

Example Thesis/Dissertation

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THESIS/DISSERTATION TITLE

by

Full Name

A dissertation submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of xx

The University of Utah

Month Year

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The University of Utah Graduate School

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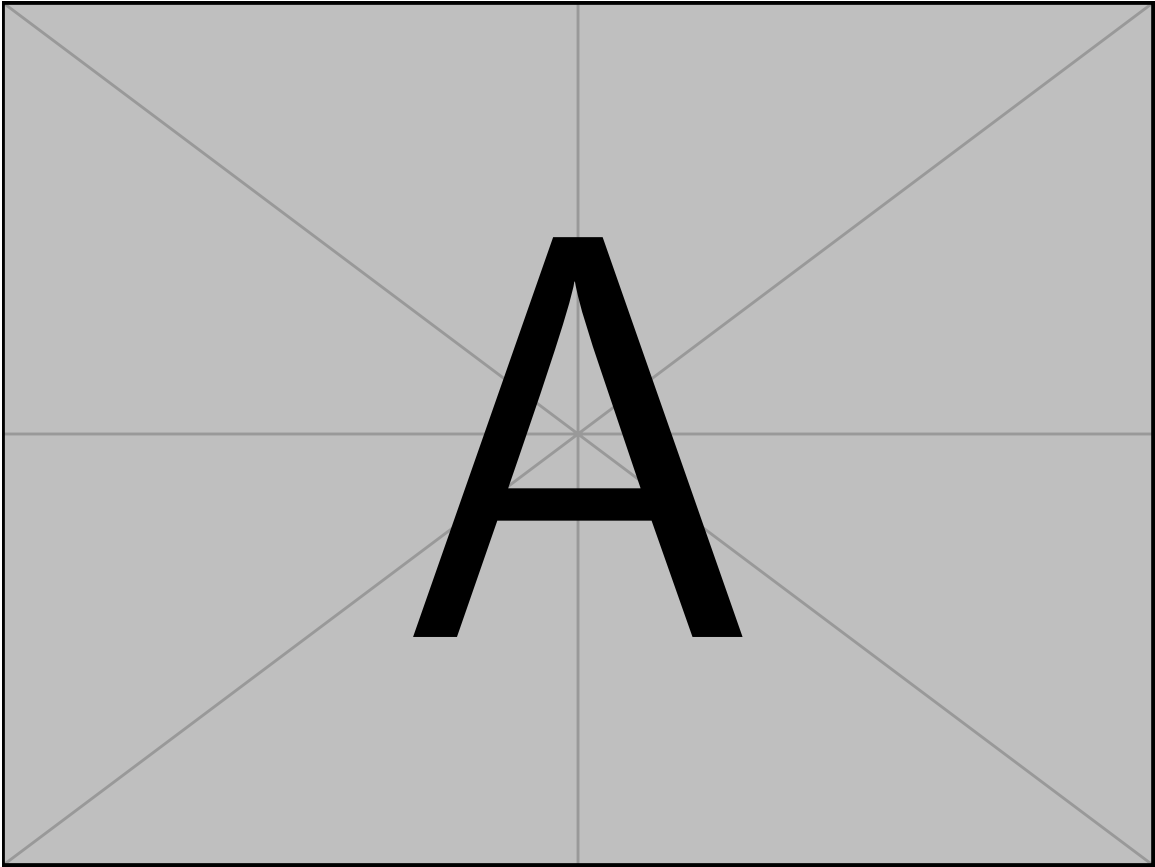
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ABSTRACT

The usability of dissertation abstracts depends largely on their content. Many journals within the medical community have settled on a seven sentence structure, which is also gaining acceptance in the social sciences, education and business. In it, the purpose of the study and methodological choices are outlined succinctly, allowing the reader or researcher to quickly scan and evaluate a number of studies to easily choose ones that meet their particular demands. The structure contains variations on the following seven sentence stems: "The purpose of this study is...." "The scope of this study...." "The methodology...." "The Findings..." "Conclusions reached are ..." "Limitations of this study include...." "This study contributes...." Abstracts of dissertation proposals contain the same seven concepts, substituting data collection and analysis in place of findings and conclusions. Abstracts are limited in the United States by the UMI to 350 words.

More info here.

