Practical Tips for Writing Effective Papers

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Highly Recommended to Read

Whitesides’ Group: Writing a Paper**

By George M. Whitesides*

G.M. Whitesides, Harvard University, is one the world most cited chemists (h index = 193) and author of over 1,000 journal publications
Tips from Whiteside….Outline!

A paper is an organized description of hypotheses, data and conclusions, intended to instruct the reader. Papers are a central part of research. If your research does not generate papers, it might just as well not have been done. “Interesting and unpublished” is equivalent to “non-existent”.

A paper is not just an archival device for storing a completed research program; it is also a structure for planning your research in progress. If you clearly understand the purpose and form of a paper, it can be immensely useful to you in organizing and conducting your research. A good outline for the paper is also a good plan for the research program. You should write and rewrite these plans/outlines throughout the course of the research.
I emphasize the central place of an outline in writing papers, preparing seminars, and planning research. I especially believe that for you, and for me, it is most efficient to write papers from outlines. An outline is a written plan of the organization of a paper, including the data on which it rests. You should, in fact, think of an outline as a carefully organized and presented set of data, with attendant objectives, hypotheses, and conclusions, rather than an outline of text.

All writing that I do—papers, reports, proposals (and, of course, slides for seminars)—I do from outlines. I urge you to learn how to use them as well.
Recommended Book for Effective Writing

Series: American Chemical Society Publication Series

More Recommended Readings

- The Chronicle of Higher Education: Why Academics Stink at Writing
  http://chronicle.com/article/Why-Academics-Writing-Stinks/148989/

- Bad Writing Contest
  http://denisdutton.com/bad_writing.htm/

General Steps

- “To produce a mighty book, you must choose a mighty theme” (Herman Melville).
  - Topic is important — new, hot topics are easier to publish, but strive for rigor and relevance (R²)

- No great and enduring volume can ever be written on the flea... (Herman Melville).
  - Good writing takes tremendous efforts
General Steps

- Decide about a suitable journal and rough title of the paper

- Likely journals in our field are *ES&T, ES&T Letters*, and other specialized journals; can aim higher – *Science, Nature, PNAS*....

- Criteria for journal: Right audience; high impact factor (not an obscure journal, like JW Gibbs)

- Start drafting the outline of the paper as you continue to collect data; it will help you to better plan the experiments
Outline as a Planning Tool

- Think about what data you plan to collect and how to present the data most effectively (insightful figures, detailed tables, etc.)
- Sketch the future figures (can be done even by hand) with the expected data; this will help you to design the experiments
- Get ideas about figures and style from good published papers that you read (of well respected authors)
General: Paper Structure for Drafting the Outline

- Papers usually have the following sections:
  - Abstract
  - Introduction
  - Theory or Modeling (for papers with modeling, if model is new)
  - Materials and Methods (some journals at the end or as Supporting Information)
  - Results and Discussion (some split to “Results” and “Discussion” as separate sections)
  - Conclusion (ES&T doesn’t have this section)

- Plan on ~4-8 figures and a few tables (if any) presenting important data

- Most journals have online Supporting Information for other data (less important or “boring” data)
Outline — General

- Decide about the journal and adopt its style for sections, subsections, etc.

- Most journals allow sections and subsections. Some (like Elsevier journals) allow sub-subsections (e.g., 2.xx, 2.1.xx, 2.1.1.xx)

- Think about a logical way to present the data so you can tell the “story” of your research in a way that is easy to follow and understand

- It is like a flowchart for a computer code — ideas should flow logically and in the right order

- Creative research, but effective writing — Story NOT a mystery
The Outline

- Have the headings (titles) of sections and subsections (and sub-subsections) in order
- Indicate what figures, tables, or equations will be included in each of the sections or subsections
- Provide final form of figures (if you have data) and sketch of what you hope will be the data while you are still collecting data or planning experiments
- Provide equations and detailed figure and table captions
Ultrafiltration Membranes Incorporating Amphiphilic Comb Copolymer Additives Prevent Irreversible Adhesion of Bacteria

In preparation for

*Environmental Science & Technology*

2009....

