

# Starting Strong: Navigating an Undergraduate Research Thesis



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# INTRODUCTION

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Hello everyone and welcome to this guide on beginning your journey in undergraduate research.

Whether you are preparing for a fourth-year thesis, exploring experiential learning opportunities, or simply curious about what life in a research lab entails, this resource is designed to help support your research journey.

Our goal with this guide is to provide some insights to help you navigate three key transitions:

- Finding the right supervisor and research environment
- Developing the professional and interpersonal skills needed to thrive in a research lab
- Learning from the experiences and perspectives of supervisors, mentors, and peers

Although this guidebook was created with Biochemistry and Biomedical Sciences students at McMaster University in mind, the guidance, strategies, and insights shared here are intentionally broad. We hope it will serve as a valuable resource for students across disciplines and institutions as they embark on hands-on research for the first time.

Entering a lab for the first time can feel exciting, overwhelming, and everything in between. This guide aims to make the transition clearer, smoother, and more supported. We hope it helps you feel ready, confident, and empowered as you take your next steps into the world of research.

Important Note:

This guide is meant to offer general advice and an overview of common experiences in undergraduate research. It is not a course syllabus, lab manual, or safety document, and it does not replace the official information provided by your program, course coordinators, or research supervisors.

Every course and research environment operates differently. For specific questions about requirements, assessments, lab expectations, or safety procedures, please refer to the appropriate official resource (such as your course syllabus, lab-specific training materials, or guidance from your supervisor, course coordinators, and lab mentors).

Sincerely,

Felicia Vulcu, Caitlin Mullarkey, and Meghan Pepler



1.

# CHAPTER 1: WHAT IS RESEARCH AND WHY DOES IT MATTER?

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## Introduction

Research is a systematic and iterative process of inquiry designed to generate new knowledge. Or, as a faculty member at McMaster University describes it:

*“The most important medical breakthroughs – vaccines, antibiotics, PCR, CRISPR – didn’t come from chasing short-term applications. They came from scientists trying to understand how the world works at the most fundamental level. That’s what basic research does. **It’s slow, often unpredictable, but it’s the engine behind every meaningful advance we have.**”*

It can look very different depending on the questions being asked – sometimes it means studying the behaviour of a single protein, while other times it involves mapping global biological networks. For undergraduates, research is both a chance to contribute something new and an opportunity to go through a transformative learning experience. Over the course of your thesis, you’ll become part of an active research group and contribute to ongoing investigations while also exploring your independence as a researcher. A thesis project is a chance to practice curiosity, develop resilience, and learn how to follow the evidence wherever it leads. In other words:

*“**Research is a chance to ask questions no one has answered yet—and sometimes, to find answers that can make a real difference**”*

*-McMaster Faculty*

## Why do research as an undergraduate?

Participating in research as an undergraduate student is an opportunity that extends far beyond mastering technical skills. Students gain hands-on experience in laboratory methods, coding, data analysis, while simultaneously developing transferrable skills like scientific writing, oral communication, and time management. Research trains you to think critically, to approach problems from different angles, and to persevere when things don’t work out the first (or second, or third) time.

**During your thesis you will foster your critical thinking, creativity, and resilience – traits that benefit you well beyond the end of a research placement.**

*“Research teaches us not just about the system we’re studying, but how to be **resilient**, how to **work with others**, how to **ask good questions** and how to be **open to the unexpected**.”*

*-McMaster Faculty*

After completing an undergraduate thesis, some students are inspired to move on to graduate school or medical training, while others head into industry, biotech, or policy work. Your thesis will help you decide what career path is right for you. No matter what path you take, the process of research equips you with problem-solving strategies and a professional identity rooted in scientific curiosity and inquiry.

At McMaster, the undergraduate research thesis represents a capstone learning experience. Students join a laboratory and work under the supervision of a principal investigator (PI), graduate students, or other mentors. The scale of the project is limited—your work will likely contribute to a larger question rather than solve it outright—but this does not diminish its value. Thesis projects are authentic: they involve generating and interpreting data, troubleshooting experiments, and communicating findings.

Or as another faculty member summarized:

*“Science is a long game and even the smallest steps matter. Thesis research is real research and critical for advancing our scientific goals.”*

In short, research benefits your:

- **Cognitive and technical growth:** Learning new methods, data analysis, and experimental design.
- **Transferable skills:** Communication, teamwork, and time management.
- **Identity formation:** Developing a sense of belonging within the scientific community
- **Resilience and independence:** Building confidence in navigating obstacles and learning to tolerate setbacks.
- **Career clarity:** Understand your goals for your future. Learn if furthering your education is something you want to do (medical, professional, or graduate school).

And for many students, the real reward of doing a thesis is the thrill of discovery—the excitement of generating data, finding patterns, or building new hypotheses.

## Research methodologies: Wet lab and dry lab

Research in the sciences is often divided into “wet lab” and “dry lab” domains. Wet-lab work includes things like culturing cells, running molecular assays, manipulating DNA and RNA, or working with proteins. In

some applied science projects—especially in immunology or pharmacology—wet-lab work may also involve animal models, which is something to consider when choosing a lab. Dry-lab research, by contrast, takes place primarily on a computer. It can involve database construction, building bioinformatic pipelines, or analyzing existing transcriptomic or proteomic data. These projects often require (or teach you) coding literacy, using languages like R or Python to analyze large datasets. Many projects combine wet- and dry-lab approaches, and increasingly, having some comfort in both areas is an advantage.

Since methodologies vary widely across labs, it's helpful to think not just about the big questions that interest you, but also about the techniques you'll enjoy working with every day. **This “methods-forward” mindset is valuable.** We recommend you take a look at the methods section for some papers that a lab of interest has published recently. Do they do biochemical assays that you find interesting? High throughput screens? Western blots, cloning, qPCR? Identifying whether you might be more comfortable at the bench, on a computer, or somewhere in the middle can help align students with a research placement that's both productive and personally satisfying.

Another way to think about research is whether a project is **fundamental** or **applied**. In Canada, NSERC typically funds research that aims to explain how the world works (i.e. fundamental science), while CIHR funds projects with more direct links to human health (i.e. applied science). Both types of research are essential, and PIs in the Biochemistry and Biomedical Sciences Department may hold either or both types of grants. Knowing the kind of funding a lab has can sometimes provide insight into the scope and focus of its research.

## Mindsets for effective research

Technical skills will get you started, but your mindset is what will carry you through the ups and downs of a thesis project. **Curiosity** drives good questions. **Problem-solving** skills help you adapt, iterate, and try again. **Integrity** ensures you record and report your results honestly, even when they're not what you expected. **Persistence** keeps you working when experiments fail. Later chapters in this guidebook will provide more detailed strategies for navigating failure, but this introduction emphasizes its role as an integral and constructive part of the research journey. Student who engages in research develop resilience, adaptability, and self-directed learning.

***“Research is a way of thinking, forcing you to slow down and question what you think you know, to follow the evidence wherever it leads. Your undergraduate thesis is your chance to make a genuine contribution. It's not about having all the answers (which is a different mindset than other courses). It's about learning how to ask better questions, how to test them honestly, and how to share what you find with integrity.”***

-McMaster Faculty

Your thesis year is designed to normalize this uncertainty. You'll discover that research rarely follows a straight line, and that's where much of the real learning happens.

## Reflection and personal engagement

Research is not just about producing data—it's also about your growth as a learner and future professional. We encourage you to pause and reflect as you begin:

- What do I hope to gain from this experience?
- Which skills or mindsets do I want to strengthen?
- How do I define success for myself in this project?

Answering these questions can help you frame your thesis as more than a requirement to complete. It becomes an opportunity to build your scientific identity, develop strong relationships, and connect your personal goals to the broader world of discovery.

2.

## CHAPTER 2: FINDING AND NAVIGATING A THESIS PLACEMENT

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### Understanding the process: When to start looking and how to identify labs

The prospect of finding a thesis placement can seem daunting. However, advanced planning and thoughtful preparation can make the process more manageable and set you up for success! Many labs start to accept applications for thesis spots up to one year in advance of the anticipated start date. **That means most often, students begin the process in September of their third year.** It's important to emphasize that the process and timelines can vary significantly between labs. That being said, the earlier you start, the better.

**The first step in securing a thesis placement is to reflect on the question “what interests me scientifically?”**

Over the course of your undergraduate career, you may have developed a particular interest in microbiology, cancer, stem cells, or bioinformatics. Take some time to consider which subjects or topics sparked your interest. Identifying these areas of interest will help inform your search for a lab and engaging project. When reflecting on your interest, avoid being too narrow in scope. While it is helpful to have a sense of your interest, there may be adjacent or related fields that would also be a good fit and hone your research skills. **Remember, the thesis is as much about developing your research abilities as it is about exploring a specific topic.**

Once you have identified several areas of interest, now it's time to explore the different labs that exist at your institution. Generally, it is best to start with your home department and faculty and branch out from there. Explore departmental websites which will list faculties and their scope of research. **Most faculty members will also have individual lab websites that will provide more detail on their research,** team members and publications. As you explore these resources, make a note of the labs that align with your interests. Write a paragraph about the research done in each lab you want to apply to and what interests you about them specifically. This will help you craft a specific and thoughtful email which is crucial in garnering a potential supervisor's attention. This will be discussed further in subsequent section, but it is important to note that generic and mass emails should be avoided. Aiming for a list of 5-10 PIs is a good starting point as you then move on to contacting PIs.