Most books at the library will have a dedication page. Normally, this page includes quotes like "For my mother" or "For Lucy who never gave up on me." A dissertation dedication is the same concept. In this part of the dissertation, the student must use a sentence or a paragraph to dedicate their text. They may want to use the dedication to recognize an individual who inspired them to go to college or someone who helped with the dissertation. Dedicating the dissertation to someone is a way to honor them. After putting so much work into this paper, it is a chance for the student to recognize the people who influenced the process.



“Quote”

—Famous Individual

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NOTATION AND SYMBOLS

x	<i>Var</i>	- the variable 'x'.
y	y	- the variable 'y'.
m	<i>Slope</i>	- The slope is one of the essential characteristics of a line and helps us measure the rate of change. The slope of a straight line is the ratio of the change in y to the change in x , also called the rise over run.
\mathbf{F}	<i>Force</i>	- Force vector.
π	<i>Pi</i>	- The number π is a mathematical constant. It is defined as the ratio of a circle's circumference to its diameter, and it also has various equivalent definitions. It appears in many formulas in all areas of mathematics and physics.

ACKNOWLEDGEMENTS

The dissertation acknowledgements section is where you thank those who have helped and supported you during the research and writing process. This includes both professional and personal acknowledgements. ...

More acknowledgement info can be found here: <https://www.scribbr.com/dissertation/acknowledgements/>.

CHAPTER 1

INTRODUCTION

1.1 Overview

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1.2 Background and Significance

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

1.3 Hypothesis and Rationale

1.3.1 Aim 1

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1.3.2 Aim 2

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1.3.3 Aim 3

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1.4 Impact and Intellectual Contributions

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semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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CHAPTER 2

MULTILINE

TITLE

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2.1 Abstract

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2.2 Introduction

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wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

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2.3 Section

2.3.1 Subsection

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luctus mauris. **Figure 2.1** and **Table 2.1** Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum. [1].

2.3.1.1 Cross Reference Label Definition

To cross reference anything in L^AT_EX you need to define a **label**. For example, *Chapters*, *Sections*, *Subsections*, *SubSubSections*, *Paragraphs*, *Figures*, and *Tables* can be labeled in the following manner:

- **A Chapter:**

```
'\chapter{Chapter}\label{chp:1}'
```

- **A Section:**

```
'\section{Section}\label{s:chp1_overview}'
```

- **A SubSection:**

```
'\subsection{SubSection}\label{ss:Subsection1}'
```

- **A SubSubSection:**

```
'\subsubsection{SubSubSection}\label{sss:sss1}'
```

- **A Paragraph:**

```
'\paragraph{Paragraph}\label{p:paragraph1}'
```

- **Inside a figure environment:**

```
'\label{fig:figure_1}'
```

- **Inside a table environment:**

```
'\label{tab:table_1}'
```

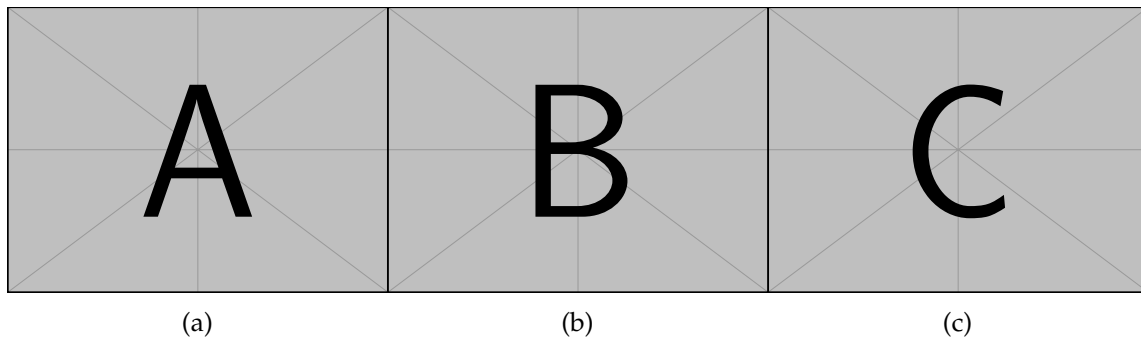


Figure 2.1: Example figure with three side-by-side images with no space between each figure. (a) ... (b) ... (c) ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

Table 2.1: Example table 1. ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

α	β	γ
0	2	4
1	3	5

2.3.1.2 Cross Referencing

2.3.1.2.1 Document sections To cross reference *Chapters, Sections, Subsections, SubSubSections, Paragraphs, Figures, Tables, References, and Codes* use the following L^AT_EX commands from the `cleveref` package:

- **A Chapter:**

`\cref{chp:1}` → Chapter 1.

