You may be wondering why we are having lectures on scientific writing. You probably thought you were finished with writing courses after your first year in college. So what is this all about?

Well, I am certainly not trying to teach you to write elegant, flowery texts that will impress an English teacher or a creative writer. I simply want you to be able to write clearly, logically and convincingly.

Over the years, I have learned that most scientists cannot write well. I have seen this in reading journal articles; I have seen it even more clearly as a referee for various journals; and I have seem it most clearly in editing contributions to TUNL’s annual progress report.

Here is a little story to help you understand the size of the problem. I once had to fill out a form at the Duke Human Relations office, explaining the problem for which I had gone to seek help. When the receptionist looked at the form, she was amazed and said, “This is clear! I can understand everything you wrote! Most scientists can’t write clearly!!”

When we can’t write clearly, it is much more difficult for readers to evaluate our work and use our results in appropriate ways. Later in your careers it can also make it more difficult to obtain funding for your research.

GOOD SCIENTIFIC WRITING IS A NECESSARY PROFESSIONAL SKILL!
Why These Lectures?

- Writing is part of doing science
- Most of us are not trained to do scientific writing

**GOALS:**

1. Give you useful professional skills
2. Improve TUNL Progress Report

In fact, writing is part of doing science:

As scientists, our main interest is research, not writing, BUT Our research isn't complete until the results are communicated

We need to tell our readers

* Our Goals
* Why it is important
* What we did
* How we did it
* What our results are

This involves journal articles, theses, research proposals, etc.

Not only do we need to communicate this information, but we need to do so clearly and effectively.

Yet most of us are not trained for scientific writing and have never thought very much about it. We tend to write in a hurry. We also tend to write in a way that is clear to us and to our collaborators, because we are already familiar with the work, but it is often not at all clear to general readers.

Therefore, these lectures are an attempt to see if we can

1. Give you some useful skills that will help you all throughout your careers
2. Improve the quality of contributions to the annual Progress Report

The first goal is primarily for you, while the second helps the lab generally and me, as editor of the progress report, more specifically.
To put this in perspective, I would like to quote Henri Poincaré, a famous nineteenth century mathematician and physicist. [see slide]

Poincaré’s famous saying about science is also true of scientific writing. We can have all the words and all the facts, but if they are not
- tied together coherently,
- presented clearly,
- in the kind of logical order that the reader expects,
- and in a vocabulary that the reader understands,
then the words and facts will not successfully communicate our results! They will not be “scientific writing” in the true sense of the term!
They will be a pile of bricks and not a house.
Themes for These Lectures

- We are writing for our readers
  “Reader expectation theory”

- Proceed from the known to the new

As I try to help you learn to communicate your results more effectively, you will hear two recurrent themes. In fact, by the end of these lectures, you will probably be tired of hearing them.

First, it’s not about you! We are writing for our readers. This is called “reader expectation theory.” It has been taught here at Duke by George Gopen, the head of the writing program. It was also published in American Scientist in 1990 and republished in 2011. The article mainly addresses what I will be covering in the second lecture, but it applies equally (and perhaps more significantly) to the broader issues I will talk about this morning. Basically we need to consider why we are writing, and therefore who our readers will be. Then we need to think about what they are interested in, and how much they already know about our subject.

The second theme follows from the first. When we give new information to our readers, they need a context in which to put it or they may have trouble understanding it. We have to start from where they are, from what they know and care about. Then we can relate the new facts back to that. In addition, readers expect information to come in a certain order. If we present it in that order, they have a much better chance of understanding what we are trying to say. These principles apply:

At the level of a full report or journal article (covered this morning)
At the level of a single paragraph or sentence (covered this afternoon)
THE MOST COMMON MISTAKE:

WE WRITE FROM OUR PERSPECTIVE AND KNOWLEDGE BASE

RATHER THAN FROM THE READER’S PERSPECTIVE!

THE MOST COMMON MISTAKE IS WRITING FROM OUR OWN PERSPECTIVE AND KNOWLEDGE BASE,

WE ASSUME THAT IF SOMETHING IS CLEAR TO US, IT WILL BE CLEAR TO OTHERS. NOT TRUE!
We tend to think that the readers will be as familiar with our subject and our vocabulary (or jargon) as we and our collaborators are. Sometimes they are, but often they’re not.