**To help you stay on track it is a good idea to keep a record of your emails. We have provided a sample excel template to help with this:**

[Finding a Supervisor\\_Template](#)

## Application tools

As you begin exploring potential research labs, you'll primarily rely on information found on departmental or university websites. From there, you'll likely be directed to individual investigators' lab pages. These websites typically provide an overview of the lab's research focus, recent publications, and team members. Reviewing this information can help you determine whether the lab's work aligns with your interests and gives you insight into the research environment. **It is often helpful to read recent publications from the research group.** When reviewing these publications, it's important to **focus on papers where the investigator you're interested in is listed as the last author** (not just the most recent publication!). In biomedical research, the last author position signifies senior authorship and is usually held by the principal investigator (PI), the person who conceptualized the study, secured funding, and provided overall intellectual direction. In contrast, the first author is usually the individual who carried out the bulk of the experimental work and writing. Middle authors, or co-authors, may have contributed in a variety of ways, including experimental support, study design consultation, provision of reagents, or assistance with manuscript preparation. However, if the investigator is listed only as a co-author, the project may be more peripheral to their main research focus. For this reason, last-author publications offer the clearest insight into the PI's primary research interests.

Crafting an email that hits on the right points and tone is essential! In your email, introduce yourself as a potential applicant, express your interest in the lab's research, and end by requesting an opportunity to discuss a position. The essential elements are described in detail below:

## Essential Email elements

**A formal salutation:** Always address the PI with their proper title (Dr.), never by their first name or Mr., Ms., or Mrs. etc. You should also begin with a professional greeting such as 'Dear,' 'Good Morning,' or 'Good Afternoon.' Avoid overly casual openings like 'Hi,' 'Hello,' or 'Hey.'"

**Introduction:** Introduce yourself, your program, and level

**Expressing interest in their lab work:** Indicate that you interested in a thesis opportunity and explain in 2-3 concise sentences, exactly what excites you about their research program. This is where you want to show off the background research you have done and tailor this section to the specific lab.

**The Ask:** Politely express your interest in meeting with the faculty member in the near future to discuss a potential position.”

**Closing:** Include a polite closing such as “Sincerely,” “Kind regards,” “Best wishes,” etc.

Faculty members receive a large volume of emails each day, so it’s important that yours stands out. To make a strong impression, focus on writing a thoughtful and personalized message, rather than sending a generic email that could be mistaken for a mass communication. **Quality and sincerity matter.**

## PI Tips and Tricks

What to include in your email

We surveyed faculty members at McMaster who frequently supervise thesis students to understand what they expect from prospective applicants. The results clearly highlight which expectations are most common—and which are less emphasized.

- 100% of faculty members surveyed expect students to provide a CV
- 90% of faculty members surveyed expect students to include a statement of interested and/or rationale for selecting their lab
- 80% of faculty members surveyed expect students to submit a transcript

On the other hand:

- **Only 20% of faculty members expected students to have previous lab experience**
- 10% of faculty members expected students to directly mention their GPA

## When to Apply and Possible Outcomes

You may be surprised about how early the thesis process starts. Students are most often beginning the process at the start of a 3rd year for a position that begins in 4th year. Most faculty members are accepting applications and offering spots between 6-12 months before the start of the project. Therefore, the earlier you start looking for a placement, the more potential positions are available. It is important to note, the availability can fluctuate throughout the year with funding and personnel changes in labs. **Following up with PIs to see if there have been any changes is always a good idea.**

There are three potential outcomes when emailing a faculty member:

### **1. No response: You don't receive a response back.**

Action item: After 1-2 two weeks, it is a good idea to send a polite follow-up. PIs receive many emails each day and it possible yours was lost in the shuffle and they did intend to reply. Less is more with a follow-up email, consider something like, “Dear Dr. X, I am following up on my email inquiring about the availability of thesis position in your lab. I would be grateful for an opportunity to discuss this further with you at your earliest convenience.”

### **2. Response with no offer: The lab is not accepting applications, or the applicant is not the right fit**

Action item: While rejection can be disappointing, it is important to remember that thesis positions are competitive, and you should remain optimistic about the other labs you have contacted.

### **3. Response with an offer: The applicant receives a follow-up for a future meeting with the PI or the lab.**

Action item: Congratulations you are one step closer – see the section below on preparing for an interview.

## **What qualities are PIs looking for in potential applicants?**

PIs value curiosity, resilience, technical competence, strong work ethic, and good interpersonal skills as the core qualities for successful thesis students. Here are some of the things PIs told us they specifically look for:

### **1. Scientific Curiosity and Enthusiasm**

- Genuine interest in research and learning
- Excitement to be in the lab and engage with experiments
- Open-mindedness and curiosity

### **2. Resilience and Work Ethic**

- Persistence and dedication to seeing projects through
- Motivation and willingness to put in consistent effort
- Ability to manage time effectively and maintain progress

### **3. Technical and Academic Preparedness**

- Basic laboratory skills
- Solid foundational knowledge in biochemistry and understanding of research processes
- Critical thinking and initiative in applying knowledge

#### 4. Teamwork and Communication

- Ability to work well with others and ask for help when needed
- Compatibility with the lab team
- Accountability and ownership of projects

## Interview Preparation

95% of the faculty members we surveyed, indicated that they or their lab members meet with potential applicants prior to offering placement. These meetings are a good way for the student and thesis supervisor to ensure a mutually good fit for the placement.

#### Some common interview questions may include:

1. Why do you want to pursue a thesis project?
2. Why are you interested in this lab specifically?
3. What research questions or topics excite you the most?
4. How does this thesis project fit into your academic or career goals?
5. What coursework or previous lab experience has prepared you for this project?
6. How would you approach troubleshooting a failed experiment?
7. Can you describe a time you encountered a challenge in the lab and how you solved it?
8. How do you manage your time and prioritize tasks?
9. Are you comfortable working independently and as part of a team?
10. How do you handle feedback in a lab setting?

**Before attending an interview, you should endeavor to read some of the lab's most recent publications** (again where the PI is the last author). This can help demonstrate to a PI your genuine interest in the research and dedication to preparation. Additionally, this will help you ask informed questions about the type of research and scope of projects in the lab.

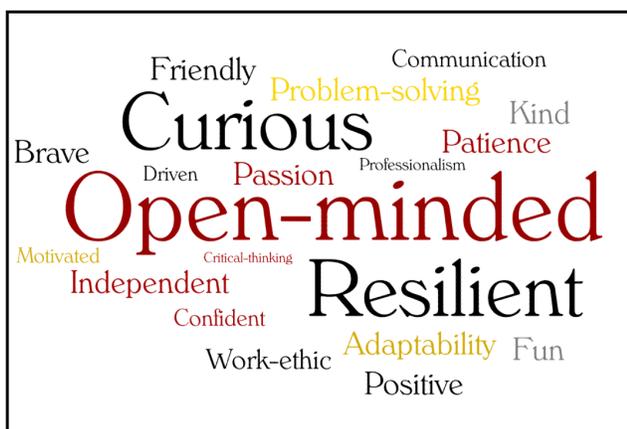
When you're exploring potential thesis placements, **it's important that a PI gives you the chance to speak with their current trainees. This is often the best way to get an honest sense of what the lab**

**environment is like**, how mentorship is provided, and what day-to-day expectations are. If a PI is unwilling to connect you with their students or discourages you from asking questions, it may indicate issues with transparency, lab culture, or support. A healthy lab should encourage open communication and make you feel comfortable gathering perspectives before committing.

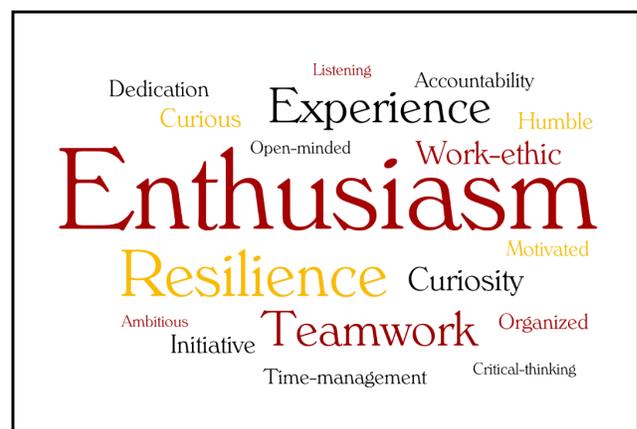
## Traits of a successful thesis student

When interviewing for thesis placements it might be a good idea to keep in mind what qualities you have that might make you a productive thesis student. We asked both past thesis students and current faculty which qualities they think are most important for success:

**Important qualities according to past thesis students**



**Important qualities according to faculty**



## Cross department and Off Campus Thesis Options

While many thesis students will find placements in their home department, it is likely and sometimes prudent to search for faculty members outside of the department whose research aligns with your academic interests.

Pursuing a thesis with a supervisor in another department, or even off campus, can expose you to new perspectives, methods, and areas of expertise that may not be represented within your home unit. This can broaden your training, help you build a more diverse professional network, and allow you to explore interdisciplinary approaches to scientific questions.

The same advice for finding a thesis supervisor outlined above applies when searching extra-departmentally. You should keep in mind that it is possible that faculty members in other departments or research institutes may be located at sites away from the main campus. If your project entails wet lab work, how you will get to and from the placement should be considered.

## Final Thoughts

With thoughtful planning and clear communication, these opportunities can provide a rich and rewarding environment for growth, often giving you a unique edge as you take the next steps in your academic or professional journey.

## 3.

## CHAPTER 3: SETTLING INTO THE LAB

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### Who is Who?