- **A Section:**

`\cref{s:chp1_overview}` → Section 1.1.

- **A SubSection:**

`\cref{ss:Subsection1}` → Section 2.3.1.

- **A SubSubSection:**

`\cref{sss:cross_referencing}` → Section 2.3.1.2.

- **A Paragraph:**

`\cref{p:paragraph_1}` → Paragraph 2.5.2.1.1.

- **Multiple Chapters, Sections, SubSections, SubSubSections**

`\cref{chp:1,s:chp1_overview,ss:Subsection1,sss:cross_referencing}` → Chapter 1 and Sections 1.1, 2.3.1 and 2.3.1.2.

with no **space** between each item being referenced.

2.3.1.2.2 References/Citations/Bibliography Use a citation manager to load your references and export a `bibliography.bib` file. Include this `bibliography.bib` file in your main dissertation file using the `\addbibresource{\subfix{Chapter2/bib_files/bibliography.bib}}` before the command: `\begin{document} ... \end{document}`. It is recommended to use [Mendeley](#) for their ease of adding references and exporting `bibliography.bib` files. [Mendeley Web Importer](#) also has a Google Chrome extension where you can add references via the web browser.

- Single references from a `bibliography.bib` file

`\autocite{Feltgen_2014}` → [1]

- Multiple references (2) from a bibliography.bib file

`\autocite{Gandorfer_2001, Feltgen_2014}` → [1], [2]

- Multiple references (3+) from a bibliography.bib file

`\autocite{Fivgas_2001, Gandorfer_2001, Feltgen_2014}` → [1]–[3]

2.3.1.2.3 Figures

- A single figure:

`\cref{fig:Figure_1}` → Figure 2.1.

- Multiple figures:

`\cref{fig:Figure_1,fig:Figure_2}` → Figures 2.1 and 2.2

with no space between each item being referenced.

2.3.1.2.4 Tables

- A single Table:

`\cref{tab:Table_1}` → Table 2.1.

- Multiple Tables:

`\cref{tab:Table_1,tab:Table_2}` → Tables 2.1 and 2.2

with no space between each item being referenced.

2.3.1.2.5 Figures and Tables

- A Figure and a Table:

`\cref{fig:Figure_1,tab:Table_1}` → Figure 2.1 and Table 2.1.

with no space between each item being referenced.

2.3.1.2.6 Codes

- A single code:

`\cref{code:Figure_1}` → Script 1.

- Multiple codes:

`\cref{code:Figure_1,code:Figure_2}` → Scripts 1 and 2

with no space between each item being referenced.

2.4 Figure and Table Placement

Due to the strict requirement of figure/table placement, it is recommended to have figure/tables placed immediately after they are referenced on a separate page. We are using the \LaTeX commands from the `afterpage` package to do this. Careful placement in the text needs to be considered to ensure that there are not additional pages of text before the figure/table is placed. In some rare instances the figure/table will need to be coded in a previous paragraph/section to have the display be on the subsequent page after the first mention. The \LaTeX code used to create [Figure 2.1](#) is in [Script 1](#).

```

</> Script 1: ...  $\LaTeX$  to display a figure with one image above and two side-by-side </>
                                     images.
1  %-----%
2  \afterpage{
3  \begin{figure}[p]
4      \centering
5      \begin{subfigure}[b]{0.33\textwidth}
6          \centering
7          \includegraphics[width=\linewidth]
8              {example-image-a} % File path to graphics
9          \subcaption{\label{fig:a}}
10         \end{subfigure}% `%' indicates no space between figures
11         \begin{subfigure}[b]{0.33\textwidth}
12             \centering
13             \includegraphics[width=\linewidth]
14                 {example-image-b} % File path to graphics
15             \subcaption{\label{fig:b}}
16         \end{subfigure}% `%' indicates no space between figures
17         \begin{subfigure}[b]{0.33\textwidth}
18             \centering
19             \includegraphics[width=\linewidth]
20                 {example-image-c} % File path to graphics
21             \subcaption{\label{fig:c}}
22         \end{subfigure}% `%' indicates no space between figures
23         \caption{Example figure with three side-by-side images with no space
24             between each figure. \subref{fig:a} \ldots \subref{fig:b} \ldots
25             \subref{fig:c} \ldots \lipsum[75]}
26         \label{fig:Figure_1}
27     \end{figure}
28     \clearpage

```

If the figure/tables are to instead be placed in the text at either the top or bottom of the page then the placement option `[tbp]` forces the figure/table to be either placed at the ‘top’, ‘bottom’, or ‘on a separate page centered vertically’. The location of the figure/table in the text will have to be shifted such that the figure shows up immediately after the figure/table is referenced in the text. \LaTeX will try and find the best location to minimize white space.

