in the same grammatical form (verb + one or more nouns). If you write the list like this, on the other hand:

mail needs to be picked up

call Hazlitt

tailgate project

don't forget to ask RJ for $$$

you're not using parallelism.

Of course, when you're just writing to yourself, you can afford to be less careful than when you're writing to someone else. After all, *you* know what you mean, don't you? In writing to other people, however, there will be many times you'll find yourself writing out lists, and in such cases it's important that you make it optimally easy to read them. Here's where parallelism has an important role to play.

Before we describe this role, however, perhaps we should clarify what we mean by the word *list*. What exactly *is* a list? As we refer to it here, a list is any set of two or more independent items, i.e., any two or more items

sharing a coordinate (related but nonoverlapping) relationship. This definition includes not only obvious cases such as the one described above but also others that may not be so readily apparent. For example, the following sentence contains a list since two different but related functions (*metabolite transport* and *metabolite signaling*) are mentioned:

> Evidence that the receptor sites on the membrane can serve both for metabolite transport and for metabolite signaling has raised many questions as to the mechanisms of membrane information-transfer.[1]

The following sentence also contains a two-item list:

> A pollution-free inertial-electric system has greater energy efficiency than an internal combustion engine.

Here the items forming a list are the two systems that are being compared.

3.1 TYPES OF LISTS

Lists are especially common in scientific/technical writing. We find lists of experimental apparatus, lists of instructions, lists of task objectives, and so on. Some lists are *fully formatted* as such, with alphanumeric sequencing and vertical alignment used as formal features to make the list stand out. Here is an example, from a company memo:

REFS:(a) Government invoice #79-1018A
(b) Bonded Stores invoice #31285
(c) DECAS letter 5/20/79
(d) Bonded Stores invoice #44590

Some lists are *partially formatted,* in the sense that they use either alphanumeric sequencing or vertical alignment but not both, as in this example:

> Factors taken into consideration include the following: (1) size of lot, (2) parking requirements, (3) need for elevator, (4) cost per gross square foot, and (5) expected annual return per gross square foot.

Some lists are completely *unformatted,* having neither alphanumeric sequencing nor vertical alignment:

> Compared to standard bipolar types, VMOS transistors offer higher input impedance, faster switching times, wider operating range, and smaller chip area.

In all cases, however, whether a list is fully formatted, partially formatted, or unformatted, *all of the items making up the list should be cast in the same grammatical form.*

Putting the items of a list in parallel grammatical form allows a busy reader to easily perceive the nature of these items and of the list as a whole. It is especially important to use this principle with unformatted lists. In the VMOS example above, notice how easy it is to glance at the sentence and see what the four criteria of comparison are: . . . *input impedance . . .switching times . . . operating range . . . chip area.* By contrast, notice how difficult it is to perceive the nature of the list, and the items making up the list, in the following badly written example:

NEGATIVE EXAMPLE

The TFC engineers and I found the selection of Hybrid Analog Transmission using FDM (Frequency Division Multiplexer) to be highly reliable, improved security of communications; complete ground isolation, freedom from cross-talk, sparking, short circuit loading; RFI (radio frequency interference), EMI (electric magnetic field), and EMP (electric magnetic polarization) immunity.

What are the major items constituting the list in this example? What role are they playing? You may be able to figure out the answers if you work at it, but many readers—especially managerial readers—are not willing to go to such effort.

As a general rule, you should always endeavor to use parallelism when you are presenting a list in written form. Often this will be a relatively straightforward matter, involving fully-formatted lists made up of simple items. In such cases, all you need do is make minor adjustments so that every item has the same grammatical form. Suppose, for example, you have written a draft of a report about wastewater processing and have included this statement:

NEGATIVE EXAMPLE

The principal processes are:

a) coagulating and flocculation

b) removing the solids

c) nitrogen-removal

d) disinfection

Surely it would be an easy matter to recast this list in a more grammatically parallel form:

The principal processes are:

a) coagulation and flocculation

b) removal of solids

c) removal of nitrogen

d) disinfection

Instead of mixing verb forms (*-ing*) and noun forms (*-al* and *-tion*) as in the first version, the second version uses all noun forms. This results in a more sharply defined list; it looks more like the work of a careful, precise technical professional.

But the proper use of parallelism can do far more than just enhance your professional image: it can also help prevent misinterpretations of your writing. To see what can go wrong when parallelism is *not* used, consider the following:

NEGATIVE EXAMPLE

This filter has two important functions: to reject impulse noise signals and passing low frequency command signals without amplitude or phase distortion.

This excerpt could easily be misread (especially by a busy nonspecialist reader) as meaning that two things are rejected: the impulse noise signals and the passing of low frequency command signals. Notice that *reject* and *passing* can be combined to produce such a misreading. Even those readers who can figure out what the writer is trying to say may have to slow down their reading just to make sure what's being rejected.