Congratulations on securing a place in a lab! This is already a huge success and marks the beginning of your thesis journey. You will encounter many different people who contribute to the functioning of a research lab. Knowing their roles and how you can learn from each of them will help you integrate more smoothly:

- **Principal Investigator (PI):** Leads the lab, secures funding, and sets the overall research vision. They provide guidance and assess your progress but may not always be present in the day-to-day.
- **Post-doctoral fellows:** These are experienced researchers. They all have PhDs, often from other institutions. They are excellent resources for technical expertise, troubleshooting advice, and project planning insights.
- **Graduate students:** Often directly supervise undergraduate students and provide hands-on training. Your best resource for tips on experiments, time management, and navigating lab culture.
- **Lab technicians/research associates:** Full-time staff with deep technical knowledge. They are often a reliable source for hands-on troubleshooting.
- **Undergraduate Students:** You and your peers. Your job is to come in with an open mind, learn foundational skills, and support ongoing projects.

### First weeks in the Lab

Your first weeks are about orienting yourself, setting expectations, and beginning to understand the rhythms of research. Here are some considerations for your first few weeks:

- **Establish Communication:** Clarify with your PI and direct mentor how and when to communicate. Some prefer email, others prefer Slack or weekly in-person meetings. Establishing norms early prevents confusion.
- **Time Commitment:** Understand the course requirements for weekly lab hours and communicate these clearly to your PI and mentor. Supervisors should not expect more than your thesis obligations, but they will value consistency and accountability. If you miss lab time during a busy week with your other

courses, you will be expected to make up that time in lab the following weeks.

- **Expectations:** Grades are based on achieving learning outcomes, not on the success of your experiments. Work ethic, curiosity, and resilience are highly valued. Getting a top-grade requires significant effort and should not be assumed.
- **Mindset:** Research is not coursework. It is ambiguous, slow, and often non-linear. Failures and setbacks are part of the process. Adopt a growth mindset: see challenges as opportunities to learn.
- **Lab Etiquette:** Show up on time, clean up after yourself, and help others when you can. Being a supportive lab citizen matters as much as your experiments.
- **Notebook & Data Management:** Keep an organized, detailed lab notebook. Some labs have handwritten or electronic notebooks. Universally, notebooks should include all details about the methods you use for a given experiment, in enough detail that someone would be able to replicate it. You should be able to look at examples of notebooks from previous students in the lab.
- **Safety & Training:** Complete all required training and understand lab hazards. Safety is a non-negotiable part of research.

The size of your lab will likely influence the frequency of how often you meet with your PI. If you have a small lab, they may be more involved, and you can expect to meet with them 1:1 once a week or more. In larger labs, you may find that you have very limited interaction with them and instead should be meeting with your mentor (grad student, post doc) at least once a week to start. As you get more confident in the lab and start independently running experiments, you might find that you need less frequent meetings. Before starting in a lab, this could be a consideration. Would you be comfortable if given independence? Do you think you would benefit most from a “hands-on” or “hands-off” supervisor?

## Tips from mentors and PIs

In the lab, punctuality matters. Show up on time and be prepared to work. **Always label everything clearly**, whether it's tubes, plates, or file names, to avoid confusion later. You might think you'll remember later, but things can get messy quick. When you're first starting out, be aware that experiments are slow the first time you run through them. **Plan for experiments to take 2-3x longer than expected.** Cleaning up after yourself is non-negotiable; it shows respect for the shared workspace and your colleagues.

Intellectual curiosity is valued more than perfect grades. **If you aren't sure about something, ask!!!** Making a mistake because you were afraid to clarify is far worse than asking a simple question. When you do ask questions, listen carefully and take notes so you don't need to repeat the same question multiple times. Be humble and honest about what you don't know and set realistic expectations for your project. You won't cure cancer in a semester; you may spend weeks troubleshooting or running controls. This is a normal part of the scientific process. Beyond your bench work, **ask to attend lab meetings or read group papers to immerse**

**yourself in the scientific community.** When the time comes for you to present your own work, be prepared to receive critique frequently. You're in a learning environment, and **constructive feedback is part of that process**—learn to receive it without taking it personally.

## Tips from previous thesis students:

Based on student reflections, here are some tips for getting off to the right start in your thesis year:

- **Be proactive:** Don't wait for guidance—initiate conversations, set up meetings, and ask questions early.
- **Clarify expectations:** Discuss time commitments, communication style, and evaluation criteria with your PI and mentor at the start.
- **Consider your learning style:** Some labs are hands-off, others hands-on. Adapt, and don't be afraid to ask how your supervisor prefers to mentor.
- **Use your peers:** Fellow undergrads are invaluable resources for troubleshooting and advice. Even if they aren't in the same lab, reach out! Everyone is in this learning journey together.
- **Balance & resilience:** Learn to pace yourself. Burnout is common if you treat the thesis like a cram course. Spread work consistently across the year. Consider your thesis as more of a marathon than a sprint.
- **Communicate honestly:** Share your struggles. Supervisors often appreciate transparency more than silence.
- **Value the process:** Success is defined by growth and learning outcomes, not just result

## 4.

# CHAPTER 4: DEALING WITH FAILURE

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## Introduction

Failure is part of every research experience. Experiments don't always work, timelines shift, and results may be unexpected or inconclusive. For many undergraduate students, this may be your first time confronting open-ended work without a guaranteed “right answer.” The lessons learned during these moments—**resilience, adaptability, and problem-solving**—are some of the most valuable outcomes of the thesis course.

To paraphrase an excellent [news article](#) about failure in research:

*If you are a baseball enthusiast, you might know that achieving a 0.300 batting average is harder than it has been in decades. The truth is that most academics would also be overjoyed by a 30% success rate across their endeavours. This high failure rate can come as a surprise for new students, who only see the successes of faculty members or graduate students. The takeaway is: hitting a round ball with a round bat is hard. So is research. And you should never expect success all the time in the pursuit of either.*

## You are going to fail. What does that mean?

This chapter is not here to discourage you or make you afraid of research. Quite the opposite. There is an inevitable, universal truth in everyone's research career: things won't go as planned. It is not uncommon for your first experimental failure to coincide with your first experiment. It can be an uncomfortable experience, particularly for students who have been academically successful. It may even be the first time for some of you where you come up against a problem with no solution.

There are different types of failure in research. Experimentally, an experiment can yield unexpected or no results for a variety of reasons:

- **Mistakes in following protocol:** Forgetting a reagent, adding the wrong antibiotics, missing an incubation step, or even dropping a tube. These are common mistakes, and everyone makes them at some time or another. Sometimes, even if you add the right reagent, it could be an old stock and needs to be made fresh to work optimally.
- **Biological inconsistency:** (i.e. Bad Luck). Biological systems are complex. When trying to manipulate

or measure this system, there is a level of inherent variability that can cause experiments to fail.

Sometimes things simply do not work. Try again and ensure your controls are behaving as expected (more about controls later in this chapter).

- **The parameters of an experiment or procedure haven't been worked out.** You might be dealing with a protocol that is not yet optimized for your system. You'll have to rely on other researchers and literature to help you figure out what parameters to adjust.

Understanding the purpose of each step and reagent is a great place to start. If you know why you're doing each step, you'll be less likely to forget one. When you start in lab it can be stressful. You'll likely have someone watching you run through your experiments the first time, and no one pipettes their best under pressure. Take your time and remember that every single other person around you has been in your shoes before.

As one mentor said in our surveys:

*“Every researcher who has ever stepped foot in a lab has messed up an experiment.”*

So, you are in good company. Failure is not a sign you don't belong – its proof you're doing real science.

## Negative results vs No results

It's important to distinguish between negative results (data that contradicts your hypothesis) and no results (when nothing measurable happens). In science, “negative results” indicate a failed attempt to confirm a hypothesis, even after a rigorous experiment with valid data. Negative results are valuable because they advance knowledge by ruling out possibilities. For example, let's say you had a hypothesis that a protein localizes to the inner membrane of your model bacteria. When you investigated this with fluorescence microscopy, you saw that the protein was cytoplasmic/diffuse. This is an example of a negative result: your experiment worked, you observed your protein's localization, but it wasn't as expected. Alternatively, if you failed to see any fluorescence at all, this would be an example of having “no results”, and your next step would be to troubleshoot the experiment.

**Negative results are still results.** They refine your research question and are worth writing about in your thesis.

**No results can still be progress.** Learning how to design an experiment or optimize a workflow are meaningful contributions. These methods can still be incorporated into your thesis. What does work? What doesn't, and why not?

One faculty member put it clearly:

*“A project might not yield ‘significant’ results, but that's still meaningful research. **The undergraduate thesis is not about the result—it's about developing technical and critical thinking skills.**”*

# The importance of controls

When an experiment fails, the first thing your PI or mentor might ask you about is your controls. Are they behaving as expected? Did you include all of the controls that would be necessary to diagnose any issues with your procedure? While this chapter won't provide a comprehensive resource for understanding how to properly design biological experiments, we would like to give you a brief overview and direct you to some excellent resources.

Essentially, controls provide a benchmark against which experimental results can be interpreted. Without them, it is impossible to determine whether observed effects are genuine or due to artifacts, contamination, or unrelated variables.

**Positive controls** are conditions where the expected outcome is already known to occur. They confirm that the experimental system is working as intended. For example, when testing the activity of a newly purified enzyme, adding a substrate known to be cleaved by that enzyme provides a positive control. If the control fails, it indicates a problem with the assay rather than the experimental variable.

**Negative controls** are conditions where no effect should be observed. They reveal background signals or false positives. For instance, performing the same enzyme assay without adding enzyme (or using a heat-inactivated enzyme) serves as a negative control. If signal is still detected, it suggests contamination or nonspecific activity.

Together, positive and negative controls allow researchers to distinguish real biological effects from noise, confirm assay sensitivity, and ensure that conclusions are scientifically valid. Properly designed controls also make results reproducible and increase confidence when sharing findings with the scientific community.

## Suggested reading:

Krzywinski, M., Altman, N. (2014). *Designing comparative experiments*. Nat Methods **11**, 597-598.

Lazic, S. E. (2016). *Experimental Design for Laboratory Biologists*. Cambridge: Cambridge University Press.

Kreutz, C., & Timmer, J. (2009). *Systems biology: experimental design*. The FEBS journal, 276(4), 923-942.

Ruxton, G., & Colegrave, N. (2011). *Experimental design for the life sciences*. Oxford University Press, USA.

## What to do when you fail

When a research failure happens, for any reason, it's okay to feel frustrated. This might be even a good sign; we hope that you feel invested enough in your project to be a bit disappointed when something fails. How you handle this failure is far more important than any mistakes you may have made along the way. Please, also remember that you deserve happiness in your personal life, even when you're struggling with your research. If you are going through a tough phase of a project, it is unhelpful and unhealthy to punish yourself further by neglecting self-care. Really, you can think of "failure" as just another word for "learning". You really do learn most when things don't work out right away.

### So how do we manage failure?

#### Step 1: Be kind to yourself

Previous thesis students have repeatedly emphasized how disorienting the first month in the lab was. Many felt they had "no structure" and were overwhelmed by the steep learning curve. Here are some words of encouragement for you as you go on this journey:

- **"Your thesis is a marathon, not a sprint.** It is a different type of learning, and I didn't know what I was signing up for"
- "Sometimes (most times) experiments don't work. **Don't take it personally,** don't crash out. Review what you did, what went wrong, and try again.
- "Everything will be okay! **Learning and growth can be uncomfortable,** but your mentors and PI have been through the same things you're going through."
- **"Be gentle with yourself!** It's easy to look at where you are now and be hyper critical, but throughout the thesis experience you'll learn more than you realize."

#### Step 2: Make a plan

Or at least enlist some help with making a plan. Think through the entire experiment. Make a list of everywhere you think something might have gone wrong and share your thoughts with your mentors – other graduate students, post-docs, or even your PI. If the failure was likely due to user error, that is an easy fix. If your protocol requires more serious troubleshooting, there are people in the lab who are there to help you out. You can also reach out to other thesis students! There's a good chance that many of your classmates might be experiencing similar problems in their own thesis.

## Separating identity from outcomes

Failure often feels personal—but it isn't. Research critiques, presentation feedback, and thesis edits are about

the work, not you. As a previous thesis student reflected, “*If someone critiques your work, it doesn’t mean that they are critiquing you*”. Receiving constructive feedback is required for your growth as a scientist and researcher. **It is not a reflection on you personally.** There’s no reason you would be expected to run an experiment perfectly the first time, know how each lab expects to see a figure presented, or what writing style your PI prefers. These experiences and feedback are for your benefit.

You should also avoid comparing yourself to others. Another student said:

***“Each lab has different expectations and projects, so don’t compare yourself to other thesis students.”***

The grad students and PIs you work with are all years ahead of you and there is an immense amount of information to learn. Other thesis students are studying different organisms, in different labs, and have different questions. Your progress is not comparable to anyone else and is not reflective of the work you’ve put in. Some areas of study are inherently more complicated than others, and some questions require more optimization to answer. Again, separate your identity from the outcomes of the lab. You are not your experiments, and your success or failure as a researcher doesn’t define your successful or failure as a person.

## Reflection prompt

At the end of the day, failure is an invitation to learn. Use it as an opportunity to pause, reflect, and plan your next step.

***What went wrong—and what did I learn?***

Consider:

- Do I understand every step of the protocol?
- Where might have the experiment gone wrong?
- What troubleshooting strategies should I try?
- What is something I did well that I want to maintain in my next attempt?

References:

<https://www.asbmb.org/asbmb-today/opinions/112922/the-f-word-failure-in-research>

<https://raybwilliams.medium.com/how-to-deal-with-failure-a-compendium-of-research-76141091913e>

<https://www.nature.com/nature-index/news/how-to-deal-with-failure-rejection-academic-research-say-senior-scientists>

<https://robertkelchen.com/2018/12/06/how-to-respond-to-rejection-in-academia/>



5.

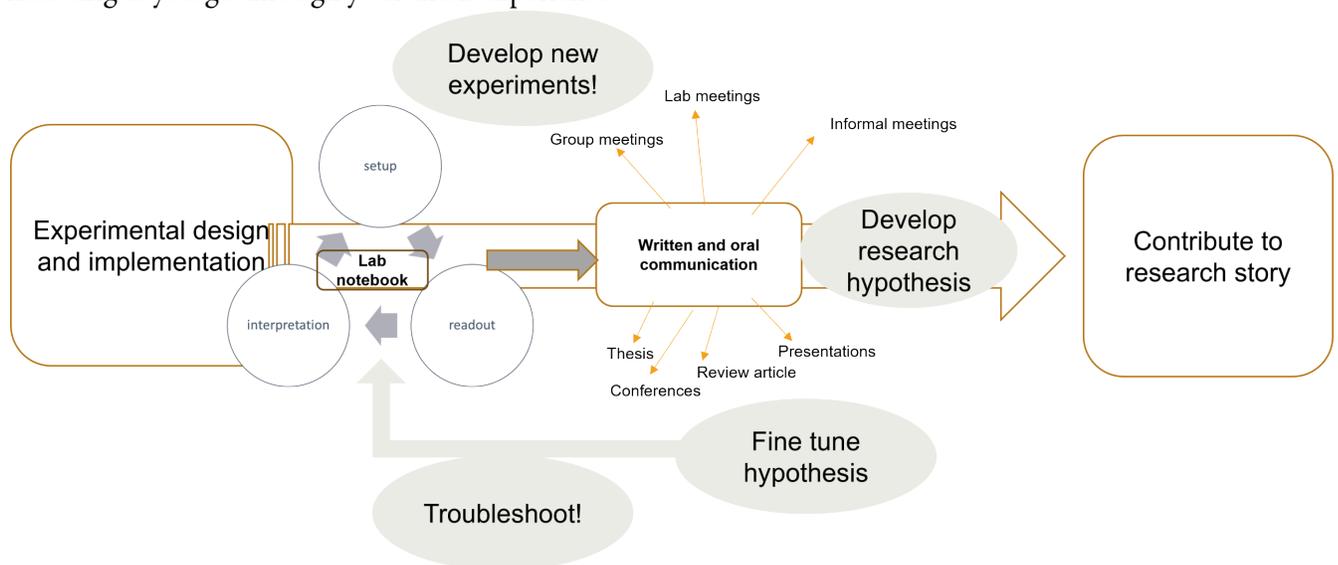
# CHAPTER 5: SCIENTIFIC WRITING – A FRAMEWORK FOR COMMUNICATION

## Introduction

Welcome to your fourth year BBS thesis experience!!! This course is unlike any other you may have taken at McMaster University. This course highlights the research experience with first-hand experiential learning opportunities in a research lab! A real, live research lab!!!! Each of you will have a unique experience in terms of content, but **at the heart of all research lies one essential element: communication.**

Believe it or not researchers are storytellers. We devise and implement stories. Usually the goal of each story is biomedical, meaning that most of the stories in our BBS (Biochemistry and Biomedical Sciences) department are borne from a biomedical need. We are studying a need, or a gap, in our understanding. Our research goal is always united: to study this gap or need and tell our story, or our findings. At the core of all of this is communication.

Now communication can come in multiple modalities, from formal written communication to informal verbal communication, to name a few. We have highlighted a few modes of communication in the following diagram. These are just a few examples and we aimed to map them on some of the processes you may be conducting as you go through your thesis experience.



## Written communication

For the purposes of this chapter, we will focus on written communication. Written work is central to your thesis experience, whether you are drafting daily lab notebook entries, preparing a literature review, or compiling your final thesis document.

Before going further, we want to be transparent. **Every laboratory has its own traditions, expectations, and standard operating procedures for writing.** Your principal investigator (PI) may have clear preferences for how certain sections are written or structured. Think of this chapter as a source of inspiration and reflection rather than a rigid checklist. Our goal is to provide a framework that helps you think about writing as an essential part of your research journey.

This chapter focuses on written communication, of which there are many different types. The main goal of this chapter is to provide you with a moment of reflection so that you can tackle each mode of communication with a set framework. From this author's perspective, scientific writing is a complex concept, but like any complex concept it is very doable if broken down into bite-sized pieces that are easier to tackle. This is so important because otherwise you will have a very hard time writing. Basically just stare at a blank page desperately looking for inspiration.

This chapter is not going to tackle the details of all of these modes of writing. The goal here is to offer a companion piece to help you through the writing process. Specifically, what this chapter hopes to highlight is that there are common threads between all of these different writing tasks. It also hopes to help you build a basic framework for implementing every time there is a new scientific writing task. And finally, it hopes to provide you with some transparency and advice for some of the writing tasks mentioned above.

## The writing process: a general framework

When thinking about writing anything in science, the most important thing to root yourself in is this idea of why you are writing. I know, for a lecture course the answer may be “I am writing this because it's part of the assessment”. But for a thesis course this may not necessarily be the answer. So let's get back to the question:

### **Why are you taking the time to write?**

The answer lies in understanding that we write in science to communicate. Writing is a form of communication. So I guess the real question should be, what am I trying to communicate AND to WHOM? Or is it to who? Well that's the grammar bit that we often wrestle with, but that is just part of the journey. Understanding how to use grammar and sentence structure and active versus passive voice, and contractions, that's just something you will need to constantly be aware of, constantly be researching, and constantly develop. But now I have digressed, not a great thing in writing as you may lose the reader, so where were we?