In doing so, sometimes the figure/tables will *float* in a less desirable location. Hence, why it is suggested to use the method described above using the `afterpage` package.

2.4.1 Table Creation

\LaTeX can be a bit tricky when it comes to tables. Therefore, it is recommended to use the two following methods to easily create your table for publication.

1. `tablesgenerator`
2. `Excel2 \LaTeX` package: Making tables in \LaTeX can be tedious, especially if some columns are calculated. This converter allows you to write a table in Excel instead, and export the current selection as \LaTeX markup which can be pasted into an existing \LaTeX document, or exported to a file and included via the `\input` command.

2.5 Section

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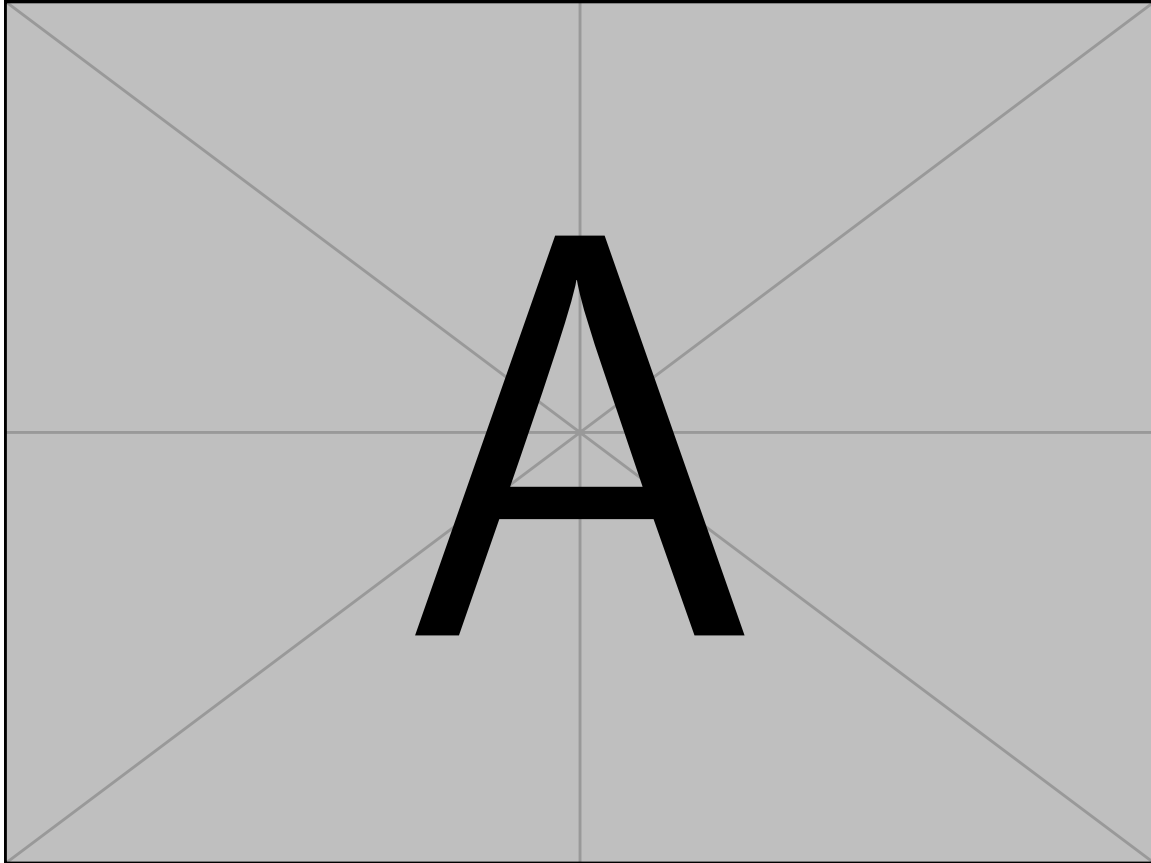
2.5.1 Subsection

