Technical Manuscript Writing for Doctoral Candidates

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Module 4. The Anatomy of a Paragraph

Introduction to Paragraphs

Once you have put together the outline of your technical paper, you've probably got about 30 paragraphs to write for a typical research article. A paragraph is, typically, not that big. If you return to our first example paper [Wang *et al.*, *Phys. Rev. E* **81** 061204 (2010)], there are 32 paragraphs. In our second example paper [Liu *et al.*, *Chem. Eng. J.* **151** pp. 235-240 (2009)], there are 26 paragraphs. In example one, the shortest paragraph is 49 words and the longest paragraph is 431 words. The average paragraph length is 145 words. From this point of view, the task of assembling a paper seems relatively easy.

The sentence is the basic unit of writing. The paragraph is composed of sentences and represents the first level of organization greater than the sentence. The paragraph is a way to convey organization of thought to the reader. We put idea one in paragraph one and we put idea two in paragraph two. We have emphasized the relationship between the paragraph and a particular idea in the previous module by assigning each paragraph a bullet in the outline. Through-out this course, we are going to continue to insist that each paragraph represent one idea or thought.

Each paragraph must have a reason to exist. If you ask yourself, "What is the point of this paragraph?" and you cannot come up with a good answer, then delete the paragraph. Moreover, the reason for existence should be unique to each paragraph. If you have two paragraphs next to each other with the same purpose, either combine them or delete one of the paragraphs. At the end of the day, each paragraph in the paper should correspond to a point in the outline that needed to be made.

Basic Paragraph Structure

When young students are first learning to write essays, they are given a simple model of the paragraph that is composed of five sentences.

- sentence one: introduce purpose of paragraph
- sentence two: provide first piece of evidence
- sentence three: provide second piece of evidence
- sentence four: provide third piece of evidence
- sentence five: close paragraph with restatement of purpose

As a trivial example, consider the paragraph below.

My friend, Jim, is mad at me for several reasons. First, I wrecked his bicycle. Second, I lost his dog. Third, I called him a

jerk when he wouldn't share his lunch with me. Come to think of it, Jim has good reason to be mad at me.

In this simple example, there is an introductory sentence, three sentences that provide support for the idea, and a concluding sentence that reinforces the point. While many paragraphs in a technical paper are conveying much more complicated concepts than the one in the example above, this simple example illustrates two important points. First, paragraphs have internal structure. Paragraphs are not an unorganized collection of sentences. Second, typically in a paragraph there is a logical order to the sentences, in which one moves from introducing an idea to supporting an idea. The restatement of the idea at the end is used sometimes, depending on the context.

Please remember that this document is providing writing guidelines. These are not laws that must be obeyed at all costs. If you write a technical paper composed only of 5-sentence paragraphs that follow this structure, it will undoubtedly look contrived, amateurish and perhaps idiotic. To get a better idea of more realistic paragraph structures for technical papers, let us turn to some published examples.

Example 1. Paragraphs in the Introduction (Theoretical Paper)

This example is from [Wang *et al.*, *Phys. Rev. E* **81** 061204 (2010)]. Below, we first reproduce the paragraph and then we discuss the paragraph.

"There are two major methods currently used to extract the non-bonded CG potentials. First, the parameters of an analytic potential such as Lennard-Jones are adjusted to closely reproduce the target PCF in the atomistic liquid/melt. Work from Harmandaris *et al.* [1,2,4] on coarse-grained modeling of polystyrene represents this approach in which target chain molecules are separated into fragments so that the non-bonded interaction between different fragment types, $\{\alpha,\beta\ldots\}$ is based on the fragment corresponding PCF, $g_{\alpha,\beta}$. A problem with this method is that the difference of conformations and orientations between fragment molecules and target molecules may not be reflected correctly on the corresponding coarse-grained potentials. [3,5] For example, the conformations of phenol rings in liquid benzene and that in PS melt where the rings are embedded into a long chain may be different. Consequently, these conformations would be misrepresented in the CG potential."