For your thesis course, you may encounter the following (though this is not an exhaustive list):

1. **A lab notebook** – You most certainly will be required to write in your lab notebook. This is probably

going to be a daily activity. You need to ask your lab mentor for training on what type of lab notebook etiquette their lab uses. Many research labs employ both an electronic and a physical lab notebook and you may be required to use both. This chapter will highlight some of the basic framework you can use when writing a lab notebook entry, but it's always highly recommended that you check your lab notebook entries with your lab mentor to ensure that you are following the appropriate protocol for your lab. This chapter will help center you with respect to the types of questions and considerations you need in order to set yourself up for writing in your lab notebook.

2. **A literature review article** – the thesis course requires that you write a literature review. Before you even begin this assignment, it is best that you know your audience, and the guidelines for writing the article. This chapter will help take you through some of the questions you should ask before tackling this type of article.
3. **Your final thesis** – another really big writing task. Again, you need to touch base with your lab mentor before tackling this task because you want to be on the same page with respect to structure and guidelines. However, this type of assignment needs to be a work in progress for the entire course. You need to work on it every single week. You will be drawing information from your weekly lab notebook entries, your conversations with your lab mentor and PI (principal investigator), and other informal conversations with your peers, your lab group, etc. This is why it is so important that you always take notes when you meet with your lab group. It keeps things organized.

There are many other modes of writing that you will be tackling in your thesis. Some PIs may ask you to help write sections of a grant proposal, you will certainly be designing scientific figures and writing figure captions, you may even help write a primary research article!

It is easy to think of writing as an “assignment”, a requirement to be completed because it is part of the course. But scientific writing is SO MUCH MORE! It is a way of communicating discoveries and advancing knowledge. If research is about asking and answering questions, writing is about sharing those answers in a way that others can understand, trust, and build upon.

**So before beginning the writing process, reflect on these three guiding questions:**

1. Why am I doing this?
2. What am I trying to communicate?
3. Who is my target audience?

Grounding yourself in these three questions will help orient every piece of writing you do this year. It turns writing from a daunting task into an intentional act of communication.

One important note: writing is a process. **No one produces a perfect first draft.** Drafts are messy. They contain awkward phrases, half-finished thoughts, and too many exclamation marks (that's totally me!!!). That is okay. The beauty of writing lies in revision, shaping raw material into something clear and professional. If

you can embrace writing as an iterative process rather than a single event, you will make your thesis year much smoother.

At first glance, scientific writing can feel overwhelming. Staring at a blank page waiting for inspiration to guide you can be a very daunting experience. But here is the reassuring truth: writing is not magic, and it is not about waiting for inspiration to strike. Writing is a process. Writing involves preparation, execution, troubleshooting, and refinement. Wait, that's the same workflow for designing an experiment! So cool!

One of the things I always try to set up when I start a complex task is an overall framework, or workflow, that can be adapted to not only the writing task, but to my individual style as well. As mentioned earlier, trying to write by staring at a blank screen and waiting for the words to come to you, this is not an efficient way to tackle writing. Every person develops their own habits and strategies for writing. In fact, writing (like teaching) is very personal as it is rooted in each individual's unique life experiences, stories, etc. The following framework is just that, a very basic framework that you can adapt and restructure to fit your own style.

## A framework for scientific writing

### **Research and reflection**

Before you can write, you need material to write about. This means immersing yourself in the literature, your experimental notes, and your data. Good writing begins with deep engagement in your field. Keep track of what you read using a reference manager. Many people underestimate how many papers they will need to read, and how quickly references can pile up. Starting early with good organizational habits will save you enormous frustration later. Also, touch base with your lab mentor/PI and even the thesis course guidelines to ensure you know all expectations for each writing task.

### **Reflection and Planning**

Once you have gathered information, pause and reflect. Ask yourself the three guiding questions: Why am I writing this? What am I trying to communicate? Who is my audience? Jot down answers in a notebook, sketch a mind map, or talk it out with a lab mate. Planning does not have to be elaborate. The point is to orient yourself before diving into sentences.

### **Start writing! (Messy is Okay)**

Now, just write. Truly. Open the document and start putting down words, even if they feel clumsy. Write in bullet points, half-sentences, or phrases if that helps. For me, when I write, I just write. I use a mix of bullet points and sentences. Anything to get my ideas down on the page. One of the things I always thought when I was a student is that when I start writing I need my words and sentences to come out perfectly the first time I jot them on the page. But what I've learned over the years is that clarity rarely arrives before you begin the writing process. It usually emerges as you write. This is why writing is such an iterative process.

### **Reflection and revising and refining**

Now that you have ideas down on the page you need to stop and reflect on what you've just written. Step back from your draft and look at it with a critical but kind eye. What is the main point? Is it clear? Is the

structure logical? Are there redundancies that could be cut? Revision is not just about fixing grammar and sentence structure, it is about shaping meaning.

### **Feedback and reflection**

Writing is an iterative process, but thus far you are the only person who has interacted with your writing. To be honest, I learned over the years that writing improves so much when shared. Ask your lab mentor to look at a section, exchange drafts with peers, and read your work out loud to yourself. Each iteration helps clarify the message.

### **A Note on Patience**

There is one thing I want to mention about the writing process. Writing takes time. Much like learning a new lab technique, it often feels slow and frustrating at the beginning. But the more you write, the easier it becomes. Do not wait until the week before your thesis deadline to begin. Instead, chip away at small sections each week. The process will feel lighter, and you will actually think more clearly about your research as you write.

OK, let's take stock of what we have learned so far:

Think of writing as a mode of communication. Before tackling a writing task, stop and reflect on specific questions. Start with:

1. Why am I doing this?
2. What am I trying to communicate?
3. Who is my target audience?

Talk to your lab mentor and PI to get the details of the writing task. Make sure their expectations are understood. Map out the writing task and time manage. Write yourself a framework of how to approach this. Add checkpoints in your calendar and meet these checkpoints. Also, leave lots of dedicated time for research. You need to do a LOT of research before you even begin the task of writing. Time management, a structured approach, clear transparent goals, and meeting set checkpoints will ensure you are successful with your writing tasks.

And finally, notice that the word “reflection” is mentioned a lot in the writing framework. That is because we reflect a lot when we write. It is so important to reflect not only on the content, but also on the process of writing.

Remember that writing is not just the way you report science, it is part of how you do science. The act of explaining your work to your reader forces you to clarify your own understanding. In that sense, writing is not separate from research; it is research.

## **Modes of Writing in Your Thesis Course**

There are several different types of writing that you will encounter throughout your thesis course. Some are

formally required by the course, while others may come from your PI or lab mentor. Each mode of writing has its own purpose and audience, but they all connect through common threads: clarity, accuracy, and communication. Let's look at some types of written communication types you may encounter in your thesis and see how you can begin to approach each task:

### **Lab Notebooks**

The lab notebook is one of the most crucial pieces of writing you will produce as a researcher. It is your daily log of work in the lab: a written record of what you did, how you did it, what you observed, and what your results were. This is not simply for your own memory. Your notebook allows results to be traced, validated, and eventually included in publications. In many ways, the lab notebook is the foundation of research communication.

Before you begin, sit down with your lab mentor and PI to understand exactly how your lab documents work. Every PI has their own system, and this may involve both physical and electronic notebooks. Some PIs even check entries regularly and sign off on them. Remember: the notebook is not your property. It belongs to the PI, and when you finish your thesis year it will remain in the lab to guide future students or provide a record for publications.

When writing in your notebook, aim for clarity and completeness. Imagine that someone new to the lab will one day need to repeat your experiment. Could they follow your notes without confusion? Think back to your previous lab courses for ideas on structure: daily purpose, materials and reagents, safety considerations, protocol steps, observations, and results. Number the pages, create a table of contents, and most importantly, always date your entries. Without dates, it becomes very difficult to trace experiments.

A personal tip: do not underestimate labeling. Tube labels like "1, 2, 3" quickly become meaningless. I used to include the date on every tube and note the exact labels in my lab notebook entry for that day. More descriptive labels (beyond numbers) are always better, and proper labeling is a core safety practice. Ask your lab mentor about your lab's SOPs for labeling reagents. Good labeling habits will save you endless confusion.

### **Literature Review Article**

As part of the BBS thesis course, you will be asked to write a literature review. This is a significant undertaking, so it must be tackled in small, manageable steps.

Before writing anything, gather details about the assignment from the course syllabus, and then discuss expectations with your lab mentor or PI. Then structure a feasible timeline to accomplish this task. This needs to include checkpoints for completing various aspects of the task (I do believe the course coordinator has given you a head start on this with some already required checkpoints). Put all this in your calendar so you can reach these checkpoints.

Make sure you have your reference manager ready to go and now start researching. Research and take notes, document your citations, start sketching general outlines of this assignment and keep writing. Draft an outline, even a rough one, and gradually fill it in as you go. Remember: this is not an assignment you can finish in a single sitting. You need a process that unfolds across weeks.

Small disclaimer here: I realize we live in the age of generative AI (genAI). If you are thinking of using genAI

as a tool in any of your writing assignments, stop and discuss this with your PI first. Also check the course syllabus to see what their policy is on genAI use. You need to get permission first before using genAI in this course (and any course really).

I personally enjoy reading papers that highlight researchers' perspectives on writing reviews. Each author has a unique approach, and while none fit every need, they always provide useful insights. I find these articles really enjoyable to read, and I always learn something. One of my favourite articles on this topic comes from a clinical researcher perspective. I enjoy it because it is a short read, it is well structured, and it provides an individual perspective on the process. It also has some really good advice that can be applied to many types of review articles.

