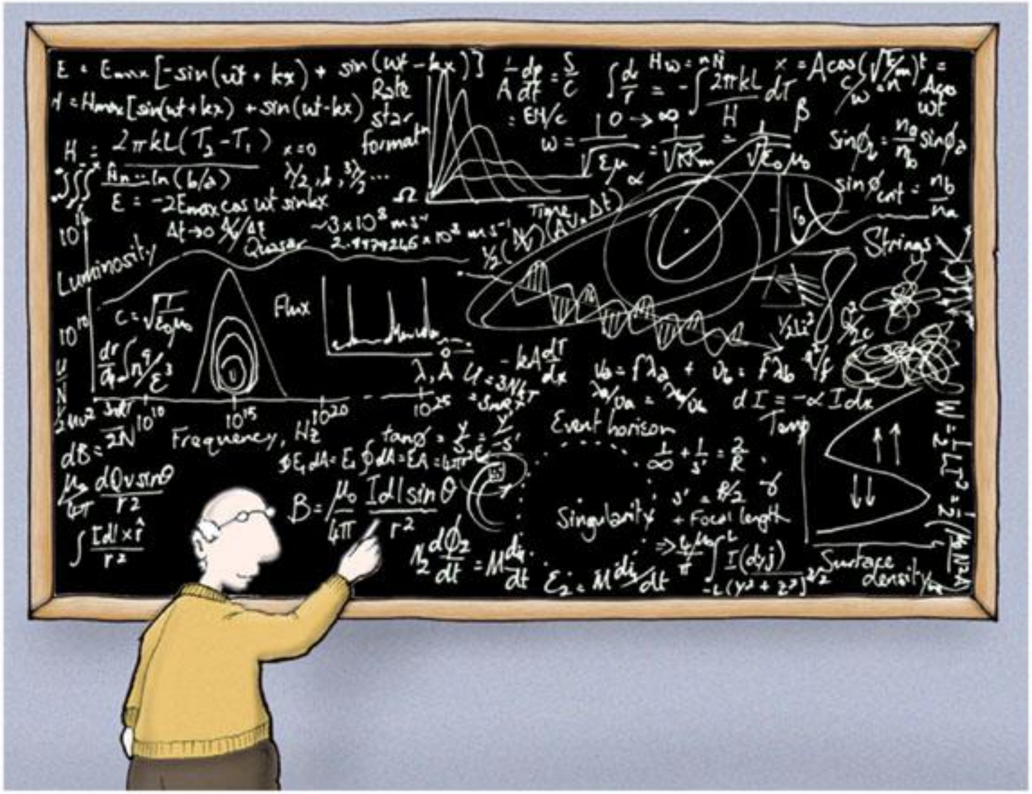
Organizing and Writing an Accessible Scientific Paper

Lance Cooper, Dept. of Physics
University of Illinois at Urbana-Champaign

Meet The Editors Workshop, UFRN, Brazil



Astrophysics made simple

Acknowledgments

Celia Elliott
Dept. of Physics
University of Illinois at Urbana-Champaign

Dr. Saad Hebboul
Associate Editor
Physical Review Letters

References:

"Whitesides' group: writing a paper," G.M. Whitesides, *Advanced Materials* **16**, 1375 (2004)

"Writing successful manuscripts for *Physical Review Letters*," S. Hebboul, http://physics.illinois.edu/careers-seminar/UIUC_PRL_Workshop_Hebboul_Pt1.pdf

Physics 598 PEN, "Communicating Physics Research" (UIUC)

Why is it Important to Write Accessible Science Papers?

Communicating your scientific results is not just about having good data or completing a significant calculation (although these are critical also!): you must also present your results and support your conclusions both **logically** and **clearly**!

Paper is more than a record of things done

Writing process helps to:

- organize thoughts & data *while* research is going on
- conduct experiments & calculations
- plan research in progress

Whitesides' Group: Writing a paper
Adv. Mater. **16**, 1375 (2004)

WRITING SUCCESSFUL MANUSCRIPTS FOR PHYSICAL REVIEW LETTERS

Saad E. Hebboul *

The American Physical Society, Ridge, NY

PART 1 of 2

*** *Email:* *hebboul@aps.org***

To see full lecture, go to: http://physics.illinois.edu/careers-seminar/UIUC_PRL_Workshop_Hebboul_Pt1.pdf

Key Steps to Writing an Accessible Paper

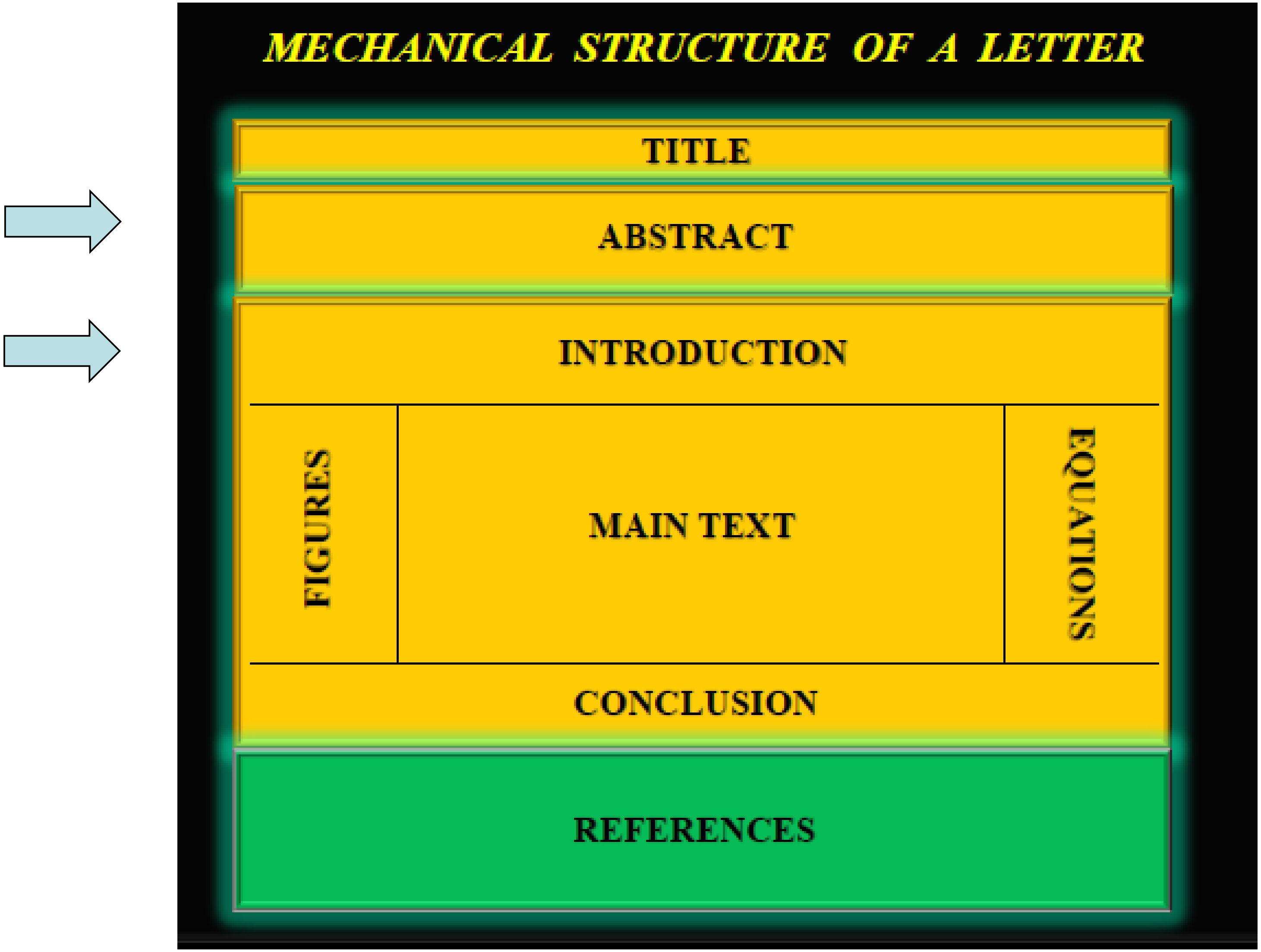
(1). Identify and ***write for*** your audience (e.g., expert, general, etc.) – this will govern the level of the presentation, i.e., the words you use, the number of topics you cover, the figures and results you present