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Outline: Rest of the Paper

Abstract
Introduction

Materials and Methods
Ultrafiltration Membrane
Membrane Characterization
Model Bacteria
Static Bacterial Adhesion and Reversibility Tests
Direct Microscopic Observation of Bacterial Deposition and Reversibility

Interaction Force Measurements

FIGURE S1

Results and Discussion
Bacterial Properties

FIGURE 1
Bacterial Adhesion and Reversibility

FIGURE 2
Bacterial Deposition Rate and Reversibility in Crossflow Filtration

FIGURE 3

Why Bacterial Adhesion to the PAN-g-PEO Membrane is Negligible?

FIGURE 4
FIGURE S2
FIGURE 5

Acknowledgement

Literature Cited
Figure 3: (a) Observed cell deposition rate of *E. coli* during 30 min of crossflow filtration. Deposition experiments were done at a crossflow velocity of 10 cm/s, permeation velocity of 30 μm/s, and cell concentration of ~1.3×10⁵ cells/mL at a constant pressure of 150 kPa. (b) Percent removal of *E. coli* cells from the membrane after 10 minutes of rinsing with the same solution at 150 cm/s cross flow velocity and with no permeate flow at 150 kPa.
ABSTRACT

INTRODUCTION
In this study, we fabricate an omniphobic membrane for MD by coating a hydrophilic glass fiber membrane with silica nanoparticles, followed by subsequent surface fluorination and polymer coating. The fabricated omniphobic membrane is then compared to a hydrophobic commercial PTFE membrane for their anti-wetting property against liquids of a wide range of surface tensions. Direct contact membrane distillation (DCMD) experiments are also conducted using both the omniphobic and PTFE membranes to compare their anti-wetting performance in the presence of a commonly used surfactant, sodium dodecyl sulfate (SDS).

MATERIALS AND METHODS
Modification of Glass Fiber Membrane.
Membrane Characterization.
Membrane Performance Testing.

RESULTS AND DISCUSSION
Morphology and Wetting Properties of the Omniphobic Membrane.

FIGURE 1

FIGURE 2

Membrane Performance in DCMD.

FIGURE 3

Implications.

ASSOCIATED CONTENT

ACKNOWLEDGEMENTS

REFERENCES
Supplementary Information

Ultrafiltration Membranes Incorporating Amphiphilic Comb Copolymer Additives Prevent Irreversible Adhesion of Bacteria

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Figure S1: Schematic diagrams of (a) flow cell and (b) close loop direct microscopic observation crossflow membrane filtration system.
Title

- Attractive titles, but not too “commercial”, “PR” style
- Should reflect the contents of the paper
- Concise but still informative
- Avoid jargon, symbols, commercial names
- Avoid papers with titles followed by “Part 1: xxx” (with future papers having “Part 2: yy” etc.)
Example of “Good” Titles

Correlation Equation for Predicting Single-Collector Efficiency in Physicochemical Filtration in Saturated Porous Media

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Aggregation Kinetics of Multiwalled Carbon Nanotubes in Aquatic Systems: Measurements and Environmental Implications

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Antibacterial Effects of Carbon Nanotubes: Size Does Matter!

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Received March 26, 2008. Revised Manuscript Received May 6, 2008
Example of Not So Good Titles

Coupled Influence of Colloidal and Hydrodynamic Interactions on the RSA Dynamic Blocking Function for Particle Deposition onto Packed Spherical Collectors

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Available online at www.sciencedirect.com

ScienceDirect

Protein antifouling mechanisms of PAN UF membranes incorporating PAN-g-PEO additive

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\textsuperscript{a}
Example of Not So Good Titles

Using indigenous microalga species to reduce $\text{HCO}_3^-$, NH$_3$N, NO$_3$N, total P, Ca$^{2+}$, SO$_4^{2-}$, and Cl$^-$ from a high conductivity concentrate
Abstract

- Concise, yet informative
- Length – about 0.5 to 0.75 page (single space)
- Unless it is a new area of research, no need for general/overview opening sentences
- Not too general and vague
- Some specific/quantitative details (but not too much)
- Avoid acronyms, equations, references
- Avoid heavy jargon
Abstract (Paper)

A new equation for predicting the single-collector contact efficiency (η₀) in physicochemical particle filtration in saturated porous media is presented. The correlation equation is developed assuming that the overall single-collector efficiency can be calculated as the sum of the contributions of the individual transport mechanisms—Brownian diffusion, interception, and gravitational sedimentation. To obtain the correlation equation, the dimensionless parameters governing particle deposition are regressed against the theoretical value of the single-collector efficiency over a broad range of parameter values. Rigorous numerical solution of the convective–diffusion equation with hydrodynamic interactions and universal van der Waals attractive forces fully incorporated provided the theoretical single-collector efficiencies. The resulting equation overcomes the limitations of current approaches and shows remarkable agreement with exact theoretical predictions of the single-collector efficiency over a wide range of conditions commonly encountered in natural and engineered aquatic systems. Furthermore, experimental data are in much closer agreement with predictions based on the new correlation equation compared to other available expressions.