Anyway, here is the citation if you are interested:

Derish, P. A., & Annesley, T. M. (2011). How to write a rave review. *Clinical Chemistry*, 57(3), 388-391.

The one piece of advice that has always worked really well for me when writing anything that's a bit bigger and more complex (why like this chapter), is to make sure I leave lots of time for edits.

The writing process is a very personal process. Every person tackles writing differently, and in research we write A LOT!!!! Like a LOT!!!! This is no problem for me as I absolutely love writing. And like how cool is this. You're currently reading my writing! That's so powerful and deeply humbling for me as the writer, to have someone actually read what I write. This is why I love writing, but the writing process can be deeply frustrating. So my advice is to get yourself organized as soon as humanly possible (research, time management, understand expectations, guidelines ,etc.) and start writing and remember, drafts are never perfect. They evolve through revision. The earlier you start, the more space you create for reflection, feedback, and improvement.

### **Final Thesis**

Your thesis is the largest and most constant writing task of the year. It cannot be left until the end; it must be built gradually over the entire course.

Start by reviewing the course requirements on Avenue to Learn (A2L), then speak with your PI or mentor about their expectations. Many supervisors prefer to see sections drafted and revised along the way, so be prepared for an iterative process.

The thesis can resemble the structure of a research article, with sections such as Introduction, Methods, Results, and Discussion. As you read papers throughout your thesis experience, pay close attention not only to the content of these sections but also to the technical language and tone. Reflecting on how other researchers write will strengthen your own writing.

Here are some strategies to make the thesis writing process smoother:

1. Do your research. keep reading papers, take detailed notes, and maintain a citation list in your reference manager. Do this weekly.
2. Maintain a strong lab notebook: this will be the backbone of your thesis.
3. Communicate regularly with your mentor and PI: take notes during every meeting
4. Stay organized and manage your time: set realistic goals and meet them.

5. Keep writing: even small sections. Momentum matters.

One thing that I found really helps the thesis writing process is to really focus on the data every week. Every time you generate new data, reflect on it. I have some tips for tackling data analysis that I think might be useful as a framework.

Let's say you just generated an agarose gel image of your very first cloning experiment. You are sitting at your lab bench looking at a picture of this gel image. What next? Well, I would say before you even glance at the image you need to take a moment to collect a few things:

1. Lab notebook entry – open your notebook to the day's entry so you can review the protocol you used to generate this data, along with your lane order, and observations. Make sure you understand what you're looking at and what the bands represent. Ask yourself: What do the bands mean? How were they visualized?
2. Take time to reflect on what you are seeing and summarize the main findings in writing.
3. Talk to your lab mentor about the data and your interpretation of it.
4. Once you have a solid understanding of what the data is telling you, design a figure and figure caption, followed by a materials and methods section for this result.

Taking time to document and reflect on data as you generate it will help you understand results, troubleshoot experiments, plan next steps, and ease the process of compiling your thesis later.

In short: keep chipping away at your thesis. Reflect weekly on data, figures, and sections. Write regularly. Stay organized. Over time, your thesis will grow naturally from the record of your year.

As usual, I find reading about how to write is always such a lovely way to learn. The following papers are some of my favourites on this topic. I especially enjoy the “ten simple rules for better figures” article. The other articles are written from a clinical researcher perspective but they are so well written and so fun I just couldn't help but share. Please note that these articles are for your general learning purposes. They are not checklists on how to write your thesis. You are responsible for ensuring that you fully understand the expectations of all written tasks, like the thesis, by understanding the course specific criteria and most importantly speaking to your lab mentor and PI to understand their expectations for each written assignment.

Rougier, N. P., Droettboom, M., & Bourne, P. E. (2014). Ten simple rules for better figures. *PLoS computational biology*, 10(9), e1003833.

Annesley, T. M. (2010). The title says it all. *Clinical Chemistry*, 56(3), 357-360.

Annesley, T. M. (2010). The abstract and the elevator talk: a tale of two summaries. *Clinical chemistry*, 56(4), 521-524.

Annesley, T. M. (2010). “It was a cold and rainy night”: Set the Scene with a Good Introduction. *Clinical chemistry*, 56(5), 708-713.

Annesley, T. M. (2010). Who, what, when, where, how, and why: the ingredients in the recipe for a successful

Methods section. *Clinical chemistry*, 56(6), 897-901.

Annesley, T. M. (2010). Show your cards: the results section and the poker game. *Clinical chemistry*, 56(7), 1066-1070.

Annesley, T. M. (2010). Put your best figure forward: line graphs and scattergrams. *Clinical Chemistry*, 56(8), 1229-1233.

Annesley, T. M. (2010). Bars and pies make better desserts than figures. *Clinical chemistry*, 56(9), 1394-1400.

Annesley, T. M. (2010). Bring your best to the table. *Clinical Chemistry*, 56(10), 1528-1534.

Annesley, T. M. (2010). The discussion section: your closing argument. *Clinical chemistry*, 56(11), 1671-1674.

Annesley, T. M. (2011). Giving credit: citations and references. *Clinical Chemistry*, 57(1), 14-17.

Beyond articles, the McMaster Writing Centre (Student Success Centre) is an excellent support.

Your lab mentor and PI are also key resources. They bring discipline-specific experience and can give you feedback that is tailored to your field. Ask them what they look for in a strong piece of writing, and use their guidance to shape your own style.

Finally, don't underestimate the value of reading scientific papers. Notice not only what they say, but how they say it. Pay attention to sentence length, transitions, figure captions, and the way arguments are built. Every paper is both a scientific contribution and a writing lesson.

**We asked PIs and lab mentors to share tips and advice for incoming undergraduate thesis students. Their feedback on the topic of communication revealed several recurring themes, summarized below:**

**Discuss expectations at the start of the thesis experience** – communicate time commitment clearly, progress milestones, and accountability.

**Maintain consistent and proactive communication between the PI and lab mentor(s)** – set regular check-ins, ask for help early, be transparent about progress and setbacks.

**Keep a detailed and up-to-date lab notebook** – discuss lab notebook etiquette with your PI and lab mentor.

**Write constantly to develop a clear central thesis** – work on this consistently and keep communicating with your lab mentor and PI.

## 6.

# CHAPTER 6: MASTERING THE SCIENTIFIC TALK

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## Communicating research, not results!

Many students find the idea of public speaking to be nerve racking or even anxiety inducing. While it is understandable that you may be nervous to present in front of your fellow students and faculty members the right approach and advanced planning can help set you up for success! In thinking about building a thesis presentation, it is important to create a narrative or story that your audience can follow. Remember, it is likely the case that you will have some audience members that are not familiar with your field of study, so aim to make your talk accessible to both experts and non-experts alike.

A good place to begin is by identifying your core message—if the audience could walk away remembering just one idea, what would you want it to be? A strong, well-defined message gives your talk focus and cohesion, ensuring that every figure, explanation, and example supports the larger point you want to make. Ultimately, this clarity not only makes your presentation more engaging but also helps your audience remember your work even after the talk is over. It can be tempting to include all the experiments that you completed over your research placement to demonstrate the time and effort you poured into your project! However, especially in the case of short presentations (10-20 minutes), this should be avoided as it will detract from the overall story you want to convey to your audience. It is easy to overwhelm the audience with too much detail or lose their attention in technical tangents. As you begin to outline your slides, you should focus on linking every slide in your presentation back to your core message.

## Structuring your talk

When it comes to giving a scientific talk the scope of research projects can vary significantly. Some students may present bioinformatics or computational work, while others will rely heavily on wet-lab or animal experiments. Others may have focused on applied or clinical research, and some projects may be focused on reagent generation. Regardless of the nature of the project a scientific talk has four key elements:

1. **Background:** What does the audience need to know to understand your question and why is it important, why should your audience care about this project? This section sets the stage for your

presentation by grounding the audience in what is known about your field of study and where your research project fits in.

2. **Science question and objective:** Clearly state the specific question your study seeks to answer or the objective it aims to achieve, ensuring it logically follows from the background. A focused, well-defined question helps guide the audience through your approach and ultimately experimental results.
3. **Experimental approach and data:** Describe the methods or experiments you used to answer your question. Organize your data in an order that allows for the results to build to tell a logical story – note this may not be the order that you did your experiments in! Try to avoid unnecessary technical detail unless it is critical to understand a result.
4. **Conclusions and future directions:** Summarize the conclusions that flow from your data and their broader implications for the field. Make sure your data supports your statements and avoid overreaching. Suggest future avenues of investigation or experimentation. Think – if you had three more months to work on the project, what would you do next!

As mentioned in the previous section, delivering a clear and cohesive presentation may require leaving out some experiments or data. While it can be difficult to omit parts of your hard work, staying focused on your core message is ultimately the most important goal.

## Design principles

### Slide Design and Visuals

A good rule of thumb is one slide, one point. You want the presentation to be easy to follow, and it is better to divide complex information, experiments, data etc. over multiple slides. Along similar lines, it is important that your slide design is consistent throughout the presentation including (but not limited to)

- Titles and figure placement, text alignment
- Font size and numbering
- Colour Palette
- Image formatting

**The title for each slide should be informative** and allow the audience to understand the implications of the content, it should not reiterate what the content is. Particularly when you are showing data, explain what the data mean, not just what you have done. For example:

**DO** write “Expression of protein X is decreased in the presence of inhibitor”

**DON’T** write: “Western blot results”

**DO** write “Antibiotic resistance in pathogenic bacteria”

**DON’T** write “Introduction”

When it comes to visuals, less is more. You should be mindful of the text:figure ratio on each slide and avoid large blocks of texts. In some cases, it may be helpful to include an anchor schematic that reference the process or pathway that you are investigating. The anchor schematic can be referred to throughout the talk to help orient the audience.