I have been to very few seminars and colloquia that were too elementary and gave too much background information, but I have been to a very large number of talks that were almost incomprehensible after the first five minutes. That is NOT good communication.
In order to meet help you write more effectively, here is the program I intend to follow:

I want to start with an overview of the TUNL Progress Report, which is one of my main concerns in giving these classes. Many of you are not familiar with the document because you are new to the laboratory, so I will start with a brief description of its purpose and who its readers are.

Then the classes will be divided into four main sections.

This morning, in Part 1, I will emphasize:

1. **Content selection**: This should be based on what the readers are interested in and how much detail they need. In Poincaré’s analogy of building a house, it would be like deciding what materials you will use to build the house and how big the house will be.

2. **Content organization**: We want to present the different sections of our document to our readers in a logical order. This would be like the architect’s floor plan for the house.

This afternoon, in Part 2, we will cover:

3. **Content communication**: Here we will consider the structure and organization of sentences and paragraphs, avoiding common errors. This corresponds to the actual construction of our brick house.

4. **Content illustration**: You want the figures and graphs in your document to be clear and compelling. The illustrations are like the windows on a house, allowing people to see “inside.”
So let’s begin with the TUNL Progress Report.

**An important document**

- Written for the Department of Energy
- Read by scientists from elsewhere
- TUNL’s face to the world

Written for the U.S. Department of Energy (our primary funding agency) and is part of our obligation and accountability to them.

- We write a new report every year.
  Every third year it is part of our grant renewal process. That will occur this year.

- Read by many scientists from other institutions
- Available online, and the goal is to eventually have it distributed in printed form

In short, it is part of TUNL’s face to the world.

If contributions to the report are poorly written and poorly organized, if the figures are of poor quality and confusing, it will not only make our results difficult to understand, it will also tend to cast doubt on the quality of the scientific research itself.
A Major document.

Around 200 single-spaced, full-size pages

Describes all the work done at TUNL by our staff and collaborators

CONTENTS [see slide]

Many contributions written by graduate students, post-doctoral fellows, and sometimes by undergraduate students engaged in the research.
A Difficult document to produce

Written by many different people with varying writing skills, many not native English-speakers
It covers a wide range of research and associated development work
Yet it should be a unified, cohesive document that is easy to read

For all of these reasons, WE NEED YOUR HELP!
The better the quality of what you submit to the report, the better the report will be.

There is never enough time in the schedule for me to do the amount of editing I would like to do. So I have a real interest in helping you write better. And you should have a real interest in developing an important professional skill.
With that introduction, it is time to begin the main content for this morning: Writing for Your Readers.

If some of the things I say seem intuitive and obvious to you, this is good! It means you will have an easier time this afternoon, when I apply the same ideas at the level of sentences and paragraphs, where I see most of the errors in the progress report.

On the other hand, if what I say this morning seems new and like a fresh way of thinking about writing, that is also good. It means you needed this class!

So, either way, please hang in there with me.
First, content selection. During the course of your career, you will be expected to write a number of different kinds of scientific documents, but the same principles always apply in deciding what to include and what to leave out.

Selecting the content of your document is a little like deciding how many bricks you want to use to build your house... and which ones... and what rooms you want to construct with them.
Types of Scientific Writing

- Lab notebooks
- Theses
- Progress reports
- Journal articles
- (Conference abstracts)
- (Conference talks)
- (Seminars and Colloquia)

Types of documents:
Here is a list of some of the kinds of documents you may be called upon to write. Each has its own purpose and its own class of readers. I won’t get into conference abstracts and talks, which follow the same guidelines as for written documents.

For the others, we will think about

- Readers (Who we are writing for)
- Purpose (Why we are writing)
- Familiarity (How much our readers will know about our subject)
- Content (How much detail they need and want)
Laboratory Notebooks:
Let’s start with where most of you have had your experience: lab notebooks.

In many ways, this is the most natural kind of scientific writing for any of us. It is a simple, chronological account of what we did, what occurred, and what we observed. I think you can all help fill in the categories here.