Sentence 1: There are two major methods currently used to extract the non-bonded CG potentials.

Purpose: This is the introductory sentence of the paragraph. It indicates the purpose of the paragraph.

Sentence 2: First, the parameters of an analytic potential such as Lennard-Jones are adjusted to closely reproduce the target PCF in the atomistic liquid/melt.

Purpose: This sentence describes the first method.

Sentence 3: Work from Harmandaris *et al.* [1,2,4] on coarse-grained modeling of polystyrene represents this approach in which target chain molecules are separated into fragments so that the non-bonded interaction between different fragment types, $\{\alpha,\beta\ldots\}$ is based on the fragment corresponding PCF, $g_{\alpha,\beta}$.

Purpose: This gives a specific example of the first method.

Sentence 4: A problem with this method is that the difference of conformations and orientations between fragment molecules and target molecules may not be reflected correctly on the corresponding coarse-grained potentials. [3,5]

Purpose: This sentence states the problem with the existing approach.

Sentence 5: For example, the conformations of phenol rings in liquid benzene and that in PS melt where the rings are embedded into a long chain may be different.

Purpose: This sentence gives a specific example of the problem with the existing method.

Sentence 6: Consequently, these conformations would be misrepresented in the CG potential.

Purpose: This sentence states the impact of the problem.

The purpose of this sentence-by-sentence analysis is to see that there must be a logical ordering of sentences within the paragraph. Moreover, each sentence has a distinct purpose.

Example 2. Paragraphs in the Introduction (Experimental Paper)

This example is from [Liu *et al.*, *Chem. Eng. J.* **151** pp. 235-240 (2009)]. Below, we first reproduce the paragraph and then we discuss the paragraph.

"There is no easy method available for the removal of boron from water and wastewater. One or more methods may be applied according to boron concentration in the medium. For boron removal, main processes that have been studied are: (1) precipitation–coagulation, (2) reverse osmosis, (3) electrodialysis, (4) solvent extraction, (5) membrane filtration, and (6) adsorption (including ion exchange adsorption) [4,5]. Among these methods, adsorption is a very useful and economical technique at low boron concentration [4,6]. In this method, conventional ion exchange adsorption, or adsorption using common adsorbents, such as oxides, clays, and activated carbons, is not so effective due to a poor ionization of boric acid and low selectivity of the adsorbents. The most promising boron adsorbents are hydroxyl-containing boron-selective adsorbents, such as Amberlite XE 243 and Amberlite IRA 743 [4], polyol and *N*-methylglucamine grafted mesoporous SBA-15 and MCM-41 [3,7]. Selective adsorption of boron by these adsorbents is caused by complexation. It was reported that coexisting salts did not significantly interfere with the adsorption when boron is adsorbed through complexation."

Sentence 1: There is no easy method available for the removal of boron from water and wastewater.

Purpose: This is the introductory sentence of the paragraph. It indicates the purpose of the paragraph.

Sentence 2: One or more methods may be applied according to boron concentration in the medium.

Purpose: This sentence states that the removal method is dependent upon the concentration.

Sentence 3: For boron removal, main processes that have been studied are: (1) precipitation–coagulation, (2) reverse osmosis, (3) electrodialysis, (4) solvent extraction, (5) membrane filtration, and (6) adsorption (including ion exchange adsorption) [4,5].

Purpose: This sentence lists technologies for boron removal.

Sentence 4: Among these methods, adsorption is a very useful and economical technique at low boron concentration [4,6].

Purpose: This sentence highlights one item from the list for futher discussion.

Sentence 5: In this method, conventional ion exchange adsorption, or adsorption using common adsorbents, such as oxides, clays, and activated carbons, is not so effective due to a poor ionization of boric acid and low selectivity of the adsorbents.

Purpose: This sentence points out a problem with existing materials.

Sentence 6: The most promising boron adsorbents are hydroxyl-containing boron-selective adsorbents, such as Amberlite XE 243 and Amberlite IRA 743 [4], polyol and *N*-methylglucamine graftedmesoporous SBA-15 and MCM-41 [3,7].

Purpose: This sentence points out the most promising materials in the literature.

Sentence 6: Selective adsorption of boron by these adsorbents is caused by complexation.

Purpose: This sentence gives the mechanism for adsorption.

Sentence 7: It was reported that coexisting salts did not significantly interfere with the adsorption when boron is adsorbed through complexation.

Purpose: This sentence states that the procedure works in the presence of other salts.

Again, the purpose of this sentence-by-sentence analysis is to see that there must be a logical ordering of sentences within the paragraph. As can be seen, each sentence has a distinct purpose. We cannot provide a blueprint from which every paragraph can be constructed. However, we can show examples, which illustrate the important points.

Example 3. Paragraphs in the Method Section (Theoretical Paper)

This example is from [Wang *et al.*, *Phys. Rev. E* **81** 061204 (2010)]. Below, we first reproduce the paragraph and then we discuss the paragraph.

"For the monatomic fluid, PCFs can be generated either from MD simulation or from solution of the OZPY equation. Using the PCFs from OZPY can provide a cleaner test of the $OZPY^{-1}$ procedure than using them from simulation. Therefore, PCFs used here for monatomic fluid were generated by solving the OZPY integral equation, using an established method and code developed by Lee. [23] Different state points were investigated for the monatomic fluid, the corresponding states varies from low-density gas to high density liquid. The dimensionless temperature of the simulation was $T^* = 2.00$ and the dimensionless densities were $\rho^* = 0.005$, 0.15, 0.25, 0.35, 0.45 and 0.55. Classical MD simulations were also run at some of these state points in order to compare the PCFs from simulation and integral equation theory."

Sentence 1: For the monatomic fluid, PCFs can be generated either from MD simulation or from solution of the OZPY equation.

Purpose: This is the introductory sentence of the paragraph. It indicates the purpose of the paragraph.

Sentence 2: Using the PCFs from OZPY can provide a cleaner test of the $OZPY^{-1}$ procedure than using them from simulation.

Purpose: This sentence gives the basis for using OZPY method over MD.

Sentence 3: Therefore, PCFs used here for monatomic fluid were generated by solving the OZPY integral equation, using an established method and code developed by Lee. [23]

Purpose: This sentence gives the details of the solution method.

Sentence 4: Different state points were investigated for the monatomic fluid, the corresponding states varies from low-density gas to high density liquid.

Purpose: This sentence gives the range of conditions studied.

Sentence 5: The dimensionless temperature of the simulation was $T^* = 2.00$ and the dimensionless densities were $\rho^* = 0.005$, 0.15, 0.25, 0.35, 0.45 and 0.55.

Purpose: This sentence gives the details of the thermodynamic state points studied.

Sentence 6: Classical MD simulations were also run at some of these state points in order to compare the PCFs from simulation and integral equation theory.

Purpose: This sentence says some points were evaluated two ways.

Example 4. Paragraphs in the Methods Section (Experimental Paper)

This example is from [Liu *et al.*, *Chem. Eng. J.* **151** pp. 235-240 (2009)]. Below, we first reproduce the paragraph and then we discuss the paragraph.

"Pure Fe3O4 particles were prepared by co-precipitating Fe(II) and Fe(III) ions in aqueous solution with ammonia according to the method reported in Refs. [24,25]. For the preparation of TSPA-functionalized Fe3O4 composite particles, 5.0 g of the wet Fe3O4 particles were dispersed in 150 ml water with stirring. 2.5 ml of TSPA (Gelest) was added to this mixture under gentle stirring. The reaction mixture was stirred for 30 min. Then, the TSPA-functionalized particles were recovered from the reaction mixture using a permanent magnet, and then washed with pure water until the pH of the water after washing was around 7. For the preparation of 1010f–Fe3O4 composite particles, 5.0 g of the wet Fe3O4 particles were dispersed in 150 ml of water with stirring. 2.5 ml of 0.5 g/l 1010f (Zibo Zhisheng Industrial Co., Ltd., PR China) aqueous solution was added to this mixture under gentle stirring until the floccules appeared. Then, the 1010f–Fe3O4 composite particles were recovered from the reaction mixture using a permanent magnet."

Sentence 1: Pure Fe3O4 particles were prepared by co-precipitating Fe(II) and Fe(III) ions in aqueous solution with ammonia according to the method reported in Refs. [24,25].

Purpose: This sentence is the introductory sentence of the paragraph. It indicates the purpose of the paragraph.

Sentence 2: For the preparation of TSPA-functionalized Fe3O4 composite particles, 5.0 g of the wet Fe3O4 particles were dispersed in 150 ml water with stirring.

Purpose: This sentence presents details of step 1 of the procedure.

Sentence 3: 2.5 ml of TSPA (Gelest) was added to this mixture under gentle stirring.

Purpose: This sentence presents details of step 2 of the procedure.

Sentence 4: Then, the TSPA-functionalized particles were recovered from the reaction mixture using a permanent magnet, and then washed with pure water until the pH of the water after washing was around 7.

Purpose: This sentence presents details of the remaining steps of the procedure.

Sentence 5: For the preparation of 1010f–Fe3O4 composite particles, 5.0 g of the wet Fe3O4 particles were dispersed in 150 ml of water with stirring.

Purpose: This sentence presents details of the first step of an alternate procedure for a different kind of nanoparticle.

Sentence 6: 2.5 ml of 0.5 g/l 1010f (Zibo Zhisheng Industrial Co., Ltd., PR China) aqueous solution was added to this mixture under gentle stirring until the floccules appeared.

Purpose: This sentence presents details of the second step of an alternate procedure for a different kind of nanoparticle.

Sentence 7: Then, the 1010f–Fe3O4 composite particles were recovered from the reaction mixture using a permanent magnet.

Purpose: This sentence presents details of the final step of an alternate procedure for a different kind of nanoparticle.

Example 5. Paragraphs in the Results Section (Theoretical Paper)

This example is from [Wang *et al.*, *Phys. Rev. E* **81** 061204 (2010)]. Below, we first reproduce the paragraph and the figure to which it refers and then we discuss the paragraph.

"For the monatomic case, we can obtain the PCF either from MD simulation or from solution of the OZPY equation directly. In Fig. 3, we compare the PCFs from these two methods at reduced densities of 0.55 and 0.9. At the higher density, there is a visible discrepancy between the two methods, attributed to the Percus-Yevick approximation. Up to a density of 0.55 the agreement between simulation and integral equation theory is very good. Similar simulation results are available in Ref. 15. For the monatomic case, we choose to use the PCF from the OZPY equation as the input into the potential generating procedure. This is the preferred approach because it avoids errors due to disagreements between PY theory and simulation and provides a test of self consistency for the procedure."

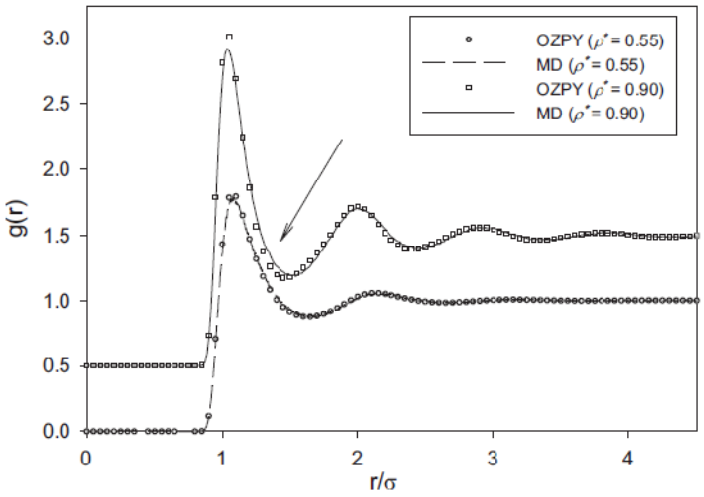

FIG. 3. Comparison of pair correlation functions (PCFs) obtained by solving OZPY equation directly and MD simulation of a Lennard-Jones fluid at $T^*=2.0$, $\rho^*=0.55$ and 0.90; here, $T^*=T/\varepsilon$, $\rho^*=\rho\sigma^3$. The data have been shifted in the vertical direction for clarity.

Sentence 1: For the monatomic case, we can obtain the PCF either from MD simulation or from solution of the OZPY equation directly.

Purpose: This is the introductory sentence of the paragraph. It indicates the purpose of the paragraph, comparison of the PCF from MD and OZPY.

Sentence 2: In Fig. 3, we compare the PCFs from these two methods at reduced densities of 0.55 and 0.9.

Purpose: This sentence defines the state point of the plot.

Sentence 3: At the higher density, there is a visible discrepancy between the two methods, attributed to the Percus-Yevick approximation.

Purpose: This sentence points out that a discrepancy exists at high density.

Sentence 4: Up to a density of 0.55 the agreement between simulation and integral equation theory is very good.

Purpose: This sentence points out that we have good agreement at low density.

Sentence 5: Similar simulation results are available in Ref. 15.

Purpose: This sentence points out that there is support for this observation in the literature.

Sentence 6: For the monatomic case, we choose to use the PCF from the OZPY equation as the input into the potential generating procedure.

Purpose: This sentence points out which method we use going forward.

Sentence 7: This is the preferred approach because it avoids errors due to disagreements between PY theory and simulation and provides a test of self consistency for the procedure.

Purpose: This sentence gives a justification for the choice of the method.

Example 6. Paragraphs in the Results Section (Experimental Paper)

This example is from [Liu *et al.*, *Chem. Eng. J.* **151** pp. 235-240 (2009)]. Below, we first reproduce the paragraph and then we discuss the paragraph.

"The effect of ionic strength on the adsorption is shown in Fig. 6. In general, the adsorption is found to decrease with the increase in ionic strength. For the adsorption of boron from aqueous solutions using fly ash, adsorptionwas also found to decrease in the presence of two salts [4]. However, for the adsorption of boron by polymer supported iminodipropylene glycol, the presence of Ca2+ or Mg2+ ions does not

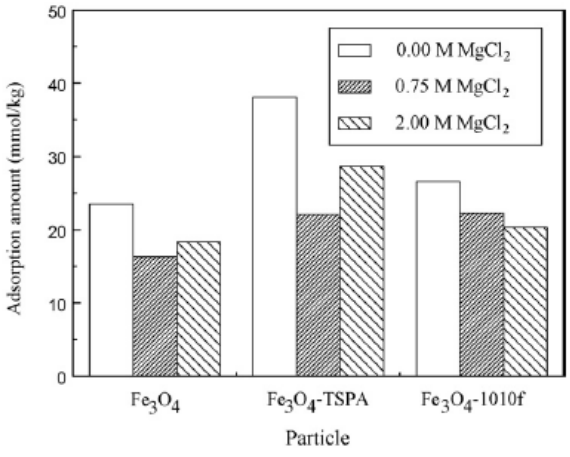

Fig. 6. Effect of solution ionic strength on the adsorption. Initial boron concentration was 2.0 mM. Initial solution pH was 6.0.

bring any significant interference on boron adsorption
[30].”

Sentence 1: The effect of ionic strength on the adsorption is shown in Fig. 6.

Purpose: This sentence is the introductory sentence of the paragraph. It indicates the purpose of the paragraph.

Sentence 2: In general, the adsorption is found to decrease with the increase in ionic strength.

Purpose: This sentence gives the primary conclusion of the plot.

Sentence 3: For the adsorption of boron from aqueous solutions using fly ash, adsorption was also found to decrease in the presence of two salts [4]

Purpose: This sentence gives support for the observation from the literature.

Sentence 4: However, for the adsorption of boron by polymer supported iminodipropylene glycol, the presence of Ca2+ or Mg2+ ions does not bring any significant interference on boron adsorption[30].

Purpose: In the interest of scientific objectivity, this sentence gives a counter example from the literature.