## Advice from faculty

Simply put, good presentations are simple, visual, audience-centered, and structured as a compelling story. Here are some key pieces of advice from faculty mentors with experiencing evaluating thesis presentations:

- Tell a story: Don’t just present a research timeline or all the data—focus on a clear, engaging narrative that connects to broader research goals.
- Keep it simple and focused: Highlight only the essential points and messages. Less is more.
- Effective visuals: Use clear, well-labeled figures, diagrams, and images. Avoid clutter, large amounts of text, or multiple graphs per slide. Titles should be descriptive.
- Audience perspective: Present information step by step (e.g., using animations strategically), only showing what’s relevant at each moment. Assume the audience may not know specialized details and explain everything clearly.
- Practice and feedback: Rehearse multiple times, ideally with peers or graduate students, and seek feedback on slides and delivery.
- Learn from examples: Watch seminars or professional talks to see effective presentation styles in action.

## Delivery

Presentation delivery is just as important if not more important than the slide deck itself. You want to focus on telling a story. Identify the main points of each slide and avoid memorizing a script. The latter can come across as overly rehearsed or robotic, making it harder to engage your audience. Repetition is a powerful tool that can help reinforce your message: tell the audience what you are going to tell them, then tell them, then tell them what you told them. Some of the trickiest part of the presentations can be the transitions between slides. One helpful tip in this regard is to visualize the slide that is coming up next to ensure that you are making connections between the content. Finally, be sure to face your audience and make eye contact! If you are staring at notes and/or the slides it will make it harder for the audience to engage and connect.

Practice, practice, practice – take every opportunity to go through your talk with different audiences – your lab group, your classmates, even friends outside of your discipline! This will allow you to gather feedback and become comfortable with the presentation. The more familiar and confident you are with your material, the more effectively you'll be able to connect with your audience and deliver a presentation that is both engaging and impactful. Remember YOU know your project better than anyone -take that confidence with you into the room!

## 7.

# CHAPTER 7: REFLECTION AS PART OF THE RESEARCH PROCESS

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## Introduction

Reflection is an essential component of the research process. It is part of our day-to-day routine. It is also something we need to practice and develop, much in the same way an athlete trains for a sport.

Before you even pick up a pipette or start mixing reagents, pause. Sit down with a pen and paper and sketch out your experiment. Think through the steps, the theory, and the expected outcomes. This deliberate act of planning is the first layer of reflection. It helps you anticipate challenges, identify gaps, and clarify your goals.

Reflection is a structured, deliberate process of critically assessing your experiences to gain deeper understanding and inform your next steps.

As we have seen in previous chapters, reflection is woven into every stage of the research process. It helps scientists troubleshoot experiments, design better controls, interpret data with awareness of bias and limitations, and grow professionally by learning from both successes and failures. Reflection also has another, sometimes overlooked, benefit: it strengthens experimental reproducibility. Experimental reproducibility is the foundation of science, and reflection helps us get there. By identifying sources of variability, improving our observational skills, and questioning our assumptions, we can make our work more transparent, reliable, and meaningful.

The process of reflection is not a vague or abstract concept. In fact, this field is well studied and there are well-established frameworks that can help guide the process. The idea for this chapter is to take a moment and reflect on the concept of reflection and how it can be applied to the research process throughout your thesis journey. See what resonates with you and maybe even read a bit more on this topic. It is a very interesting field. The important bit is to step back, be present in the moment, ask yourself questions, and make sense of what you are doing and why.

## Reflection in the Thesis Process

Reflection plays a huge role in the thesis experience. It is not just about improving your experiments, though that is a big part of it. It is also about taking the time to pause and reflect on the thesis journey and how this journey shapes you as a researcher.

In my opinion, when you reflect on your work, you begin to see patterns in your thinking, recognize your strengths, and notice areas where you can grow. Reflection can help you refine your experiments, better understand and visualize your data, and communicate your science more clearly. But it can also help you think about the bigger picture: where your interests lie, how you want to develop as a scientist, and what kind of career path might be meaningful to you.

Of course, reflection is not always an individual practice. Sure, we internalize and reflect on our experiments and our experiences, but reflection can only grow if we also discuss with others. Take the thesis experience as an example. The following figure outlines some of the ways we reflect and communicate. Both reflection and communication go hand in hand:

Below I have provided you with some frameworks that you could use at various stages of your thesis experience.

## Reflection in Experimental Design

Reflection is just as important at the start of an experiment as it is at the end. Here is a simple framework for tackling experimental design through reflective practices:

1. **Experimental Setup:** Review your theory, protocol, and safety considerations. Make sure you pay close attention to all safety considerations and always discuss safety with your lab safety representative before you begin any task in the lab. Ask: What exactly are we testing, and why?
2. **Readout:** Define the parameters of your experimental readout. Ask: How are we measuring it, and what does that measurement mean?
3. **Assumptions:** Challenge your experimental assumptions. Ask: Could this result mean something else? This is where we design sound controls that test our assumptions.

By reflecting before and during your experiments, you design stronger, clearer, and more reproducible science.

It is also imperative that you discuss this with your lab mentor so you can design experiments rooted not only in theory and practice, but also in experience.

## Reflection for Reproducibility

Reflection directly supports reproducibility. It helps us:

- Identify sources of variability
- Improve documentation and transparency
- Design better controls and protocols

- Avoid experimental bias

Practical tips like recording all observations in your lab notebook, using controls wisely, and repeating key experiments may sound simple, but reflection is what turns them into habits. With reflection, these practices become part of your mindset, not just items on a checklist. Also, discuss these observations alongside your results with your lab mentor so they can see the full picture of your results, not just your interpretation.

## Reflection in Data Analysis and Visualization

Reflection as part of data analysis and visualization. I am providing a very basic reflective framework that I often rely on when working with data:

1. Preparation: Review your protocol and the theory behind your experiment. Don't forget to take into account all observations you jotted down. Ask yourself: What am I looking at? What does this data represent?
2. Interpretation: Think aloud, sketch notes, or write a rough draft (I prefer the rough draft). Look for patterns, inconsistencies, or assumptions you might be making. Ask: Could this result mean something else?
3. Visualization: When designing figures, focus on telling a clear story. Your captions should guide the reader without jumping to interpretation. Reflect on: Am I being transparent and accurate?
4. Ethical Reflection: Every data point represents a real measurement. Avoid the temptation to "clean up" results by discarding outliers just to improve your data. Instead, reflect on what variability might be telling you about your technique, your system, or your assumptions. This also helps you understand the importance of reproducibility in your experimental replicates.

This kind of step-by-step reflection does not just improve your figure design. It deepens your understanding of your data. You should also discuss this process with your lab mentor. Take them through your data analysis and visualization to see what they say. Experience matters a lot in research and they bring a lot of research experience that can help you develop even stronger data analysis/visualization skills.

## Final Thoughts

Reflection in research is more than just a tool. It is a mindset. It helps us become better scientists.

Whether you are analyzing a gel, designing a figure, writing a thesis section, or planning your next experiment, take a moment to pause and reflect. Ask yourself what worked, what didn't, and what you might do differently next time.

And finally, reflection is not a solitary practice. While building your own reflective habits is essential, research thrives on collaboration and constant communication. It is imperative that you share your thought process and experimental reflective practices with your lab mentor, your PI, etc. It is important to keep communication open as this is the best way to learn how to be a good researcher. Building your own reflective practices and research skills is imperative, but making sure you allow insight from others with research experience is just as critical. Experienced researchers can offer perspectives that challenge assumptions, highlight blind spots, and strengthen your approach to experimental design and data analysis.

In short, reflection and communication go hand in hand. Reflection helps you grow internally; communication amplifies that growth by connecting you to the collective wisdom of your research community.

**We asked PIs and lab mentors to share tips and advice for incoming undergraduate thesis students. Their feedback on the topic of reflection in research revealed several recurring themes, summarized below:**

**Embrace experimental failure as routine** – Treat setbacks as learning opportunities, analyze why things didn't work, generate hypotheses, and plan iterative next steps. Communicate these failures with your lab mentor and PI so they can provide feedback!

**Slow down and question assumptions** – Reflection means pausing to examine what you think you know, aligning evidence with claims, and refining research questions.

**Set goals, celebrate small wins, and track progress** – Break work into manageable steps, note incremental gains, and reflect regularly.

**Learn from shared stories** – Always, always communicate with your lab mentor and PI so they can provide their experiences and help support your learning journey.



# APPENDIX OF ENCOURAGEMENT AND ADVICE FROM THESIS STUDENTS, MENTORS, AND FACULTY

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As we built this guidebook, we gathered a remarkable amount of encouragement and advice from past thesis students, graduate mentors, and faculty. You'll see many of their words woven throughout the book, but we couldn't fit everything in. This appendix is the full collection that we wanted to share with you as you navigate your upcoming (or ongoing) thesis journey:

## STUDENT QUOTES

### **Integration and Lab Culture**

Be yourself and open yourself to everyone in the lab without considering your position in the lab as just a thesis undergrad student which can create a barrier.

I would tell them to be proactive and approachable from day one. Don't wait for others to include you, introduce yourself, ask questions.

I'd tell them to build rapport with the lab manager and the other masters and post grad students.

I'd tell them to volunteer for small side projects early on to meet everyone and learn techniques. Showing willingness to help builds goodwill.

Jump in on communal lab tasks—cleaning, restocking—to show commitment.

Make an effort to know your Masters students and PhD students since they will be able to provide mentorship and support.

Be willing to listen and learn, go into new and old experiences with an open mind.

Ask to help with data entry or literature searches in week one to learn the ropes.

Discuss and set clear expectations first. Learn to ask questions and rely on your mentor early on. Learn to socialize and assimilate to the lab culture.

Learn as much as possible however and whenever you can. Shadow anyone that will let you and ask questions.

Take the initiative to show up in person when you can and be open to learning.

Go to lab meetings, socialize when you can with them, and ask for the expectations from the get go.

Be open to new experiences and ask questions.

Get out of your comfort zone, eat lunch with the students.

Be there even when you have nothing to do.

Encourage thesis students to go to lab meetings!!!

Your thesis story can just be about your journey.

### **Communication and asking for help**

Also, don't be afraid to ask for help or clarification.

Always ask questions.

If you're unsure about something, don't hesitate to ask questions.

Ask questions and don't be afraid.

Relax and ask questions!

I wish I communicated more at the start with my PI.

Work hard, ask lots of questions! Science is hard, 90% of your experiments will probably fail—and that's ok!

Stay curious and don't let your nerves get the best of you! Every expert was once a beginner.

Own up to how much you don't know!!!

### **Resilience, mindset, and the emotional experience**

Expect it to be messy, and don't panic when it is.

Trust yourself more—you know more than you think you do.

Accept that things will go wrong.

Rest is not a reward, it's a necessity.

Celebrate small wins.

Start drafting even when you don't feel "ready."

Treat your thesis like a part-time job.

Your thesis won't be groundbreaking, and that's okay.

Don't be afraid to pivot if something isn't working.

Track your work so you don't lose sight of how far you've come.

It is not a race, but a marathon.

Don't stress too much and enjoy the experience.

It is a different type of learning. Didn't know what I was signing up for, but grateful for it in the end.

Don't think you can just grind it out.

Can't just get it done in one evening—you'll burn out.

If someone critiques your work, it doesn't mean that they are critiquing you.

Failing is okay!!!! Negative results are results.

It's about the progress, not the end results.

Marathon not a sprint.

Not having results is okay!!!

Honestly about what the thesis experiment will look like. You might feel alone. Things are going to be hard, and it's slow, and you're self-directed.

The point of science is to find the truth of what is in your experiments, not to be right!

### **Practical tips and skill development**

Write as you go instead of saving it all for the end.

Choose a topic you're genuinely curious about, not one you think sounds impressive.

Keep your notes and sources organized from day one.

Talk to former thesis students—they're a goldmine of helpful advice.

Don't be afraid to reach out to your supervisor sooner.

Backup your work religiously.

Break the work into smaller, manageable chunks.

Be proactive about seeking feedback.

Read a couple of past theses in your department.

Learn the field well.

Don't be afraid to give your own ideas and do additional research.

Write everything down, and take good notes. Try not to make the same mistake twice.

Being open-minded and trying out a different experiment/technique can work wonders for you.

Be open-minded when choosing projects.

I would remind how important it is to be curious.

Just reach out to labs you are interested in even if you think you are not qualified.

Literature is so helpful, go read!!!

### **Literature review and Writing**

You don't need to read everything—just read strategically.

Start building a writing habit early.

Grammar less important than the words you choose and how you describe work.

Past lit reviews are helpful.

Having the PI edit something small first.

Put real effort into it!

### **Presentation and sharing your work**

Presentation doesn't have to all be data analysis but can be progressive.

Advice on how to present what you've done even if you don't have results.

Take pics!

## **MENTOR & FACULTY QUOTES**

### **Why Research Matters and Why You Should Care About It**

Be curious and specific about your goals and make sure the answers you are looking for are the same as the labs.

Research teaches us not just about the system we're studying, but how to be resilient, how to work with others, how to ask good questions and how to be open to the unexpected.

The most important medical breakthroughs didn't come from chasing short-term applications. They came from scientists trying to understand how the world works at the most fundamental level.

Science is a long game and even the smallest steps matter.

Research is a chance to ask questions no one has answered yet—and sometimes, to find answers that can make a real difference.

Research is a way of thinking, forcing you to slow down and question what you think you know.

Scientific research is the foundation of innovation.

The only way to solve the world's most pressing challenges is through science/research.

Science is ultimately focused on understanding the world. I can think of no better way to spend one's life than by learning more about how it all works.

The naive questions students ask can be very important because they provide an opportunity to reflect.

The pure joy of discovery that young students experience is a great reminder of why we got into this business.

### **Expectations and Advice for Thesis students**

Be curious and don't worry about guidelines.

If you miss a week—you need to make up that time.

Understanding where your research fits into the larger research goals of the lab.

Learn how to make good figures and how to tell a story.

Keep it simple, and worry about main messages only.

# ABOUT THE AUTHORS

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This guidebook was developed as part of a grant funded by The McMaster OER Grant Program (which is supported by McMaster's MacPherson Institute, the McMaster Student's Union, the Office of the Provost, and the University Libraries). The aim was to support students embarking on their undergraduate research journey by providing a comprehensive, flexible resource that guides them through key transitions, such as finding the right supervisor, developing essential research skills, and learning from the experiences of mentors and peers.

The creation of this guidebook was a true collaborative effort which showed us that the project was more than writing a guide. It was an opportunity to reflect on our own experiences, work together effectively, and develop a resource that we hope will be useful not only to Biochemistry and Biomedical Sciences students at McMaster University, but also to students across disciplines and institutions as they navigate the world of research.

We hope this guide provides clarity, confidence, and inspiration to students as they begin their own research journeys.

## About the authors

**Dr. Felicia Vulcu** is an Associate Professor (teaching stream) in the Department of Biochemistry and Biomedical Sciences (BBS) at McMaster University. Her teaching is deeply rooted in promoting mental health awareness, with a personal commitment to fostering environments where students feel respected, heard, and empowered. Her teaching practices are built on a foundation of safety, respect, and inclusivity. She believes in creating nurturing spaces that support lifelong learning. Felicia's approach includes integrating innovative techniques such as team think tanks, flipped-classroom case studies, and virtual labs, where students apply biochemistry skills to real-world biomedical issues, like drug discovery. Felicia has taught Biochemistry lab courses for many years, with a focus on introducing students to the research process in a environment. She believes that lab courses provide students with the opportunity to experience the true wonder of research, while also building fundamental frameworks for tackling experimental design, whether for research, thesis courses, or grad school. Her main approach emphasizes breaking down complex experimental tasks into four key stages: experimental design, readout, interpretation, and challenging assumptions in the system. Felicia is dedicated to fostering reflective research practices, which she believes enhance lifelong learning. She is also passionate about exploring accessibility in teaching lab spaces to ensure inclusivity and support for all students. A key achievement in her teaching journey has been the development of a second-year undergraduate laboratory course that introduces students to the research process. She has also co-developed

online learning resources with the design of a popular Massive Open Online Course (MOOC) and a range of Open Educational Resources (OER)s to offer flexible and learning opportunities for students.

Felicia was also involved in the design and implementation of McMaster's Biomedical Discovery and Commercialization (BDC) program and continues to shape the curriculum in ways that reflect her commitment to student well-being and academic growth.

**Dr. Caitlin Mullarkey** is an Associate Professor and the Associate Chair of Undergraduate Education in the department of Biochemistry and Biomedical Sciences. She is focused on providing undergraduates with a rigorous and cutting-edge scientific education that will allow them to excel in diverse careers and graduate/professional school. With extensive training and expertise in infectious disease and vaccine development, she teaches virology, cell biology, biochemistry, and immunology to undergraduates at all levels. She is keenly interested in developing new curricula and her current scholarship centers on exploring advanced methods of delivering learning content.

Dr. Mullarkey received her doctorate from the University of Oxford, where she studied as a Rhodes Scholar. She subsequently completed a postdoctoral fellowship in viral immunology at the Icahn School of Medicine at Mount Sinai (New York City) under the mentorship of Dr. Peter Palese. Her teaching and scholarship have been recognized with numerous accolades. In 2024, she received the Minister of Colleges and Universities' Award of Excellence. She was also awarded the President's Award for Outstanding Contributions to Teaching and Learning in 2023 and is a three-time recipient of the McMaster Student Union Teaching Award for the Faculty of Health Sciences for her instruction in virology and advanced immunology.

**Meghan Pepler** is a PhD Candidate in Dr. Marie Elliot's lab at McMaster University, where her research focuses on RNA-based regulation in *Streptomyces venezuelae*. She is funded by the NSERC Canada Graduate Scholarship–Doctoral and has been recognized with multiple departmental awards for research excellence and scientific communication. Meghan completed her BSc Honours in Molecular Biology and Genetics (Co-op) at McMaster, where she also conducted her undergraduate thesis. As a graduate student, she has since trained several thesis students in the Elliot lab, supporting their development as emerging researchers.

Alongside her research, Meghan has developed a strong interest in teaching and pedagogy. She has twice served as a Sessional Instructor for *Techniques in Molecular Genetics (MOL BIOL 3V03)* and has contributed to curriculum development and inclusive learning material design. She completed the Teaching and Learning Theory and Inquiry Certificate through McMaster's MacPherson Institute and has recently been nominated for the CCUBC–oCUBE Emerging Educational Leader Award in recognition of her growing contributions to undergraduate teaching and mentorship.

Meghan's longitudinal experience at McMaster as both an undergraduate thesis student and a thesis student mentor, along with her involvement in departmental teaching, has given her a deep understanding of the

program. This perspective inspired her to help write and shape this guidebook as a resource to make the experience more transparent, approachable, and empowering for future students.