Such ambiguity is completely unnecessary. By putting the two key verbs in parallel form, the writer can create a much clearer version:

This filter has two important functions: *rejecting* impulse noise signals and *passing* low frequency command signals without amplitude or phase distortion.

Other parallel forms would work equally well: *to reject . . . to pass; the rejecting of . . . the passing of.*

EXERCISE 3-1 Each of the following contains a list that lacks parallelism. See if you can devise an improved version.

A The building is 140 feet in length, 78 feet wide, and has a height of four stories.

B Test results indicate that soil #1 is likely to settle, since high plasticity is equivalent to highly compressible.

C The widest employment of DDT is in the control of insects of public importance (as a mosquito larvicide, a spray for malaria eradication, and to control typhus by dust application).

D The reason for this is that most small businesses have a lower budget for their managers than do government or industrial managers.

E In this particular case the most important variables are the following:
(1) pressure and temperature of the boiler
(2) what type of fuel is required
(3) the amount of oxygen
(4) fuel temperature

F As a result of the above problem, this report addresses the following tasks:
a. To redesign the mix for the concrete slabs
b. An evaluation of the compressive strength with the use of test cylinders for various designs
c. Determining both the theoretical and actual material costs per cubic yard

G We recommend the purchase of the New Orleans heat exchanger because (i) it can be obtained for $25,000, a savings of 80% over the new cost, (ii) production could be increased by 28% if needed, 8% higher than requested, and (iii) it will help recoup losses incurred in our benzene plant.

H Advantages of this system are:
1. Automatically controlled
2. Less operating cost

Disadvantages are:
1. May cause slugging of liquid refrigerant to compressors
2. Complex automatic controls
3. Substantial replumbing of existing system is required

I This buoy terminal has three components that rotate as a single unit:
(a) The Rotating Mooring Bollard allows floating mooring lines to lie on the lee side when weather conditions become bad.
(b) Products are carried by a Rotating Cargo Manifold from the terminal-to-tanker hoses to the multiproduct distribution unit in the center of the buoy.
(c) A Rotating Balance Arm not only maintains the buoys on an even keel but also provides an accommodation ladder.

J The purpose of this report is to present evidence that the contracting officer acted within the range of his authority and his final opinion was binding.

3.2
MISLEADING PARALLELISM

Given the fact that readers use parallelism as an aid in perceiving and interpreting a list, it is important that you *not* use parallelism in situations where lists are *not* involved. Otherwise, readers are apt to be misled and may misanalyze the passage *as* a list, which in turn can lead to comic interpretations or to unnoticed misinterpretations. Here is an example:

NEGATIVE EXAMPLE

Richard Clarke, senior systems programmer, asked me to develop a magnetic tape management system, to reside permanently on the computer, to give better control, and to coordinate the numerous magnetic tapes.

The parallel use of infinitives in this sentence makes it appear that a four-item list is being presented:

Richard Clarke, senior systems programmer, asked me:

- to develop a magnetic tape management system
- to reside permanently on the computer
- to give better control
- to coordinate the numerous magnetic tapes

This would mean, among other things, that it is the writer, not the system, that will "reside permanently on the computer, give better control," etc., surely a strange state of affairs! Of course, most readers would probably figure out what the writer means, but this requires extra time and effort on the reader's part—precisely what good writing avoids.

In cases like this, the writer should break up the misleading parallelism so that only those items that really are part of the list appear in parallel form. In this particular case, only the last three items belong together; the first item should be kept separate. If the last three items were written as relative clauses, say, instead of as infinitives, they would be distinguished from the first item:

Richard Clarke, senior systems programmer, asked me to develop a magnetic tape management system:

- which will reside permanently on the computer
- which will give better control
- which will coordinate the numerous magnetic tapes

This can be simplified by factoring out the relative pronoun and auxiliary verb (*which will*) and making them part of the lead-in:

> Richard Clarke, senior systems programmer, asked me to develop a magnetic tape management system which will *reside permanently on the computer, give better control,* and *coordinate the numerous magnetic tapes.*

Compare this version to the original one and see what a difference there is in readability.

EXERCISE 3-2 Each of the following passages contains misleading parallelism. Correct each passage by making appropriate grammatical changes.

A My present occupation is repairing typewriters, printing machines, and duplicating machines.

B You learn many reasons why our product failed by reading, observing, talking and listening to our sales people.

C This technology consists of three methods of scrambling, which are the coupling of light source and optical fiber in low-order mode, splicing, bending and tightening the fiber near its connectors, and installing the scrambler into the existing fiber optic in intervals of 1 km along the route.

3.3
PARALLELISM IN PARAGRAPHS AND LARGER UNITS

Perhaps the most important use of parallelism—one which poor writers usually neglect—is to indicate the presence of listlike structures in paragraphs and groups of paragraphs. Two or more sentences may be related coordinately within a paragraph; two or more paragraphs may be so related. Since these kinds of larger lists are customarily unformatted, parallelism is usually the only formal cue that can be used to guide the reader.

Here is an example of how the failure to use parallelism to indicate paragraph structure can make it difficult to read quickly and selectively, if not accurately:

> **NEGATIVE EXAMPLE**
> All-Savers Certificates will not benefit all investors. Investors exceeding a deposit of $7931 ($15,861 joint return) would have an after-tax yield far lower than alternative investments such as money market funds or Treasury bills. Alternative investments would also yield better after-tax yields and no penalty if the certificate was redeemed within the 1-year maturity period.

A common strategy used to skim-read paragraphs is to first read the topic sentence and then read the beginning words of the following sentences to see what kind of support these sentences provide for the topic sentence. In the case above, a person using this technique can easily be misled into

perceiving the paragraph as having a general-to-particular structure. The first sentence is clearly the topic sentence. The second sentence supports it by describing a class of investors who would benefit more from alternative investments than from All-Savers Certificates. The third sentence then appears to provide additional details about alternative investments. The diagram below illustrates this structure:

All-Savers Certificates will not benefit all *investors.*

Investors exceeding a deposit of $7931 . . . would have an after-tax yield far lower than *alternative investments.* . . .

Alternative investments would also yield better after-tax yields and no penalty. . . .

Notice how the chain of repeated words links one sentence to the next, each one appearing to be subordinate to the one above it. In actuality, however, the writer means to say that there are not one but *two* classes of investors who will not benefit from All-Savers Certificates: those who exceed a deposit of $7931 and those who redeem their certificates before 1 year has elapsed. The purpose of the paragraph (as we were informed by the writer) is to describe these two classes. The second and third sentences, therefore, constitute a two-item list, with each of the sentences describing one of the two classes. If the writer had cast these two sentences in parallel form, it would be much easier for readers to see this listlike structure:

> All-Savers Certificates will not benefit all investors. Investors exceeding a deposit of $7931 ($15,861 joint return) would have an after-tax yield far lower than alternative investments such as money market funds or Treasury bills. Investors redeeming the certificate within the 1-year maturity period would have to pay a penalty and would also have a lower after-tax yield than with alternative investments.

The diagram below illustrates why this revision has a more transparent listlike structure:

All-Savers Certificates will not benefit all *investors.*

Investors exceeding a deposit of $7931 . . . would have an after-tax yield far lower than alternative investments. . . .

Investors redeeming the certificate within the 1-year maturity period would have to pay a penalty and would also have a lower after-tax yield. . . .

The use of parallelism enables the reader to see very quickly that the second and third sentences constitute a two-item list.

EXERCISE 3-3 Each of the following passages contains information that can be presented in the form of one or more lists. Reconstruct each passage accordingly, using appropriate parallelism.

A In order to meet the job requirements it became clear that a microcomputer would be required to do this type of work. Microcomputers are very compact and portable. They are easily programmed and can be used for a wide variety of data processing. These computers are normally quite easy to operate and capable of storing large amounts of data both inside and outside of the computer itself. The most attractive part of using a microcomputer is that it is very inexpensive in comparison to other large-scale systems.

B Reuse of treated water is most applicable where large amounts of water are used and the wastes are not too contaminated. Industrial wastes may be heavily contaminated and therefore may not be very suitable for reuse. The location of the treatment plant and the possible transport of the renovated water are also important factors. The treatment process works most efficiently and economically when dealing with a steady flow of wastewater. A very important point is whether the wastewater will be reused only once or whether it will be reused many times. Multiple recycling results in a buildup of certain dissolved materials, especially inorganic ions, that may make demineralization necessary. Most reuses do not lead to a high degree of recycling.

C By checking the instrumentation used for this experiment, it was noticed that the collimator is not close enough to the x-ray film, and therefore a lot of neutrons have been lost in this way. But if we minimize this distance, fewer neutrons will be lost by leakage. Also, for better and sharper pictures we need a high resolution which is obtained when neutron beams are as parallel as possible; to achieve a higher resolution we have to either decrease the collimator or increase its length. In this case we cannot increase the collimator length, since it is as long as the depth of the reactor pool, which is a constant. Therefore the only alternative is to decrease the diameter of the collimator for a better resolution.

D The new design meets all of the important criteria. The new design uses the same sulfur dioxide scrubbing process used in the present scrubbing system. Therefore, the new design gives the same sulfur dioxide removal rate as the present system. The new design includes

a regeneration loop for the absorption reactant, thereby cutting the absorption reactant consumption considerably. The new design also terminates with a solid waste product. Thus, a very manageable waste product is produced.

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