FOUR BULLETS – try to elicit
PhD (or senior or masters) Theses:

The next most natural kind of writing is the thesis, whether it is the report on a senior project, a master’s thesis, or a doctoral thesis. Post-docs have all ready written these, but those who go into academia will eventually be supervising students who write them.

Usually there are careful guidelines from the university along with examples of earlier theses from your department and group. These will serve as a guide.

FOUR BULLETS – Elicit

The same level of detail can be used in technical reports, such as users manuals. The manual for my computer code is the best summary of all the physics that is in the code! It is useful for me, as well as other users. Otherwise, the information is scattered throughout a large number of journal articles.
Progress Report Contributions:

- **Readers**: Funding agency (primarily)
- **Purpose**: Convince them their money is being spent well on what was proposed
- **Familiarity** of readers: General nuclear physics (plus a few specialists)
- **Content**: Overview of work THIS YEAR

References for earlier work

Very few details

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**Progress Report Contributions:**

This is where we will be spending the most time and where I will seek most of my examples!

**READERS**: As I said, we are writing this mainly for the U.S. Department of Energy, though the report is also distributed more broadly and is available online.

**PURPOSE**: An important purpose is to convince DOE that their money is being well spent, and that we are doing what we said we would do.

**FAMILIARITY**: Some people who read your contribution will be specialists in your particular field of nuclear physics, but many will not. Therefore it is important to use a minimum of specialized vocabulary and to define all your acronyms.

**CONTENT**: The emphasis is on the work that has been accomplished this year. Earlier work should be summarized VERY BRIEFLY, with references to earlier progress reports. This is an overview. Contributions are strictly limited to two pages in the prescribed format. Details of your work will be in journal articles, and if readers don’t want to wait that long, they can contact one of the authors.
Journal Articles

Readers: Other researchers in your field; Those needing to use your results

Purpose: Communicate results; Convince readers the results are correct

Familiarity of readers: Specialists

Content: What was done & results
Medium level of detail
Previous work summarized & referenced

Journal Articles:
This is the other very important kind of writing that most scientists do. This is where you convey your results in a final, definitive form to the general scientific community.

[Ellicit BULLETS]

READERS: Most of your readers will be familiar with your field of work, though some will be people from related fields who want to use your results.

PURPOSE: Your goal is to communicate your results with enough detail so that they can evaluate the quality of the work.

FAMILIARITY: Most of your readers will be familiar with your field of work, so more specialized vocabulary can be used than in the progress report, though defining terms and acronyms is always good.

CONTENT: This means much less detail than in a thesis, but more than there is room to give in a progress report contribution.
Also, unlike in a thesis, most journals will not allow you to describe in detail any preceding work from your group or others. You simply quote the results and cite the reference where it is published.
Journal Articles

- Recent Disturbing Trend
  More concern with getting it in print than getting it right!
  Relying on the referee to find problems

  In the long run, this will hurt your reputation as a scientist. **Quality matters as much as quantity**

Journal Articles:

I have been talking about the way a paper is written, but let me mention a **scientific problem**. In recent years, some authors have been in a hurry to get things into print. There is more interest in publishing a lot of papers quickly than in publishing **scientifically** good papers.

This is partly driven by the desire for academic promotion and tenure. The result is lack of care with regard to **peripheral** aspects of the work, such as theoretical calculations to reproduce the data. The attitude is, “My data are correct. If the referee doesn’t object to the comparisons with calculations, it doesn’t matter. If the referee objects, I’ll redo the analysis.” When an experimental colleague said that to me and refused to address the problems I pointed out, I took my name off the paper.

There are two reasons for wanting to get it right before submitting for publication:

1. The referee will be in your field, and if part of the work is of poor quality, it will hurt your reputation. You and your collaborators want to find the problems **first**, not rely on the referee to do so.
2. If the referee doesn’t notice the problems and the paper is published, others in the field will likely notice them. Again, your reputation as a scientist will suffer.

Publishing quickly may seem to help in the short term, but it will hurt you in the long term. **Quality matters!**
That was an aside. Now, let’s return to the main topic of producing good scientific writing.