(2). Develop a coherent and concise "story" to present your data – sketch out an abstract and introduction

(3). Sketch out a logical and concise outline for presenting the "story" of your scientific results – create an outline!

(4). Write simply and concisely, following the outline of your "story", avoiding disruptions to the flow of your narrative

The Mechanical Structure of a *Physical Review Letter*



Editor Saad Hebboul: http://physics.illinois.edu/careers-seminar/UIUC_PRL_Workshop_Hebboul_Pt1.pdf

First Identify a Coherent Story You Want to Tell About Your Results: **the Scientific Abstract**

The abstract is the most succinct expression of **what** you did, **why** you did it, and **what** was important about what you did.

Consequently, after conducting your research, ***sketching out a draft abstract*** will help you organize your thoughts so you can identify whether you have a coherent story that you can support with scientific evidence.

This process can help you tell if you're ready to write a paper and what the focus of your paper is.

Elements of a Scientific Abstract

Why is an abstract useful in this regard? The abstract should contain (in this order):

1. A brief statement of the motivations and/or issues associated with the research

2. A short description of the methods used

3. A summary of the key results obtained

4. A statement of the implications of the key results

So, the abstract contains all the essential elements of your paper, which is why starting with an abstract allows you to construct the coherent story you want to tell about your research!

Example Scientific Abstract

PRL 107, 117401 (2011) PHYSICAL REVIEW LETTERS week ending 9 SEPTEMBER 2011

Optical Response of Relativistic Electrons in the Polar BiTeI Semiconductor

J. S. Lee,[1,*] G. A. H. Schober,[2,3] M. S. Bahramy,[4] H. Murakawa,[5] Y. Onose,[2,5] R. Arita,[2,4]
N. Nagaosa,[2,4] and Y. Tokura[1,2,4,5]

The transitions between the spin-split bands by spin-orbit interaction are relevant to many novel phenomena such as the resonant dynamical magnetoelectric effect and the spin Hall effect. We perform optical spectroscopy measurements combined with first-principles calculations to study these transitions in the recently discovered giant bulk Rashba spin-splitting system BiTeI. Several novel features are observed in the optical spectra of the material including a sharp edge singularity due to the reduced dimensionality of the joint density of states and a systematic doping dependence of the intraband transitions between the Rashba-split branches. These confirm the bulk nature of the Rashba-type splitting in BiTeI and manifest the relativistic nature of the electron dynamics in a solid.

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Motivation

The transitions between the spin-split bands by spin-orbit interaction are relevant to many novel phenomena such as the resonant dynamical magnetoelectric effect and the spin Hall effect. We perform optical spectroscopy measurements combined with first-principles calculations to study these transitions in the recently discovered giant bulk Rashba spin-splitting system BiTeI. Several novel features are observed in the optical spectra of the material including a sharp edge singularity due to the reduced dimensionality of the joint density of states and a systematic doping dependence of the intraband transitions between the Rashba-split branches. These confirm the bulk nature of the Rashba-type splitting in BiTeI and manifest the relativistic nature of the electron dynamics in a solid.

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Methods used

The transitions between the spin-split bands by spin-orbit interaction are relevant to many novel phenomena such as the resonant dynamical magnetoelectric effect and the spin Hall effect. We perform optical spectroscopy measurements combined with first-principles calculations to study these transitions in the recently discovered giant bulk Rashba spin-splitting system BiTeI. Several novel features are observed in the optical spectra of the material including a sharp edge singularity due to the reduced dimensionality of the joint density of states and a systematic doping dependence of the intraband transitions between the Rashba-split branches. These confirm the bulk nature of the Rashba-type splitting in BiTeI and manifest the relativistic nature of the electron dynamics in a solid.

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Brief summary of key results

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Brief statement of implications of results

Celia Elliott's Abstract Recipe

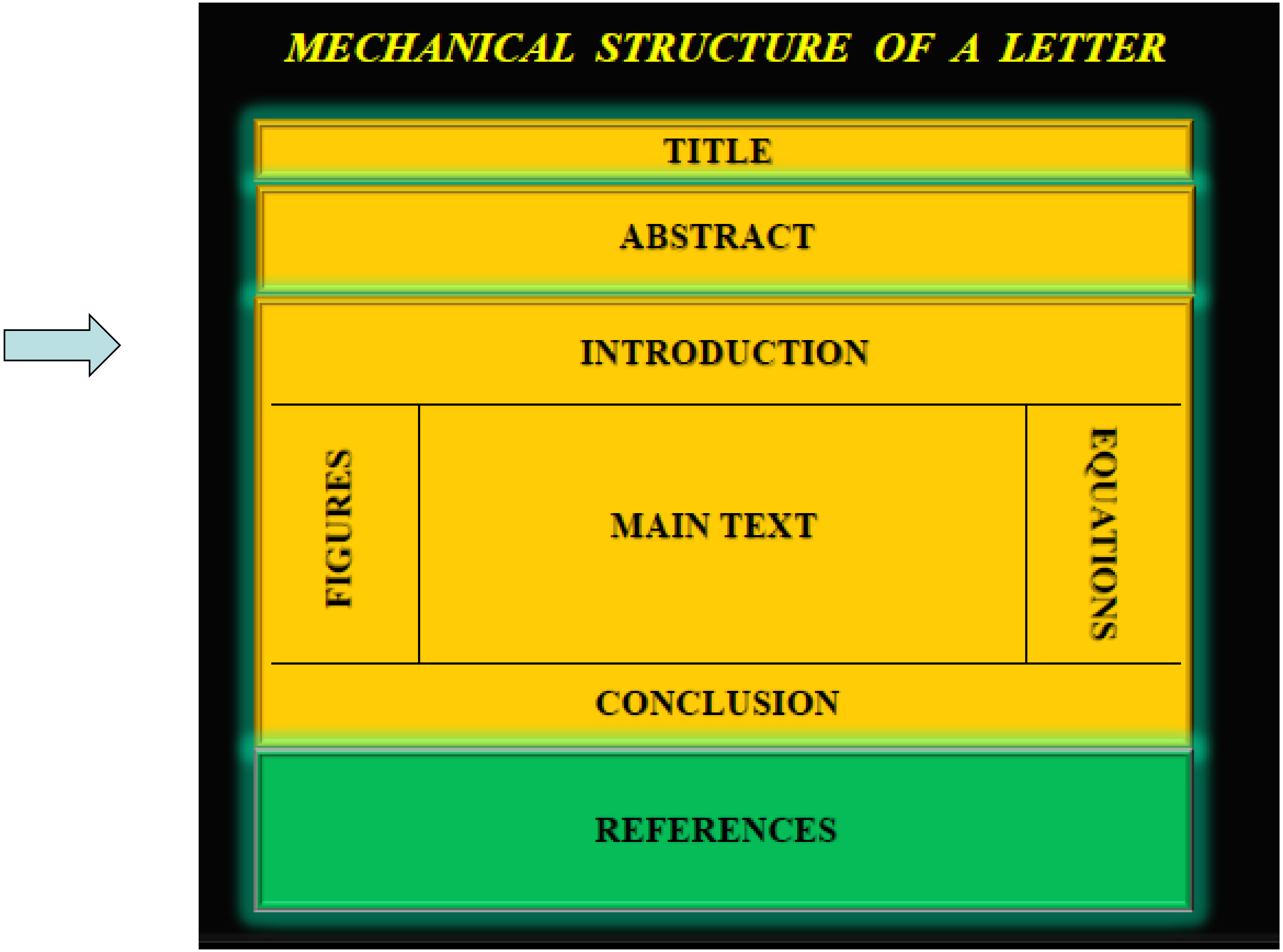
Generate your abstract by answering the following questions, in this order:

- What problem did you study and why is it important?
- What methods did you use?
- What were your principal results?
- What conclusions can you draw from your results, or what are the implications of your results?

Make your answers as *specific* and *quantitative* as possible!!

Expand or contract the length of each answer depending on the abstract length

The Introduction: Most Important Part of an Accessible Paper



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The Introduction: Most Important Part of an Accessible Paper

An accessible introduction provides:

-- The motivation and importance of the research

-- Background information a non-expert scientific audience needs to understand the research

-- A justification of why the research is needed

-- A preview of the key results of the paper

Note that, like the abstract, the introduction provides all the crucial elements of the story you want to tell.

The Typical Structure of a Scientific Introduction

INTRODUCTION

FOR LETTERS

Consists of three crucial parts …

BACKGROUND or SURVEY
PHYSICAL MOTIVATION
IN THIS LETTER (Contribution)

… that form a single coherent story.

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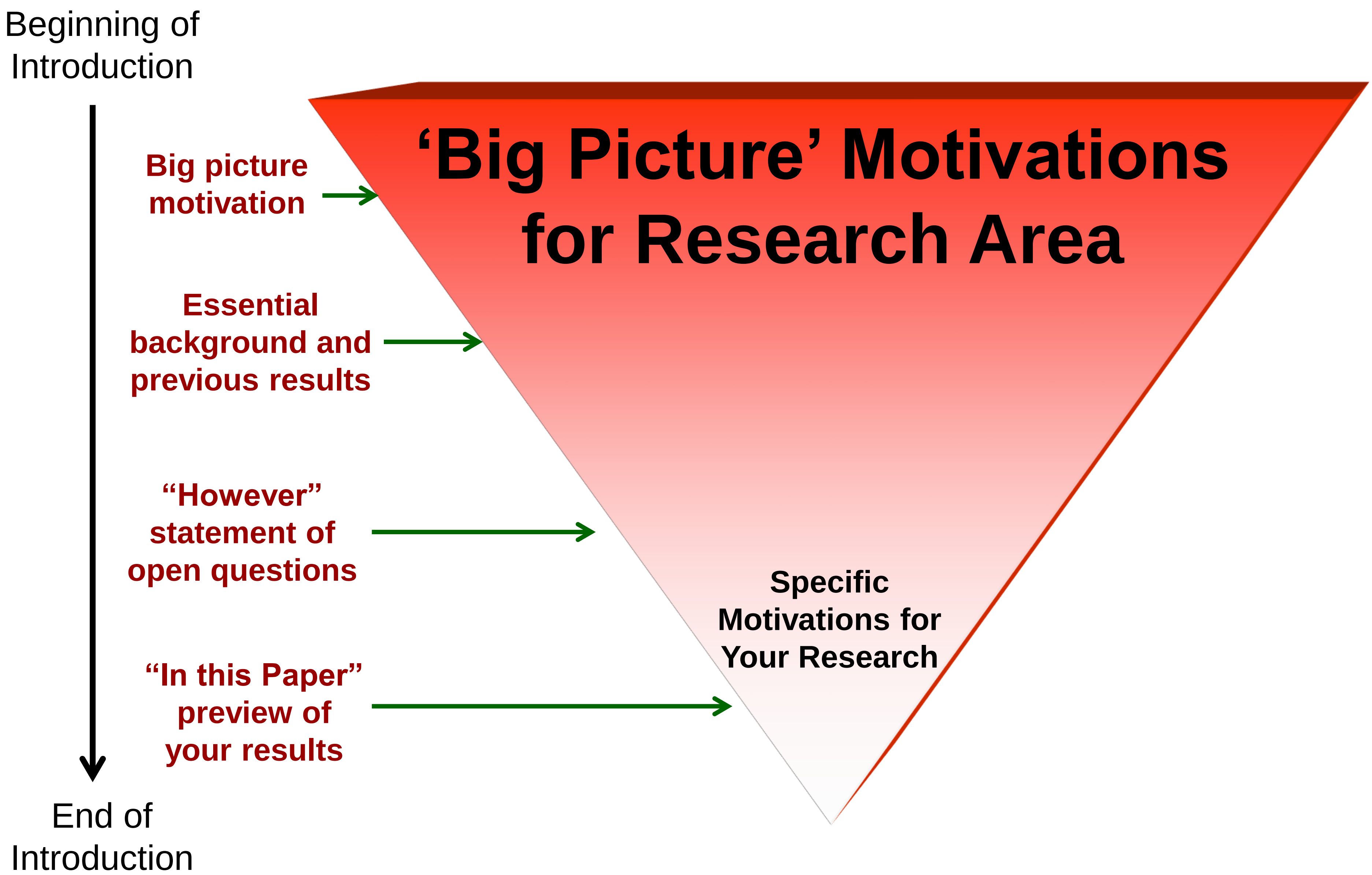
Information in the Introduction is Generally Organized in an “Inverted Pyramid” Structure



Effects of Particle Shape on Growth Dynamics at Edges of Evaporating Drops of Colloidal Suspensions

Peter J. Yunker,[1] Matthew A. Lohr,[1] Tim Still,[1,2] Alexei Borodin,[3] D. J. Durian,[1] and A. G. Yodh[1]

"Big Picture" motivation ↗

Examples of surface and interfacial growth phenomena are diverse, ranging from the production of uniform coatings by vapor deposition of atoms onto a substrate [1], to burning paper wherein the combustion front roughens as it spreads [2,3], to bacterial colonies whose boundaries expand and fluctuate as bacteria replicate [4]. The morphology of the resulting interfaces is a property that affects the macroscopic responses of such systems, and it is therefore desirable to relate interface morphology to the microscopic rules that govern growth [1,5,6]. To this end, simulations have directly compared a broad range of growth processes [5,6] and have found, for example, that the random deposition of repulsive particles is a Poisson process, while the random deposition of "sticky" particles belongs to a different universality class that leads to different interface morphology.

Besides discrete models, theoretical investigation of this problem has centered around continuum growth equations (e.g., Ref. [7]). One interesting approach that unified a large set of discrete simulations is based on the so-called Kardar-Parisi-Zhang (KPZ) equation [6,8–12]. This nonlinear equation relates stochastic growth and interfacial growth fronts, lines, or surfaces to diffusion and local lateral correlations; its solutions are known and belong to the KPZ universality class [13–16]. The KPZ class presents a rare opportunity for connecting exact theoretical predictions about nonequilibrium growth phenomena with experiment. However, to date only a few members of the KPZ class have been experimentally identified [2–4,17]. This paucity of KPZ examples is due, in part, to the presence of quenched disorder and long-range interactions in experiment, as well as to limited statistics, which make growth process differences difficult to discern. In fact,

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Background info; narrowing of focus to specific topic

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"However" statement justifying why your research needed to be performed →

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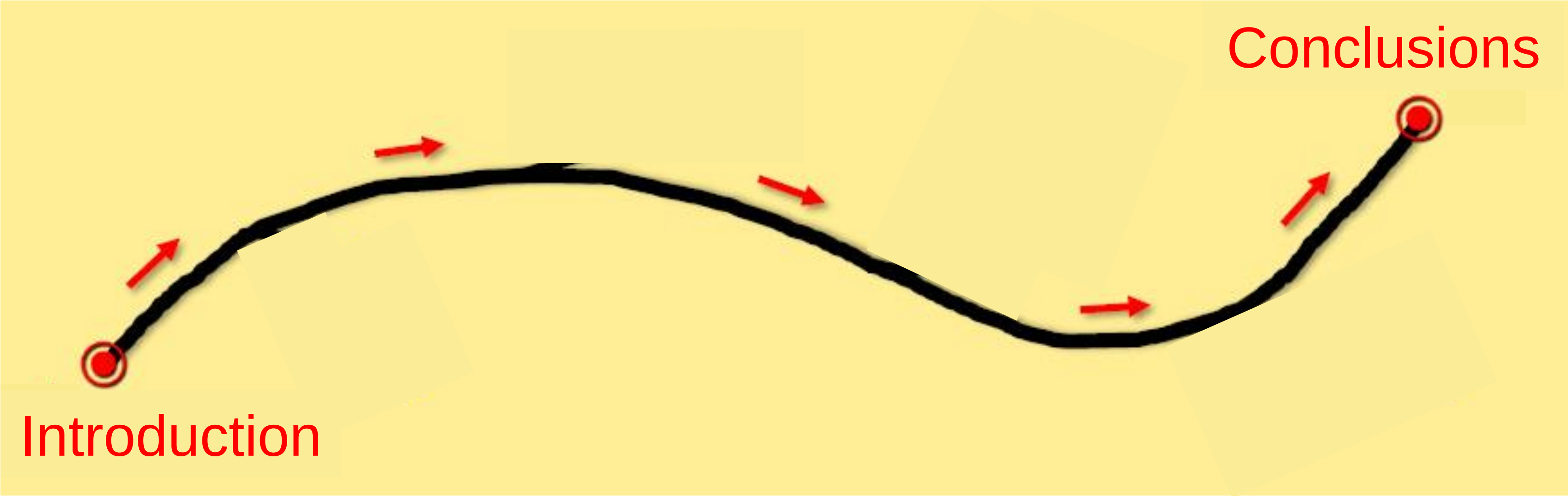
Preview of key results in this paper: "**In this contribution…**"

broadly speaking, experimental confrontation of the microscopic rules explored by theory and simulation has been difficult.

In this contribution we demonstrate that the rich nonequilibrium physics of evaporating colloidal drops provides an attractive experimental system for study of such growth processes and for testing theory and simulation predictions. Specifically, we investigate the growth of particle deposits from the edges of evaporating colloidal drops. Particle deposition is observed by video microscopy at the single particle level. Aqueous suspensions of colloidal particles are allowed to evaporate on glass slides at constant temperature and humidity, and radial convective flows during evaporation carry particles from drop center to drop edge, where they accumulate [Fig. 1(a)] [18]. The resulting deposits of particles grow from the edge on the air-water interface in two dimensions, defining a deposition front, or growth line, that varies in space and time. Interestingly, these interfacial growth processes are strongly dependent on colloidal particle shape [19]. Three distinct growth processes were discovered in the evaporating colloidal suspensions by tuning particle shape-dependent capillary interactions and thus varying the microscopic rules of deposition. The substantial shape fluctuations of the growth line of spheres are readily explained via a Poisson-like deposition process; slightly anisotropic particles exhibit weaker fluctuations characteristic of KPZ class behavior, and very anisotropic ellipsoids exhibit behavior consistent with the KPZ class in the presence of quenched disorder [20–22].

Our experiments employ water drops containing a suspension of polystyrene spheres (Invitrogen) stretched asymmetrically to different aspect ratios [19,23,24].

Accessible Papers Avoid Disruptions to the Narrative



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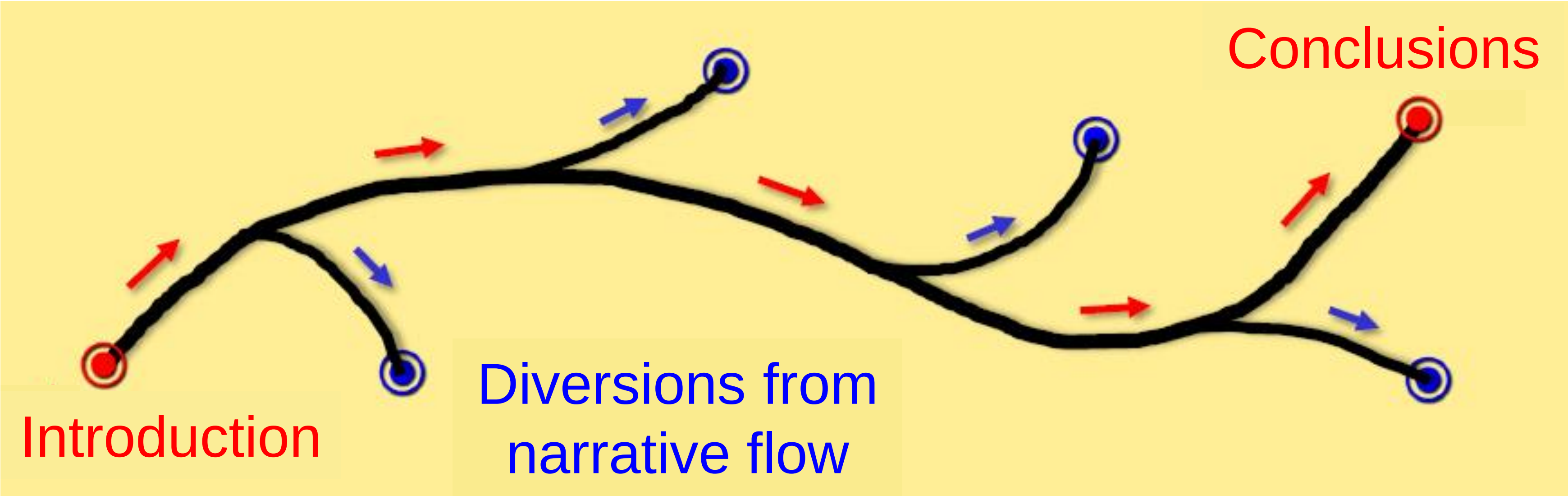
Accessible Papers Avoid Disruptions to the Narrative



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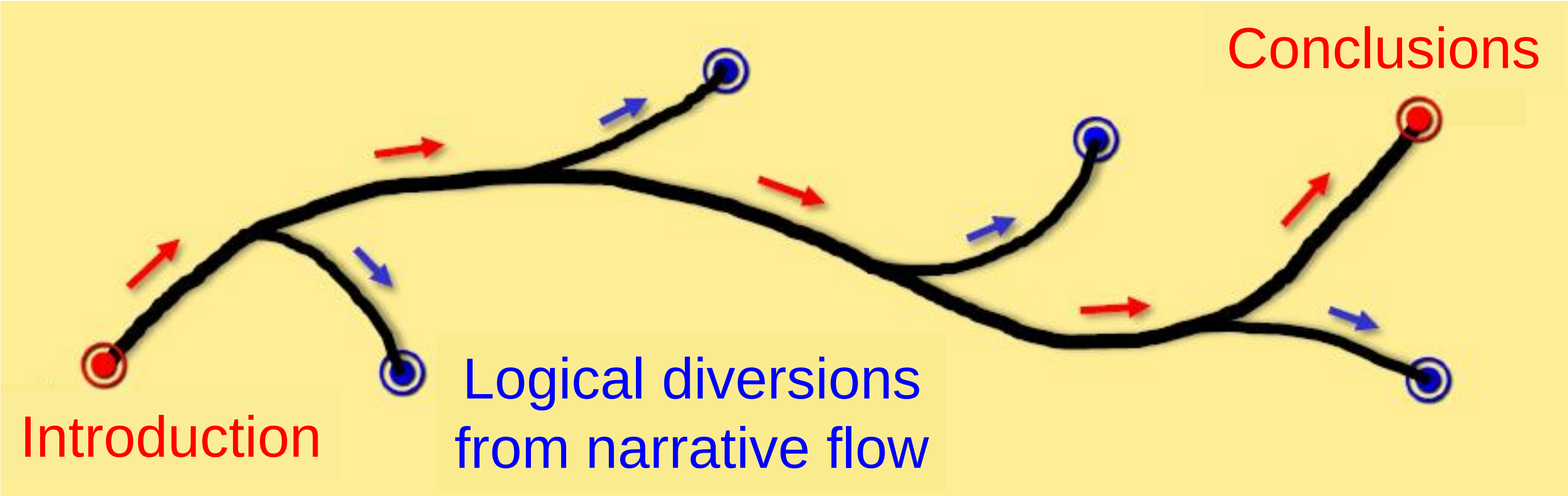
Common Disruptions That Limit the Accessibility of Your Scientific Writing

Logical Organization: An accessible scientific paper clearly and logically connects your introduction to your conclusions without disruptions to the narrative flow of your paper!



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Avoiding Disruptions That Limit Accessible Writing:

Create Logical Structure With Outlines

Make a habit of creating an outline and a clear paragraph structure for all your scientific papers and presentations!

"I emphasize the central place of an outline in writing papers, preparing seminars, and planning research. 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, objectives, hypotheses, and conclusions, rather than an outline of text."

Whitesides' Group: Writing a paper
Adv. Mater. **16**, 1375 (2004)

Example of basic (Level 1) structure of scientific outline:

I. Introduction (Get the reader's/viewers attention; states key idea(s) or thesis; provides essential background)

II. Procedures (Provides background on key experimental/theoretical methods)

III. Results (Presents key results that support ideas discussed in Introduction)

IV. Discussion (Interprets results; Discusses results in the context of prevailing models)

V. Summary and Conclusions (Reemphasizes key results and how they support thesis; Discusses new directions)

Example of a more detailed (Level 2) structure of scientific outline

I. Introduction

A. Attention-grabbing, “big picture” statement of issue
B. Key previous results leading to state of the field
C. Unaddressed problems
D. Preview of key points of talk/paper

II. Procedures

A. Experimental methods
B. Theoretical methods
C. Data processing
D. Error analysis

III. Results

A. Key results 1
B. Key results 2
C. Key results 3

Provides more details of internal organization of each section

Example of a more detailed (Level 2) structure of scientific outline

IV. Discussion

A. Interpretation of results
B. Comparison with key models/previous results
C. Possible sources of errors

V. Summary and Conclusions

A. Reemphasis of key results
B. Summary of key conclusions
C. Possible future directions
D. Exciting closing statement

Provides more details of internal organization of each section

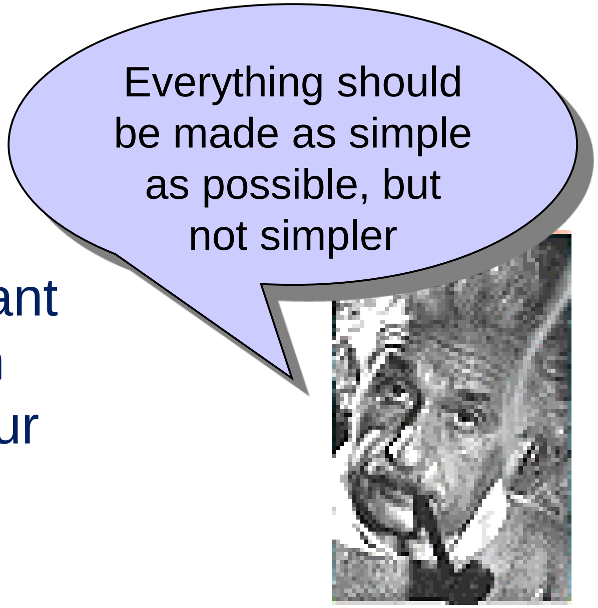
Create Logical Flow in Scientific Papers Using an Outline and a Clear Paragraph Structure

Benefits of outlining:

(1). Your papers and presentations will be logically organized from the beginning

(2). Outlining helps you identify the key points you want to make, and helps you avoid extraneous information that will distract the reader from the logical flow of your argument: ***always write as simply as possible***!

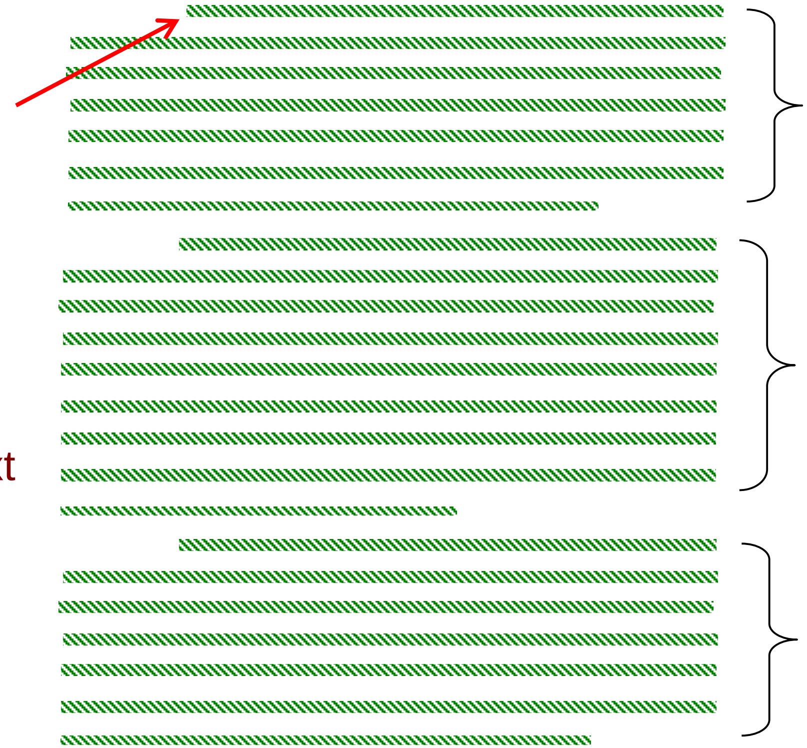
(3). Outlines allow you to break up large projects into more manageable chunks that you can tackle (e.g., a thesis, a big review article, etc.)



Avoiding Disruptions That Limit Accessible Writing: **Create a Clear Paragraph Structure**

Every paragraph should contain roughly one idea + supporting evidence for that idea, if possible (see http://people.physics.illinois.edu/Celia/Lectures/Paragraphs.pdf)

The first sentence in each paragraph is usually the main idea, i.e., the “topic sentence”, while the body of the paragraph supports that idea, then transitions to the next paragraph.



paragraph 1
Idea 1, supporting examples/references, logical transition to next idea

paragraph 2
Idea 2, supporting examples/references, logical transition to next idea

etc., etc.

Physical Review Letters Example: an Introduction With No Paragraph Structure

The high-pressure and temperature phase transition of dioxides is of fundamental interest in solid-state physics, chemistry, and geosciences. In many dioxides, TiO_2 is well known as an important wide-gap oxide semiconductor with various industrial applications such as electrochemical solar cells and photocatalyst due to the characteristic high refractive index [1–9]. Apart from those technological aspects, high-pressure transformations of TiO_2 have attracted special attention as a low-pressure analog of SiO_2, the most abundant component of the Earth's mantle. A number of experimental and theoretical studies have revealed many crystalline polymorphs of TiO_2 at high pressures and high temperatures [10–14]. At ambient conditions, rutile is the most stable phase of TiO_2. Anatase and brookite are also known as natural minerals. All of these phases transform to an α-PbO_2-type, to an orthorhombic-I-type, then finally to a cotunnite-type structure at approximately 50 GPa [11,14]. The cotunnite-type polymorph is identified as the highest-pressure phase, as in many dioxides [15]. Although the analogy of the phase change to the cotunnite structure was applied to TiO_2 [16,17], a very recent *ab initio* study predicted a different phase transition from the pyrite-type structure to an unexpected Fe_2P-type structure (hexagonal, space group *P*62*m*) (Fig. 1) at 690 GPa, bypassing the cotunnite-type phase stability at low temperature [18]. Since no dioxides or difluorides with this crystal structure were reported, physical and chemical properties of this new class of oxide are still unknown. Although the extremely high transition pressure predicted in SiO_2 seems unreachable in the laboratory, TiO_2 shows significantly lower transition pressures. For instance, the α-PbO_2 phase stabilizes at ~10 Gpa in TiO_2, while the same phase at 100 GPa in SiO_2. High-pressure behavior of TiO_2 is therefore a key to understanding the rich polymorphism in the metal dioxide systems, in particular, the post-cotunnite phase relations. However, all the studies performed on TiO2 were limited below 100 GPa, and no post-cotunnite phase has been identified. In this study, we investigate the applicability of the Fe_2P-type structure to TiO_2 both theoretically and experimentally.

Topic sentences

Transition sentences

The high-pressure and -temperature phase transitions of dioxides are of fundamental interest in solid-state physics, chemistry, and the geosciences. In particular, because of its high refractive index [1-9], TiO_2 is an important wide-gap oxide semiconductor for various industrial applications, such as electrochemical solar cells and photocatalysts. Additionally, high-pressure transformations of TiO_2 have attracted special attention as a low-pressure analog of SiO_2, the most abundant component of the Earth's mantle.

Previous experimental and theoretical studies reveal many crystalline polymorphs of TiO_2 at high pressures and high temperatures [10–14]. Rutile is the most stable phase of TiO_2 at ambient conditions, but TiO_2 exhibits a structural phase transition from orthorhombic-I-type to cotunnite-type structures at approximately 50 GPa [11,14]. Cotunnite was previously reported to be the highest pressure phase of TiO_2 [15]. However, a recent *ab initio* study of TiO_2 predicted a transition from the pyrite-type structure to an Fe_2P-type structure (hexagonal, space group *P*62*m*) (Fig. 1) at 690 GPa. This transition bypasses the cotunnite-type phase stability at low temperatures [18]. Unfortunately, because no dioxides or difluorides with the high pressure Fe_2P-type crystal structure have been reported, the physical and chemical properties of the high pressure structural phase of oxides are still unknown.

Studying the high-pressure structural phases of TiO_2 is key to understanding the rich polymorphism in the metal dioxide systems. TiO_2 exhibits significantly lower transition pressures to post-cotunnite phases than other dioxides. For instance, the α-PbO_2 phase stabilizes at ~10 GPa in TiO_2, while the same phase stabilizes at 100 GPa in SiO_2. However, all the studies performed on TiO_2 have been limited to 100 GPa, and as yet no post-cotunnite phases have been identified. In this study, we theoretically and experimentally investigate the high pressure structural phases of TiO_2, in particular to determine if this material exhibits a Fe_2P-type structure at high pressures.

Using Your Outline to Create a Paragraph Structure

Expand your outline into a “Sentence Outline”:

1. Expand your outline “bullets” into complete sentences

2. Each sentence in the outline becomes the topic sentence that conveys the main idea of a paragraph

3. Sentences should be as specific as possible (i.e., convey one idea)

4. The sentences should be organized to construct a clear logical argument supporting your conclusions, i.e., should follow your organized outline

Other Common Disruptions That Limit the Accessibility of Your Scientific Writing

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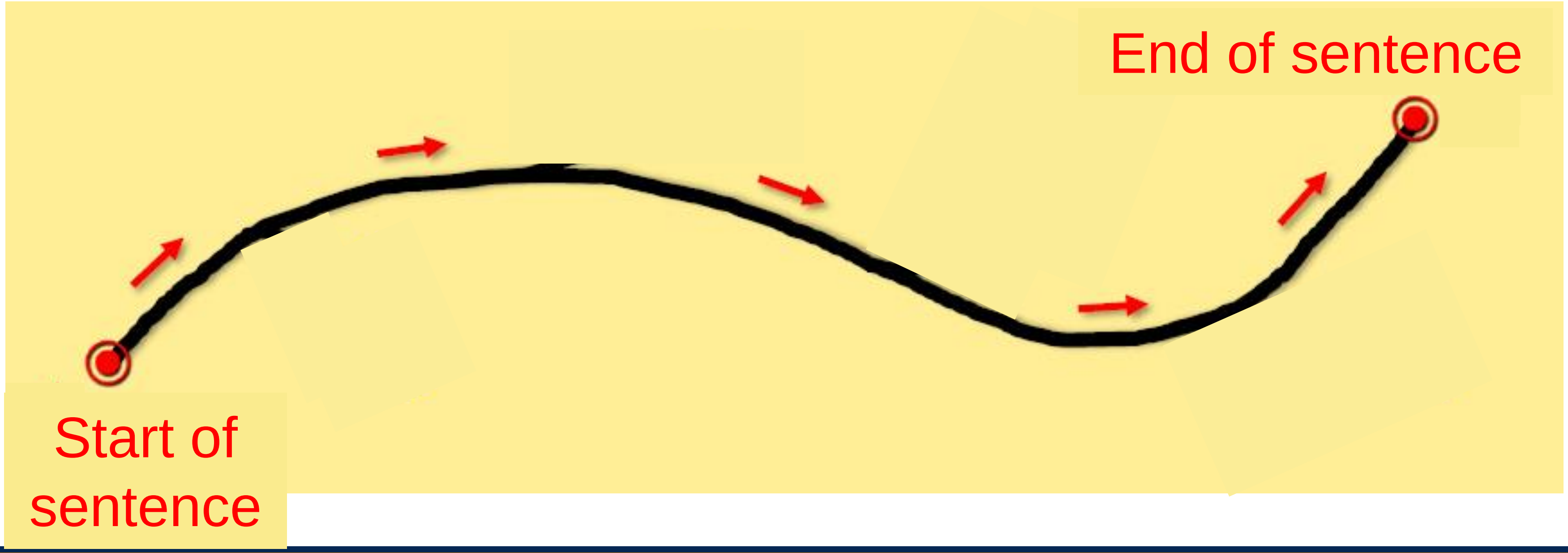

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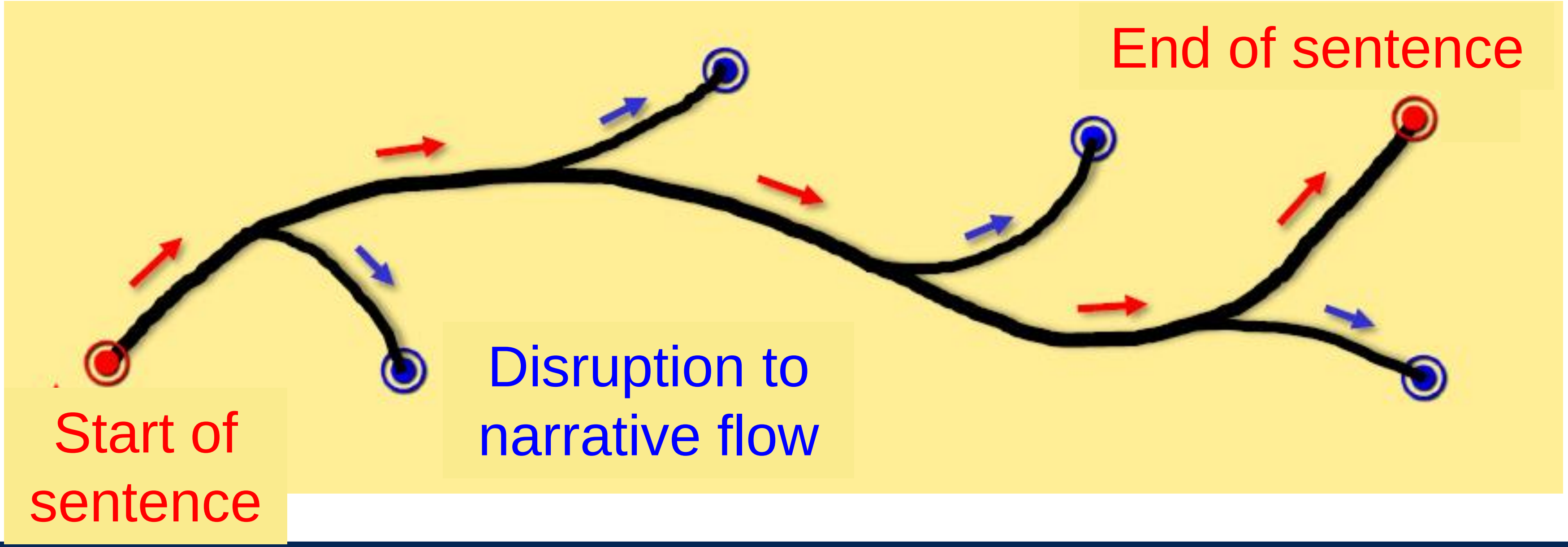
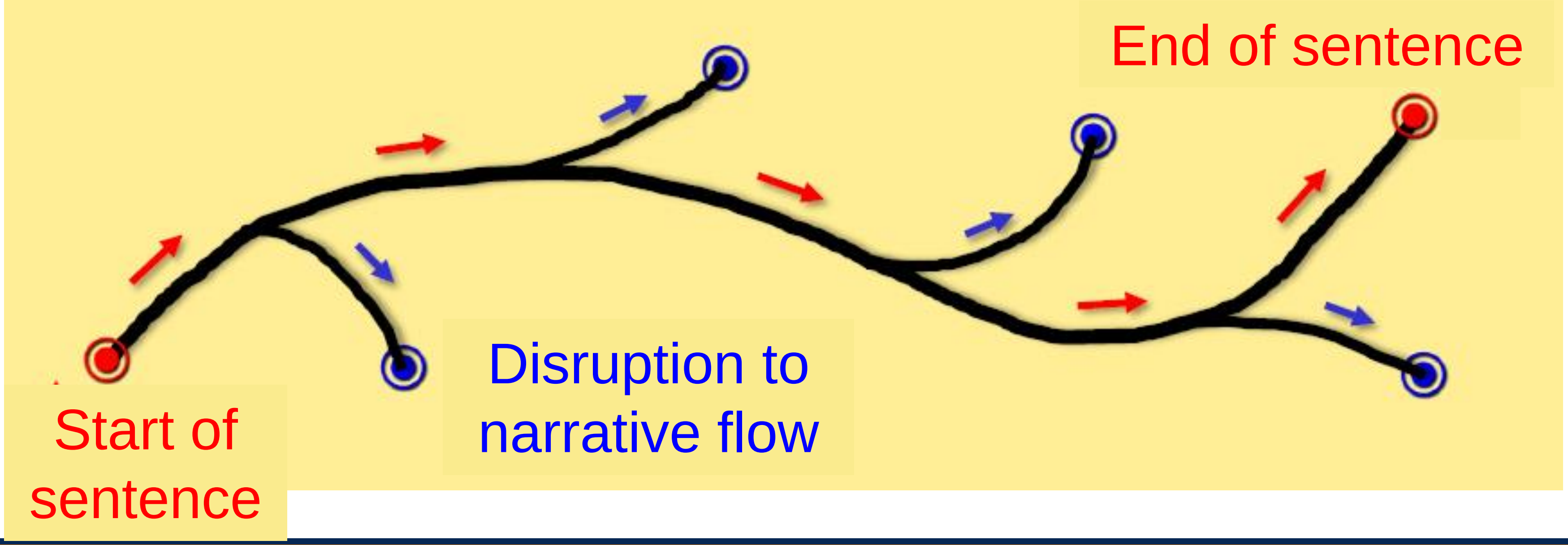


Avoiding Disruptions That Limit Accessible Writing: **Avoid Abbreviations, Acronyms, Jargon, Colloquialims**

The measured PL spectra of a single one-micron-long SWCNT that encapsulates a chain-like agglomeration of colloidal ZnS QDs appear to be shifted with respect to PL spectra recorded for an empty SWCNT.



Avoiding Disruptions That Limit Accessible Writing:
Avoid Abbreviations, Acronyms, Jargon, Colloquialims

The measured PL spectra of a single one-micron-long SWCNT that encapsulates a chain-like agglomeration of colloidal ZnS QDs appear to be shifted with respect to PL spectra recorded for an empty SWCNT.

Solution: Write out acronyms as much as possible. Define acronyms at first usage in your paper.

Also: Avoid colloquial phrases, unfamiliar words, jargon terms familiar only to specialists, etc.!

Avoiding Disruptions That Limit Accessible Writing: **Avoid Abbreviations, Acronyms, Jargon, Colloquialims**

The measured photoluminescence spectra of an isolated carbon nanotube shift when it encapsulates colloidal ZnS quantum dots.

Solution: Write out acronyms as much as possible. Define acronyms at first usage in your paper.

Also: Avoid colloquial phrases, unfamiliar words, jargon terms familiar only to specialists, etc.!

Avoiding Disruptions That Limit Accessible Writing:

Avoid Long, Unwieldy Sentences (> 20-25 words)

Although the signal-to-noise is small for a single line of sight and peaks at somewhat smaller redshifts than those probed by the Lyman-α forest, we estimate a total signal-to-noise of 9 for cross correlating quasar spectra of SDSS-III with Planck and 20 for cross correlating with a future polarization based cosmic microwave background experiment. [54 words]

Solution: Keep your sentences simple, ideally one idea per sentence. Break up long sentences into multiple shorter sentences.

Avoiding Disruptions That Limit Accessible Writing: **Avoid Long Sentences**

The signal-to-noise ratio (SNR) is small for a single line of sight and peaks at somewhat smaller redshifts than those probed by the Lyman-α forest. We estimate a total SNR of 9 when cross correlating SDSS-III quasar spectra with Planck data. Further, we estimate a SNR of 20 when cross correlating these quasar spectra with a future polarization-based cosmic microwave background experiment.

Solution: Keep your sentences simple, ideally one idea per sentence. Break up long sentences into multiple shorter sentences.

Avoiding Disruptions That Limit Accessible Writing: **Avoid Ambiguous Pronouns (it, this, that, they, etc.)**

In the Landau's theory of phases, different phases are classified by whether the state of the system obeys or breaks the symmetries of the Hamiltonian. In turn, this gives rise to local order parameters which can be measured to determine which phase a system is in.

"This" what?

Solution: Avoid ambiguous pronouns and simply repeat the particular noun you're referring to in the sentence.

Avoiding Disruptions That Limit Accessible Writing:
Avoid Ambiguous Pronouns (it, this, that, they, etc.)

In the Landau theory, different phases are classified by whether the state of the system obeys or breaks the symmetries of the Hamiltonian. These broken symmetries, in turn, give rise to local order parameters that can be measured.

Solution: Avoid ambiguous pronouns and simply repeat the particular noun you're referring to in the sentence.

Avoiding Disruptions That Limit Accessible Writing: **Use Active Verbs, Place Verbs Early in Sentence**

Scaling functions for both gauge-invariant and non-gauge invariant quantities across topological transitions of noninteracting fermions driven by the non-Abelian gauge potentials on an optical lattice have also been derived.

Scaling functions were derived for both gauge-invariant and non-gauge invariant quantities across topological transitions of noninteracting fermions driven by the non-Abelian gauge potentials on an optical lattice.

Solution: Place verbs early in the sentence

Avoiding Disruptions That Limit Accessible Writing: **Use Active Verbs, Place Verbs Early in Sentence**

By solving the time-dependent Schrödinger equation in an extensive field parameter range, it is revealed that highly nonresonant dissociation channels can dominate over ionization.

Solving the time-dependent Schrödinger equation in an extensive field parameter range reveals that highly nonresonant dissociation channels can dominate over ionization.

Solution: Replace weak verb phrases with active verbs

Avoiding Disruptions That Limit Accessible Writing:

Avoid Unnecessary and Imprecise Qualifiers

The electron-phonon coupling matrix elements for different phases have been computed in the first Brillouin zone on a reasonable q-point mesh obtained from a sufficiently dense k-point Monkhorst-Pack mesh.

The electron-phonon coupling matrix elements for different phases have been computed in the first Brillouin zone on a q-point mesh obtained from a k-point Monkhorst-Pack mesh.

Solution: Remove imprecise and unnecessary qualifiers

Avoiding Disruptions That Limit Accessible Writing: **Maintain Parallel Structure of Verb Form in Lists**

The project will proceed in four stages: review of the literature, designing the optical trap, construction of the optical trap, and data-taking and analysis.

The project will proceed in four stages: reviewing the literature, designing the optical trap, constructing the optical trap, and taking and analyzing data.

Solution: Use same –*ing* verb form with this list of steps

Summary: Crafting an Accessible Scientific Paper

Make sure you have a coherent story to tell:
writing a draft abstract and introduction can help identify and refine your story.

Create a logical flow to the story you're telling:
start with a detailed outline! Make use of paragraphs with a clear topic sentence and one idea per paragraph.

Avoid disruptions to accessibility in your narrative:
keep sentences short, avoid acronyms and unfamiliar words and scientific terms, avoid colloquial phrases, avoid ambiguous pronouns.

Questions? slcooper@Illinois.edu