Correlation Equation for Predicting Single-Collector Efficiency in Physicochemical Filtration in Saturated Porous Media

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Abstract (Letter, Feature/Perspective Article) – Shorter than Paper

Antibacterial Effects of Carbon Nanotubes: Size Does Matter!

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We provide the first evidence that the size (diameter) of carbon nanotubes (CNTs) is a key factor governing their antibacterial effects and that the likely main CNT-cytotoxicity mechanism is cell membrane damage by direct contact with CNTs. Experiments with well-characterized single-walled carbon nanotubes (SWNTs) and multiwalled carbon nanotubes (MWNTs) demonstrate that SWNTs are much more toxic to bacteria than MWNTs. Gene expression data show that in the presence of both MWNTs and SWNTs, Escherichia coli expresses high levels of stress-related gene products, with the quantity and magnitude of expression being much higher in the presence of SWNTs.

The unique and tunable properties of carbon-based nanomaterials enable new technologies for identifying and addressing environmental challenges. This review critically assesses the contributions of carbon-based nanomaterials to a broad range of environmental applications: sorbents, high-flux membranes, depth filters, antimicrobial agents, environmental sensors, renewable energy technologies, and pollution prevention strategies. In linking technological advance back to the physical, chemical, and electronic properties of carbonaceous nanomaterials, this article also outlines future opportunities for nanomaterial application in environmental systems.
Introduction

- At least 3-4 paragraphs (short paragraphs, each ~ 1/3 page or less, but no less than 3 sentences)
- First paragraph – overview about the general, broad importance
- Second paragraph (optional) – more overview about the specific focus of your paper
- Middle paragraphs – critical review of past work
- One before last – why your work is new and how it will add to the body of knowledge
- Last paragraph – state the objectives and scope of the paper, with possibly a general finding and/or importance
Last Paragraph of Introduction

- State the objective(s) and scope of the paper — Don’t repeat the abstract!
- Avoid specific details on the experiments and detailed results
- After stating the objective, highlight in general terms what you have done and the general/broad findings
General Tips for Writing the Main Body of Paper

- Use short paragraphs (typically ~ 3-6 sentences)
- Minimize the use of long sentences
- Simple is better!
- Elegant and eloquent, but not Shakespearean
- Avoid redundancy
- Can use “we”, “our”; NOT “I”, “my”
- When you are not sure about style (e.g., equations), look at previously published papers in that journal
Conclusion Section

- “Conclusion” or “Concluding Remarks” — not “Conclusions” where you itemized the conclusions
- Do not repeat the abstract
- Summarize the key findings
- Indicate the broader impact
- Avoid references and equations
- ES&T and some other journals do not have a Conclusion section
- For ES&T can use “Implications”
Figures

- Thoughtful and clear presentation of data
- Avoid simple figures with only one data set
- Use figures with multiple panels/graphs, labeled as (a), (b), (c), etc.
- Use san serif fonts
- Large fonts and symbols
- Minimize use of **bold** fonts
- Provide clear and easy to read legends
- Provide units for y and x axes; e.g. “Residence Time (min)”, “Cell Viability (%),”
Figures (continued)

- Capitalize first letter of each word in title of x and y axes (US style)
- Use moderately thick lines
- Provide very detailed figure captions with all necessary experimental conditions
- Use colors when needed (dark colors): black, blue, red, green, etc.

- Recommended Software for Publication Quality Graphs:
  - Origin (OriginLab Corporation)
  - SigmaPlot (Jandel Corporation)
Examples of Good Figures

Figure 5. Specific energy vs power density for three different types of counter-current modules: an ideal module with no reverse salt flux or concentration polarization (solid red line), a module using advanced membranes (dashed and dotted green line), and a module using currently available commercial membranes (dashed blue line). The ideal membrane has a water permeability coefficient, $A$, of $3 \text{ L m}^{-2} \text{ h}^{-1} \text{ bar}^{-1}$ and $B = 0$. For the advanced membrane, $A = 3 \text{ L m}^{-2} \text{ h}^{-1} \text{ bar}^{-1}$, $B = 0.36 \text{ L m}^{-2} \text{ h}^{-1}$ (determined from the permeability-selectivity trade-off, eq 5), and $S = 100 \mu\text{m}$. The commercial membrane properties are representative of a thin-film composite membrane from Hydration Technology Innovations ($A = 2.49 \text{ L m}^{-2} \text{ h}^{-1} \text{ bar}^{-1}$, $B = 0.39 \text{ L m}^{-2} \text{ h}^{-1}$, and $S = 564 \mu\text{m}$). In both cases with concentration polarization, a mass transfer coefficient of $k = 138.6 \text{ L m}^{-2} \text{ h}^{-1}$ is used. The feed solution is river water (0.015 M NaCl) and the draw solution is seawater (0.6 M NaCl). Curves are obtained by increasing the membrane area with fixed operating conditions of $\phi = 0.5$ and $\Delta P = 14.5$ bar. For each membrane, the maximum specific energy (hollow circle) and 80% of the maximum specific energy (hollow square) are indicated. The coupon-scale power density for each membrane occurs at the horizontal axis (power density) intercept.
Examples of Good Figures

Figure 3. Experimental and modeled projected power densities as a function of applied hydraulic pressure difference, $\Delta P$. Draw (NaCl) solution concentrations of (A) 0.6, (B) 1, (C) 2, and (D) 3 M were used with osmotic pressures of 28.3, 49.4, 111.2, and 188.8 bar, respectively (calculated using OLI software). Modeled power densities (light blue lines) were determined using parameters from an RO and FO characterization. Experimental power densities were determined in duplicate using eq 1 (blue circles and red squares). All experiments were performed with feed (DI water) and draw solutions at 25 ± 0.5 °C.
Examples of Good Figures

Fig. 3. (A) A schematic of the interfacial polymerization used to form thin-film composite (TFC) membranes. The monomers m-phenylenediamine and trimesoyl chloride react to form a highly cross-linked polyamide layer, which allows for the selective transport of water over salt. Ultrathin films are fabricated by dissolving the m-phenylenediamine in water and trimesoyl chloride in a water-immiscible organic solvent, such as hexane. A porous support is soaked in the aqueous solution and then contacted with the organic solution. The resulting polyamide formation is confined to the region near the interface of the two solutions. One drawback of the polyamide chemistry is the amide linkage (highlighted in dashed box), which is susceptible to attack by chlorine and other oxidizing agents. (B) Micrographs displaying the structure of the TFC membranes (48). A transmission electron micrograph of the membrane cross-section shows the extremely thin polyamide layer on top of a porous polysulfone support. The dark regions on top of the polyamide layer are gold nanoparticles used to obtain sufficient contrast between the polyamide and polysulfone layers during imaging. (Inset) A scanning electron micrograph of the polyamide top surface showing the rough ridge and valley structure typical of these films. (C) Surface properties of TFC membranes (49, 50). Fouling-resistant membranes would be smooth and possess surface chemical properties postulated by (30); TFC membranes do not meet all of these constraints, consistent with their high fouling propensity. (D) Chemistries that have demonstrated the ability to resist protein or organic macromolecule adhesion: poly(ethylene oxide) (31), zwitterions such as polysulfobetaine (32), sugar-derived molecules (30), and polyglycerol (34).
Examples of Good Figures

A

B

C

PSf
328.3 ± 53.4 nm

PSf-Ag
356.8 ± 68.3 nm
Examples of Good Figures

Fig. 3. SEM micrographs displaying the cross-section of membranes cast at a fixed PSf concentration (12 wt%) and increasing DMF concentrations: (A) 0, (B) 25, (C) 50, (D) 75, and (E) 100%.
Recap

- Good writing takes tremendous efforts
- Always start with an outline!
- Creative research, but effective writing — a story not a mystery
- Strive for rigor and relevance ($R^2$)