Now that you understand the principle of writing for your reader and have some idea of how much detail to include in the document you are writing, it is time to consider how to organize the content into the different parts of your document. This is a bit like setting up the architectural drawing for our brick house. You have to decide what goes where.

My examples will be taken from TUNL progress report contributions, but similar considerations apply to other types of documents.
The Title: Orienting your readers

- You want to interest your readers
- Shorter titles are better
- Where appropriate, relate the work to a broader goal.
  “The reaction A(a,b)B at energies important for nuclear astrophysics”
- Don’t put too much detail into the title;
  “The reaction A(a,b)B at energies near threshold”

Titles:

Let’s begin at the beginning. The kind of title you put on your document will depend on what your readers are interested in. A title that works in one place may not work in another. Your title should:

- Fit the interests of your readers and
- Relate to your specific goals

In general, shorter titles typically work better than long ones.

Where appropriate, relate the work to a broader scientific goal. In the TUNL Progress Report, things of interest to the funding agency are:

- Does the work relate to larger scale national research priority?
- Will the work be practically useful?

Otherwise, try to give a little perspective in the title. For example, “Energies near threshold” may be more informative than listing the exact range of incident energies, because your reader may not know the threshold energy of the reaction.
This is an example of why it is not enough to take something from a document written for one set of readers and directly insert it into a different kind of document for a different group of readers.

This title comes from a collaborative project with people from outside nuclear physics.

What’s wrong with this title? . . . [elicit]

It might be appropriate in a specialized journal on membrane science or drinking-water purification, but it means little to a nuclear physicist. Therefore it would not work well in the progress report. If we don’t understand the title, typically we don’t want to read the rest of the document. Short, simple titles also tend to work better than long ones.

Having read the contribution, I was able to come up with the second title option is [READ]. It eliminates the material a nuclear physicist would not understand and is much simpler, though it is still a little longer than I would like. It summarizes the essentials and leaves the details for the abstract.

Which title would make you want to read the contribution?!?
The Abstract: A quick overview

- A miniature version of the full contribution or journal article
- Common mistakes
  - Duplicate your introductory sentence
  - Put in too much detail
- It should BRIEFLY summarize
  - What you did
  - What you found or accomplished

Abstract:
The next part of your document is typically an abstract. This is your opportunity to summarize the entire paper and convince readers they want more details. It is essentially a miniature version of the document.

Common mistakes:
The first few years we included abstracts in the TUNL Progress Report, many people simply took their introductory sentences and copied them into the abstract. That doesn't work! The abstract is not an introduction, it is a summary.

The second common problem is to put too much detail in the abstract. Leave that for the main text. For the progress report, we would really like the abstract to be no more than five lines.

However, it is also possible to put too little information in the abstract. “We are developing this kind of equipment for this kind of experiment. We report updates to the system.” What kind of updates?

You want the abstract to briefly summarize what you did and what you found or accomplished. It should address WHAT you did, WHY, HOW, and your RESULTS.
Abstract:

Here is a good abstract from an earlier progress report, though I have simplified it slightly from the way it appeared. It fits the length guideline and has all the important elements:

WHAT was done: uranium targets were prepared
WHY: For fission fragment asymmetry measurements at near-barrier energies
HOW: Evaporation and electro-deposition
RESULTS: Varied quality but few impurities
Main Text Organization

“Tell them what you’re going to tell them;
Tell them;
Tell them what you told them”
— (Aristotle)

Introduction
Description of work
Summary & Conclusions

Now let’s consider the main body of your document.

How you organize the material should follow the general guidelines suggested by Aristotle for speeches. In their best-known form, the guidelines are:

Tell them what you’re going to tell them;
Tell them;
Tell them what you told them.

This is what readers expect, and this is what they will be looking for.

The three parts will normally be

Introduction (background, goals, motivation, approach to be taken)
Description of the work (main body of the contribution)
Summary and Conclusions (what you found and what it means)

In a journal article, the introduction and summary will be separate sections. In the progress report, where contributions are only two pages, they will normally be separate paragraphs.

Now let’s consider each of these sections, in turn.
“Introduction” Section

❖ “Tell them what you’re going to tell them”
❖ **Motivate** your work; put it in a context that will interest your readers.
   
   What interesting question does it address? (interesting to the reader!)
   
   What has previously been done?
   
   How will you address the question?

❖ **Special cases:** One PR contribution among many on the same large project

**Introduction:** (background, goals, motivation, approach to be taken)

**Special cases:** There are some exceptions to this rule. Some of you will be involved in large, multi-institutional collaborations -- Neutron EDM and Majorana projects. For our progress reports, these projects typically have an introductory “contribution” that motivates the project and places the TUNL work in a broader context. The abstract and introduction for your contribution mainly needs to fit your work into the context of the overall project.
Description of Your Work

- “Tell Them”
- Big error is following chronology not logic
- Typical organization for experiments:
  - Experimental technique
  - Data analysis
  - Results
  - Comparison with other work
  - Conclusions

Now, at last, we come to the description of what you did. This is where your main interest lies. BUT be aware that your reader will expect the information to come in a logical sequence.

A big error is to follow chronology. You will tend to think of things in the order that you did them. “We tried this, we saw that; then we tried something different and found a different result. We did this analysis and decided we needed to take more measurements…”

Your reader will be expecting a more thematic or logical approach based on all the work you did. “Here is the experimental technique we used. Here is the way we analyzed the data. Here are the results we obtained. Here is how they compare with other measurements and with calculations. Here are our conclusions.” This is much better!
Description of Your Work

- Organization for equipment development
  - Design goals
  - Design
  - Construction & its challenges
  - Testing and results
- Each topic in a separate section
  - With headings in an article
  - Without headings in P.R. contribution

If, rather than running experiments, you are developing equipment or measurement techniques, you still want to follow a thematic approach.

  Design goals and specifications
  How and why you decided on the design.
  How it was executed.
  How it was tested and whether it worked well

In a journal article, each of the logical steps will typically be a separate section with its own heading and perhaps some sub-headings.

In the progress report, we discourage the use of section headings unless the material is complicated. The reason is that the contributions are only two pages long, so the sections would typically be only one or maybe two paragraphs. And the headings take up a lot of space!
“Summary & Conclusions” Section

❖ “Tell them what you told them”
❖ **Summarize** the main points of document:
  Goal (Reader’s main interest!)
  Method (refer to technique briefly)
  Results
  Analysis
  Conclusions (significance of results)
❖ Future work projected (if appropriate)

**Summary and Conclusions:**

This section is usually simple, straightforward, and brief.

**Essential for a journal article or thesis.**

This is where you get to remind the reader of what has been said.

**Less essential for the progress report,** where contributions are short and keeping to two pages is difficult. But it is still **VERY helpful.** Too many contributions just end with an experimental or equipment detail but no real “ending” or conclusion to put things in perspective.

When it is included,

**Be specific.** “We made great progress!” doesn’t really say anything.

Mention the initial GOAL, how it was met, or what progress has been made toward meeting it. That’s where the reader’s interest is!

Sometimes it is helpful to mention where additional work is needed or what new questions have been raised.
Main Points of this Class

- **Content selection:**
  We are writing for our readers, so we need to understand
  - The purpose of the document,
  - Who the readers will be,
  - How much they know about the subject,
  - How much detail they need and want,
  - How much “jargon” they understand.

Here is an example of a summary and conclusion: the main points of this morning’s class:

First, we are writing for our readers, so in selecting the content for our document we need to consider the points listed in the slide.
Main Points of this Class

- **Content organization:**
  - Start with the reader’s interest.
  - Then move from the known to the new.
    - The purpose or goal of the research
    - How you worked to meet the goal
    - Results obtained

Second, we need to organize the content into sections of the document in a way that makes sense to the reader. We start with the reader’s interest and knowledge base and then relate new material to it. We move from the known to the new. Thus we

- Start with the purpose or goal of the work,
- Describe how we worked to meet the goal,
- Tell them what results we obtained.
Now for the “future work” part of my summary and conclusions. . .

This afternoon, the plan is to move on to take the same two principles — writing for the reader and moving from the known to the unknown — and apply them at a smaller scale. So we will consider:

Content Communication:
How we construct sections and paragraphs that are logical and easy to understand

And then Content Illustration:
How we design figures that are clear and easy to read