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

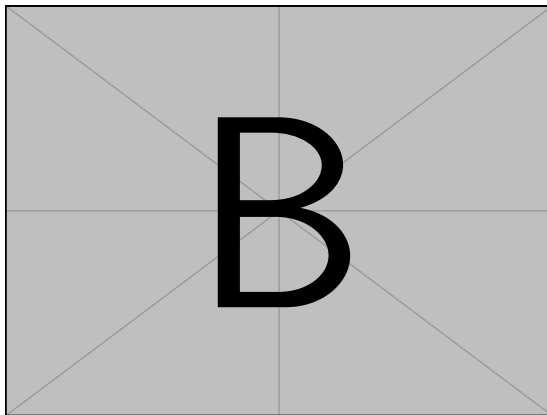
Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris. **Figure 2.2**

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

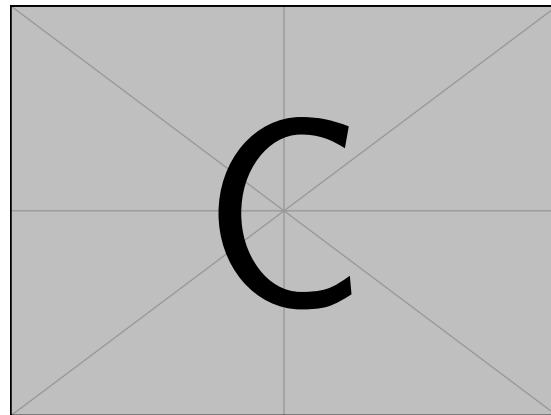
Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet,



(a)



(b)



(c)

Figure 2.2: Three figures, one on the top and two side-by-side with gaps between figures. ... (a) ... (b) ... (c) ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

The \LaTeX code used to create [Figure 2.2](#) is in [Script 2](#).

```

</> Script 2: ... $\LaTeX$  to display a figure with one image above and two side-by-side </>
      images.
1  %-----%
2  \afterpage{
3  \begin{figure}[p]
4    \centering
5    \begin{subfigure}[b]{1.0\textwidth}
6      \centering
7      \includegraphics[width=\linewidth]
8      {example-image-a} % File path to graphics
9      \subcaption{\label{fig:d}}
10   \end{subfigure} \\[1ex]
11   \begin{subfigure}[b]{0.5\textwidth}
12     \centering

```

```

13     \includegraphics[width=0.95\linewidth]
14     {example-image-b} % File path to graphics
15     \subcaption{\label{fig:e}}
16 \end{subfigure}% '%' indicates no space between figures
17 \begin{subfigure}[b]{0.5\textwidth}
18     \centering
19     \includegraphics[width=0.95\linewidth]
20     {example-image-c} % File path to graphics
21     \subcaption{\label{fig:f}}
22 \end{subfigure}
23 \caption{Three figures, one on the top and two side-by-side with gaps
24 between figures. \ldots \subref{fig:d} \ldots \subref{fig:e} \ldots
25 \subref{fig:f} \ldots \lipsum[75]}
26 \label{fig:Figure_2}
27 \end{figure}
28 \clearpage}
29 %-----%

```

2.5.2 SubSection

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

2.5.2.1 SubSubSection

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

2.5.2.1.1 Paragraph1 Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat

ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Figure 2.3

The \LaTeX code used to create [Figure 2.3](#) is in [Script 3](#).

```

</>      Script 3: ...  $\LaTeX$  to display a figure with two side-by-side images.      </>
1  %-----%
2  \afterpage{
3  \begin{figure}[p]
4      \centering
5      \begin{subfigure}[b]{0.5\textwidth}
6          \centering
7          \includegraphics[width=\linewidth]
8              {example-image-a}
9          \subcaption{\label{fig:g}}
10     \end{subfigure}%
11     \begin{subfigure}[b]{0.5\textwidth}
12         \centering
13         \includegraphics[width=\linewidth]
14             {example-image-b}
15         \subcaption{\label{fig:h}}
16     \end{subfigure}%
17     \caption{Two figures side-by-side. \ldots \subref{fig:g} \ldots}
18     \subref{fig:h} \ldots \lipsum[75]}
19     \label{fig:Figure_3}
20 \end{figure}
21 \clearpage}
22 %-----%

```

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin

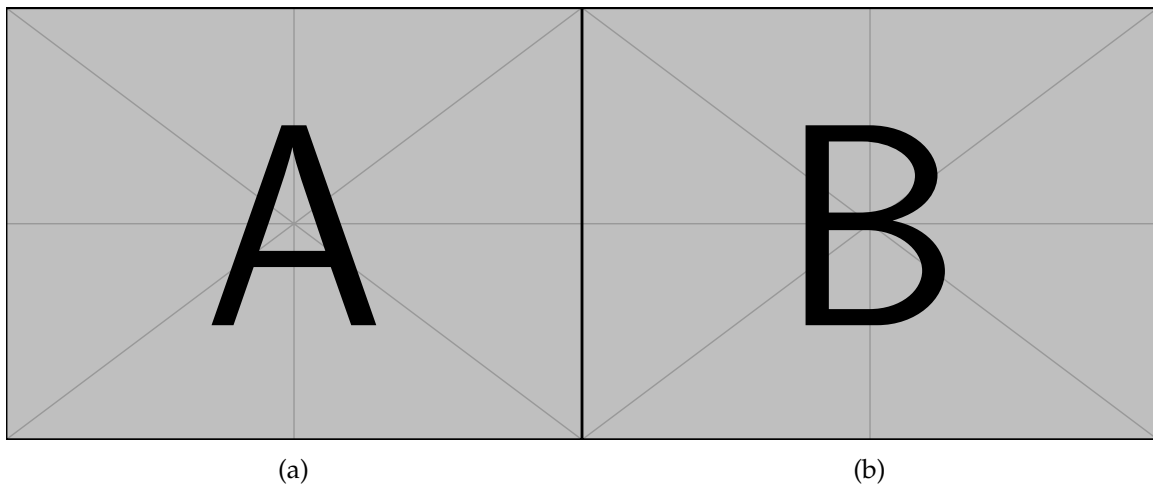


Figure 2.3: Two figures side-by-side. ... (a) ... (b) ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

2.5.2.1.2 Paragraph2 Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi. **Figure 2.4**

The \LaTeX code used to create **Figure 2.4** is in **Script 4**.

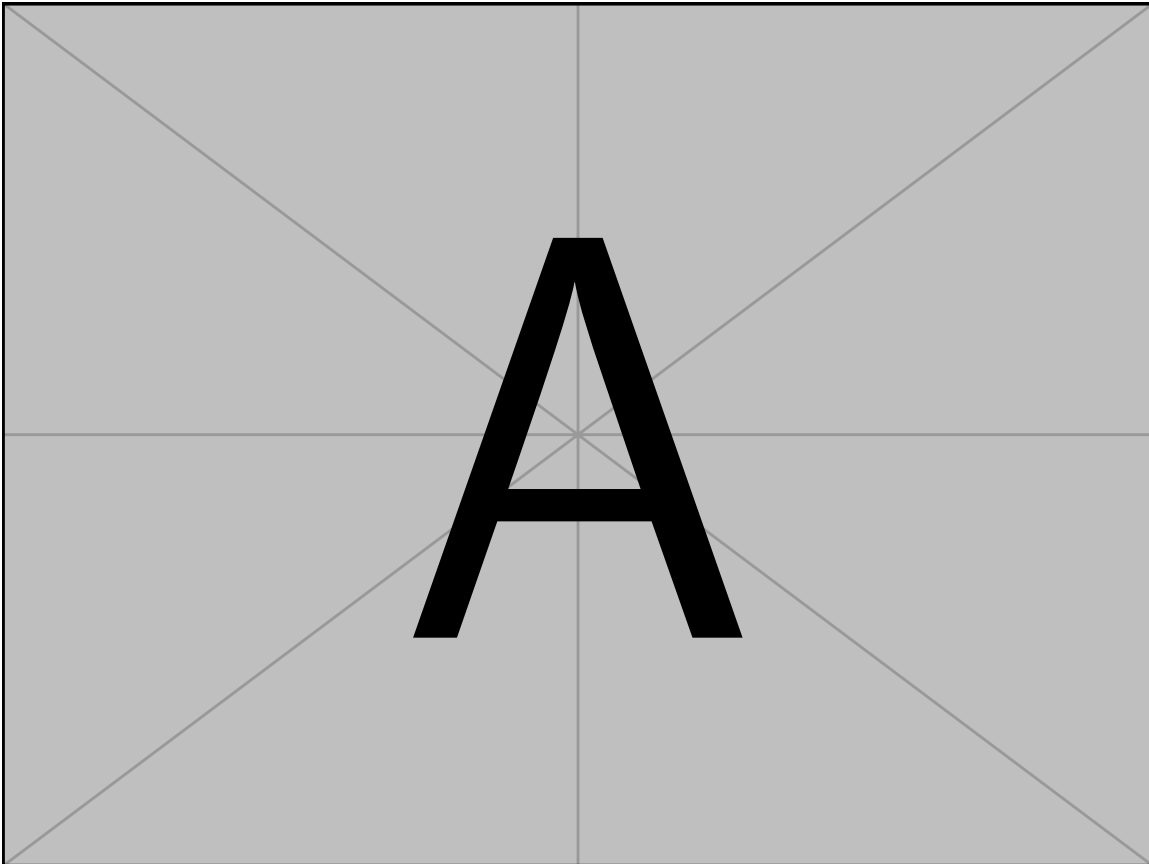


Figure 2.4: Single image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

```

</> Script 4: ... $\LaTeX$  to display a figure of a single image. </>
1 %-----%
2 \afterpage{
3 \begin{figure}[p]
4   \centering
5   \includegraphics[width=1.0\textwidth]
6   {example-image-a}
7   \caption{Single image \ldots \lipsum[75]}
8   \label{fig:Figure_4}
9 \end{figure}
10 \clearpage}
11 %-----%

```

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas

non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consetetur odio sem sed wisi. Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum. **Figure 2.5** Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum.

Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

2.5.3 SubSection

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consetetur odio sem sed wisi.

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consetetur eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consetetur tortor sapien facilisis magna. Mauris quis magna

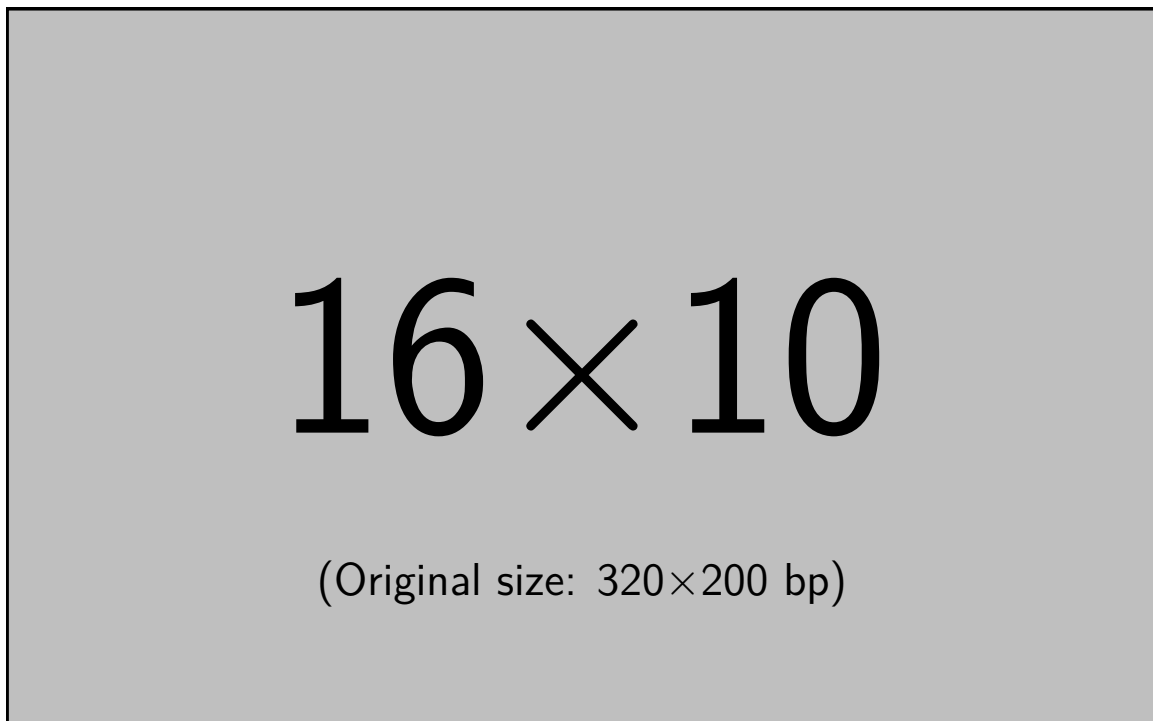


Figure 2.5: Single image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam portitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

2.6 Results

Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. **Figure 2.6**

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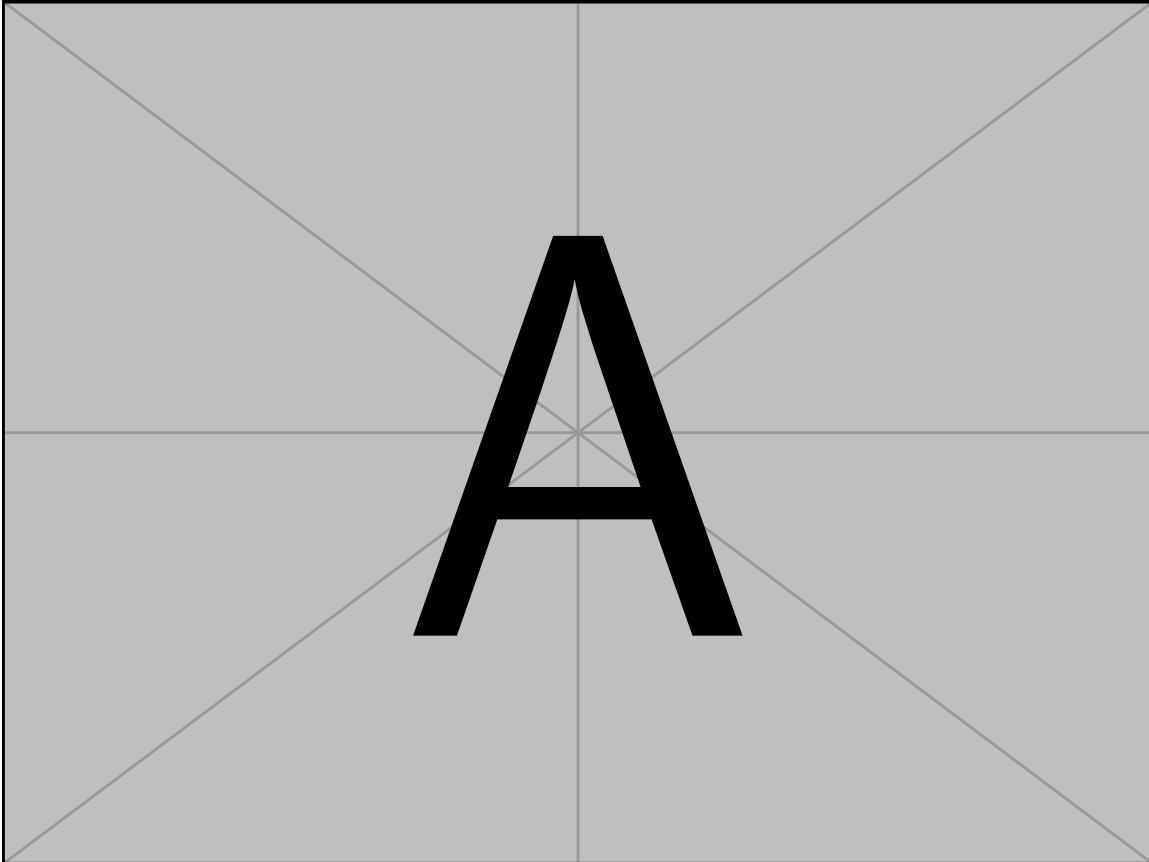


Figure 2.6: Example figure ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

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2.6.1 Animation

Using the \LaTeX package `animate`, you can embed PDF gifs in your PDF. When printed, java-enabled macros will disable the play icon and will print the first figure in the sequence. An example animation is in [Figure 2.7](#).

2.6.1.1 \LaTeX Code for Animations

[Figure 2.7](#) was created using [Script 5](#).

```

</>      Script 5: ...  $\LaTeX$  script using the package animate to embed gifs.      </>
1  %-----%
2  \afterpage{
3  \begin{figure}[tbp]
4      \centering
5      \animategraphics[loop,controls,width=1.0\textwidth]{20}
6      {pngs/anim-}{0}{24}
7      \caption{Example of an embedded animation in the PDF using the  $\{\LaTeX\}$ 
8      package \href{https://ctan.org/pkg/animate?lang=en}{\texttt{animate}}.}
9      \label{fig:animation}
10 \end{figure}
11 \clearpage}
12 %-----%

```

2.6.2 Subsection

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Figure 2.7: Example embedded animation in the PDF using the \LaTeX package `animate`.

purus urna posuere velit, et commodo risus tellus quis tellus. