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CONSTRUCTING EFFECTIVE PARAGRAPHS

A well-written scientific manuscript demands strong, effective paragraphs for support. An effective paragraph is characterized by unity of theme, and those themes from all paragraphs together provide the constituents of the manuscript. This chapter describes how to construct potent paragraphs, focusing on the coherence internal to a paragraph centering about the unitary theme, as well as the coherence between paragraphs that make the manuscript fluid.

As atoms are to matter, paragraphs are the fundamental organizational unit of a paper. Paragraphs serve this role because each one contains only one theme, which is explored within the bounds of the paragraph. Subsequent paragraphs deliver different themes, and the accumulation of themes with each paragraph builds the content of the manuscript. Thus, effective paragraphs bind the manuscript together.

Effective paragraphs possess two primary characteristics: unity and coherence. Unity means a paragraph consists of one theme only. Everything within that paragraph should be related to that one theme. The focal point of the paragraph, the *topic sentence*, defines the theme of the paragraph. Although typically the first sentence of the paragraph, the topic sentence may sometimes appear at the end of the paragraph for additional emphasis. Should more than one theme be in a paragraph, three options exist—break up the paragraph, one new paragraph for each theme; revise the topic sentence and, hence, the scope of the paragraph to encompass multiple themes; or delete one or more themes. The importance of the topic sentence should not be underestimated. As part of their outlining, some authors write the topic sentences for each paragraph, ensuring a logical flow between topics early in the writing process.

Coherence within a paragraph derives from the ordering and relationship between sentences. Sentences within each paragraph should proceed in

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ELOQUENT SCIENCE



A practical guide to becoming a better
Writer, Speaker & Atmospheric Scientist

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AMERICAN METEOROLOGICAL SOCIETY

The writer has much control over the paragraph. The main sections of the paper are largely determined by convention, and the structure of sentences is determined by the syntax of the language. The paragraph however has no such formal constraints; the chief constraint is content. —Antoinette M. Wilkinson (1991, p. 437)

a logical order, introducing new concepts sequentially. (An example of how improper ordering can affect coherence is presented in Section 7.3.)

8.1 COHERENCE WITHIN PARAGRAPHS

When I was living in Norman, Oklahoma, colleagues at Iowa State University in Ames, Iowa, invited me to visit. I had never been to Iowa State before and I wanted to see some other places on my way back home, so I drove the 600 miles. From the Web, I determined the following directions to the building that housed the Meteorology Program:

1. From Norman, take Interstate 35 north to Ames.
2. Leave the highway at Exit 111.
3. Drive west on Highway 30.
4. Turn right on University Boulevard.
5. Turn left on Lincoln Way.
6. Turn right on Union Drive.
7. Turn right on Wallace Road.
8. Turn left into the parking lot of Agronomy Hall.

Imagine if I misread the directions, rearranged the order of the instructions, forgot one of the eight steps, or made a wrong turn. With a little concerted effort, I probably could still get to Agronomy Hall. The more the directions were altered, the more effort (and gasoline and time) would be wasted. For travelers familiar with Ames, these directions would probably suffice, even with a few transcription errors. But, for me, making a mistake, being confused, and getting lost were possibilities.

To supplement these directions from the Web, I asked one of my colleagues, Prof. Bill Gallus, to send me directions. Here is what he sent:

1. From Norman, take Interstate 35 north to Ames.
2. Take the first exit for Ames, which is exit 111 (Highway 30), with signs mentioning Iowa State University.
3. Drive west on Highway 30 until the third exit, which is University Boulevard.
4. Take a right on University Boulevard and drive past the big football stadium and the large coliseum.
5. Just beyond the coliseum will be Lincoln Way. Turn left at this light.
6. Be sure to get in the right lane, because you'll be making a right onto Union Drive in only two blocks. This road takes you past the president's mansion.

7. Turn right onto Wallace Road after a block or so. This intersection is at the bottom of the hill.
8. Stay on Wallace for about two blocks until you see the Agronomy Building on your left. It is the large, red-brick building on the southeast corner of the intersection of Wallace and Osborne Drive. Turn left into the parking lot.

Had I misread Bill's directions, rearranged their order, forgot some steps, or made a wrong turn, the additional detail would have been incredibly helpful in returning me to my desired route. Bill's directions are more informative and longer, but the turns, where I potentially could have made an error, are more descriptive. Sometimes his directions repeat elements from the previous step. For example, the coliseum was mentioned at the end of the fourth step and the beginning of the fifth step. Had I omitted step 4 inadvertently, I might have still found my way knowing that I was to pass the coliseum. As a result of the additional detail and repetition, Bill's directions gave me additional confidence during my drive.

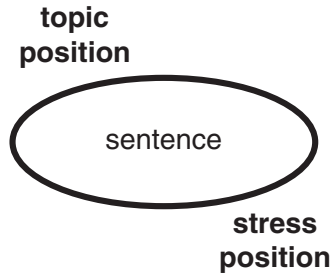
Writing is like providing directions to the reader. You could provide directions such as the terse first set and wish the audience luck on their journey through your manuscript, hoping that they fully understand what you wrote and make no mistakes. Or, you could provide clear, detailed directions, describing how each turn relates to the next, as with Bill's directions. Readers, like travelers, appreciate being led through all the steps. The transitions may be clear in the author's mind, but the author needs to inform the readers of those transitions, especially if the audience is unfamiliar with the topic, just like the traveler unfamiliar with Iowa will want detailed directions. Anticipating how the audience will interpret your writing is one challenge of coherent writing.

The secret to creating a coherent paragraph lies in recognizing the structural expectations that the audience places on the text they read (Gopen and Swan 1990). As the audience reads text, they have "old information," material that they have already been exposed to, and "new information," material that they are just being exposed to. Just as the beginning of a paragraph has a topic sentence, the beginning of the sentence has a *topic position* (Fig. 8.1a). Placing old information in the topic position comforts the reader, providing links backward and context forward. The topic position connects the material previously introduced in the text (e.g., the prior paragraph) and the new material to be introduced in the present paragraph. In this way, writing is linking up information in a logical, flowing manner (Fig. 8.1b), just like steps 4 and 5 in Bill's directions were linked through his repetition of "coliseum."

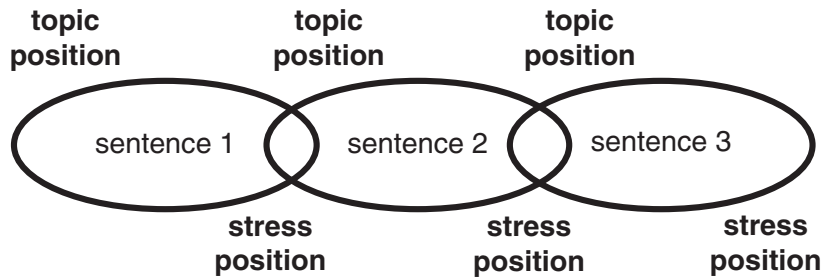
In the same way that the beginning of a sentence or paragraph is important, the end also has special significance. New information to be emphasized

I aim for the happy medium between too much and too little information. I don't know of any formula that directs one toward the optimal amount of information. Inasmuch as the optimal amount depends on the receiver as well as the transmitter—I try to be sensitive to audience response to see what works and what doesn't and adjust accordingly. —Richard Rotunno, National Center for Atmospheric Research

Fig. 8.1 (a) A single link in the chain: a sentence with a topic position at the beginning and a stress position at the end. (b) Creating a chain of links: linking the sentences together by connecting the stress position of one sentence to the topic position of the next sentence.



(a) Structure of a sentence



(b) Maintaining transition in a paragraph by linking the stress position of one sentence to the topic position of the next

should appear at the end, in the *stress position* (Fig. 8.1a). Readers naturally emphasize the material at the end, whether it be at the end of a sentence, the end of a paragraph, or at the end of a novel. Secondary stress positions within a sentence may also occur before colons or semicolons.

Read this paragraph out loud. Notice how you naturally place the emphasis in your voice at the end of each sentence? Material improperly occupying the stress position might receive undue attention from the reader, and, therefore, the author would fail to communicate the most important point. Furthermore, the material in the stress position typically links forward. Such linkages help the reader infer the relationship between one sentence and the next, thus helping to keep that link in the chain intact.

8.2 EXAMPLES OF COHERENCE

There are many ways to maintain coherence within a paragraph. Here are three examples: repetition, enumeration, and transition.

8.2.1 Repetition

Repeating key words and phrases (what Michael McIntyre of the University of Cambridge calls lucid repetition) is one of the easiest ways to maintain coherence. The words or phrases do not have to be identical, but the linkage should be clear. In the paragraph below, the topic, the life cycle of a cyclone, appears in the first sentence. Each subsequent sentence is linked to the previous one by the italicized words.

The life cycle of a Bjerknes and Solberg (1922) cyclone, hereafter the Norwegian cyclone model, begins with a small-amplitude *disturbance* on the polar front. This *disturbance* consists of a cyclonic circulation that advects cold air equatorward west of the cyclone center and warm air poleward east of the cyclone center, forming *cold and warm fronts*, respectively. Because the *cold front* is observed to rotate around the system faster than the *warm front*, the cold front eventually *catches up* to the warm front, forming an occluded front. Originally, Bjerknes and Solberg (1922) believed that this *catch up* initially would occur away from the low center.

Pronouns can also be used to link sentences, if the pronoun has a clear noun to which it refers.

Galway (1975) developed an outbreak definition that included three classifications of family outbreaks: small (6–9 tornadoes), moderate (10–19 tornadoes), and large (20 tornadoes). *He* found that 73% of the tornado deaths from 1952 to 1973 were attributed to outbreaks with 10 or more tornadoes.

In the two examples above, despite being excerpted from journal articles and devoid of the surrounding text, the text makes sense because the grouping of sentences exhibits coherence.

8.2.2 Enumeration

Organizing a list of items through enumeration helps readers follow your argument. If more than a few sentences for each item are needed, start a new paragraph for each item. Make this enumerated list within the text painfully clear to the audience. Use “first,” “second,” etc., as the extra “-ly” in the adverbs “firstly,” “secondly,” etc., is not needed. Alternatively, for longer enumerations, the topics could be listed as a numbered list, as a bulleted list, or as a table.

These jet-streak winds could play *three* roles in the resulting convection. *First*, the jet streak provides upper-level synoptic-scale ascent leading to development of cirrus, reducing insolation and slowing the removal of the low-level

capping inversion. *Second*, the low-level synoptic-scale ascent associated with the jet streak favors the removal of the cap through adiabatic cooling, which would counter the cloud-radiative effects and promote the development of deep, moist convection. *Third*, the strength of the incoming winds affects the magnitude of the deep-layer shear and storm organization, favoring long-lived, isolated, rotating storms.

8.2.3 Transition

Read the following paragraph.

DRAFT: Whether or not the center of a mammatus lobe is warmer or colder than ambient depends on the individual lobes and the height at which the temperature is examined. Lobes simulated in experiment M2 have both warmer and colder cores than ambient (Fig. 4a). Lobe 1 has a warmer-than-ambient core near the bottom of the lobe. Lobes 2 and 3 have colder-than-ambient and near-ambient cores (Fig. 4a). Lobe 1 is warmer than ambient at lower heights near the base of the lobe; at higher heights, the perturbation is colder than ambient. Lobes simulated in experiment M3 have core temperatures near ambient for most of the depth of the mammatus lobe (Fig. 4b).

The paragraph seems to read as a list of observations about lobes 1, 2, and 3 and two experiments, M2 and M3. Why are these observations important and how do they relate to one another? Although repetition of “lobe” and “experiment” provides some comfort, meaning may still elude the reader.

Transitional devices are words or phrases that are used to maintain coherency by indicating relationships between sentences and sentence fragments. Transitional devices can indicate similarity, contrast, sequence, emphasis, causality, or summary (see the sidebar). By inserting just a few transitional devices into the paragraph (seven italicized words in a 119-word paragraph), the relationship between these observations becomes much clearer.

IMPROVED: Whether or not the center of a mammatus lobe is warmer or colder than ambient depends on the individual lobes and the height at which the temperature is examined. *For example*, lobes simulated in experiment M2 have both warmer and colder cores than ambient (Fig. 4a). *Specifically*, lobe 1 has a warmer-than-ambient core near the bottom of the lobe, *whereas* lobes 2 and 3 have colder-than-ambient and near-ambient cores (Fig. 4a). *Furthermore*, lobe 1 is warmer than ambient at lower heights near the base of the lobe; at higher heights, the perturbation is colder than ambient. *In contrast*, lobes simulated in experiment M3 have core temperatures near ambient for most of the depth of the mammatus lobe (Fig. 4b).

COMMON TRANSITIONAL DEVICES FOR SCIENTIFIC WRITING

Sequence

again, and, besides, then, further, furthermore, next, moreover, in addition, first, second, third, etc.; (a), (b), (c), etc.; 1), 2), 3), etc.; following this, subsequently, to enumerate, also, another, last, plus

Comparison and contrast

at the same time, on the contrary, in contrast, nevertheless, notwithstanding, nonetheless, conversely, like, unlike, even so, in the same way, as, unless, whether, though, even though, regardless, irrespective, otherwise, in comparison to, even when, to the contrary, but, or, nor, yet, inasmuch, contrary to, comparing, alternatively, rather, despite, ironically

Examples

for example, for instance, in the case of, in general, especially, if, specifically, in particular, generally, on this occasion, in this situation, to illustrate, to demonstrate, as an illustration, as a demonstration, unless, such as, provided that, once again, another example, a further example, a further complication, in such cases, in this way, in some of these cases, for these reasons, one way, another way, as discussed, using, particularly, that is, more specifically, except

Time

while, since, simultaneously, presently, meanwhile, thereafter, thereupon, afterward, at the same time, next, sometimes, in the meantime, eventually, following this, later, usually, occasionally, concurrently, preceding this, as, presently, at the time of this writing, often, rarely, throughout, by, at, during, continuing

Cause and effect

therefore, thus, consequently, as a consequence, for this reason, hence, accordingly, because, due to, in spite of, despite

Emphasis

surprisingly, indeed, interestingly, curiously, in fact, of course, naturally, evidently, certainly, clearly, obviously, apparently, fortunately, especially, significantly, perhaps, from my perspective, if possible, if so, basically, in reality, essentially

Concluding

finally, therefore, in summary, to conclude, in conclusion, to summarize, as I have shown, hence, thus, in other words, as said earlier, in any case, as a result, at least, as mentioned above, as said previously, thereby, in the present article, simply put

8.3 COHERENCE BETWEEN PARAGRAPHS

Coherence exists within a paragraph through the orderly succession of sentences. Yet, to create fluidity through the document and a lucid story for the reader, coherence must also exist through the orderly succession of paragraphs. Coherence between paragraphs is created through the same mechanisms discussed in Section 8.1, except on the paragraph scale using sentences, and occasionally words, as the transitioning elements. To demonstrate this coherence for a specific example, the first one or two sentences and the last sentence in the first six paragraphs of an article have been reprinted below, omitting the citations.

Introduction

[1] Single- and multiple-banded (hereafter, banded) clouds and precipitation are commonly observed in association with frontal zones in extratropical cyclones. . . . Indeed, some observational studies over extended periods of time show the presence of MSI [moist symmetric instability] in association with banded precipitating baroclinic systems to be rather common.

[2] Although we do not deny the likely existence of slantwise convection or the possible involvement of MSI in some precipitating systems in the atmosphere, it is our contention that CSI [conditional symmetric instability, a form of MSI] is frequently misused and overused as a diagnostic tool. We believe the following four reasons are responsible, in part, for the present situation. . . . Thus, for these four reasons, CSI is commonly observed yet often misinterpreted and misunderstood.

[3] The purpose of this article is twofold: to attempt to limit further misuse of the CSI paradigm by researchers and forecasters alike by highlighting common pitfalls, and to encourage future research explorations that are directed at the deficiencies in our understanding of MSI and slantwise convection. The remainder of this article is as follows. . . . Finally, Section 8 consists of a summary of main points, directions for future research, and a concluding discussion.

An ingredients-based methodology for slantwise convection

[4] Throughout this article, we wish to differentiate between *free convection* and *forced convection* as motions in the atmosphere that are associated with the presence and absence of instability, respectively. Unless otherwise specified, we use the generic term *convection* to imply free convection (gravitational or symmetric). [This paragraph is only two sentences long.]

[5] To clarify some of the confusion surrounding the concepts of CSI and slantwise convection, we find it useful to demonstrate parallels with the more familiar concepts of moist gravitational instability and convection. An exploration of these parallels begins with an ingredients-based methodology for forecasting deep, moist convection. . . . “Remove any one of these [ingredients] and there well may be some important weather phenomena, but the process is no longer deep, moist convection.”

[6] For the purposes of this article, we adopt the same triad of ingredients from moist gravitational convection (instability, moisture, and lift) for the production of moist slantwise convection, where the requisite instability becomes MSI, rather than moist gravitational instability. . . . The ingredients-based methodology firmly labels CSI as the instability, clearly separate from the lifting mechanism.

Even with most of the central text within each paragraph omitted, the remaining text remains mostly readable. The reason is the effective coher-

ence between the paragraphs. For example, enumeration was used within paragraphs 2 and 3. Repetition of “MSI” and “precipitating systems” was used between paragraphs 1 and 2, and repetition of “ingredients” was used between paragraphs 5 and 6.

Some improvement in coherence between paragraphs 2 and 3 could have been gained by repeating “misinterpreted and misunderstood” at the beginning of paragraph 3 with a slight revision: “The purpose of this article is twofold: to attempt to limit further *misinterpretation* of the CSI paradigm by researchers and forecasters alike by highlighting common pitfalls, and to encourage future research explorations that are directed at *correcting our misunderstandings* of MSI and slantwise convection.” This revision shows more

SECTIONS AND SUBSECTIONS

Sections and subsections can be important to your paper for helping the reader see the organization of the paper more clearly. Sections and subsections allow readers to identify quickly the topics of interest to them and to skip the others. Section headings also provide some relief from whole pages of uninterrupted text, which can be imposing to a reader. However, creating subsections does not substitute for good transitional writing between the paragraphs (Section 8.3). Here are a few basic rules for creating sections and subsections:

- ▶ In general, at least two sectional headings are needed (e.g., Section 3.1 or 3a must be followed by a Section 3.2 or 3b). However, a minority of authors have argued that a single subsection within a section is legitimate. Creating a second subsection, they argue, would be forced, not natural.
- ▶ In general, some introductory text should exist between a major heading and a subheading (e.g., between the heading for Section 4 and the heading for Section 4.1). This material can be introductory material or a discussion of what will be covered within the section.

- ▶ Balance the number of headings, the number of topics to be discussed, and the length of the text under each heading. Too few headings and the corresponding text may be too long; too many headings and the corresponding text may be too short.
- ▶ Heading titles should have the same properties of a manuscript title, albeit much shorter: informative, accurate, clear, concise, and attention commanding (Table 3.1).
- ▶ Use descriptive titles, avoiding one-word titles (except for “introduction,” “conclusions,” etc.).
- ▶ Keep titles at each level parallel, if possible. If the titles are verb phrases (e.g., “Constructing the climatology,” “Evaluating model performance”), do not intersperse noun phrases (e.g., “Comparison of control and no-flux simulations”).
- ▶ Repeating the title in the body of the text shortly after starting the new section can give the readers comfort that you are going to address the topic that is described by the title.

Before submitting a manuscript, separate from the text and list all the section and subsection headings (e.g., table of contents, outline). Are the titles parallel (Section 9.4)? Does the organization of the paper as told through the outline make sense? See Section 4.15 for examples of effective paper organization.

clearly that the misinterpretations and misunderstandings of CSI will be addressed within the article.

8.4 LENGTH AND STRUCTURE OF PARAGRAPHS

In scientific writing, four to eight sentences per paragraph seems to be optimal in most cases. Although shorter paragraphs of two or three sentences can be used for emphasis from time to time, avoid single-sentence paragraphs as a general rule. Such paragraphs should be eliminated, merged in with another paragraph, or developed into a longer paragraph. On the other hand, coherent paragraphs much longer than eight sentences may be functional, but you may wish to break them up. Because the white space around paragraphs on the printed page serves partially as a visual break for the reader, long tracts of text can be imposing to the reader and are candidates for splitting into multiple paragraphs.

Within the paragraph, the sentences should vary in length and in rhythm, specifically in their construction or the location of the subject and verb within the sentence. Too many short sentences sound too sing-songy or elementary, whereas too many long sentences tire the reader. In the same way, the assemblage of paragraphs in the manuscript should also have variety in length and structure.

Paragraphing calls for a good eye as well as a logical mind. —William Strunk and E. B. White (2000, p. 17)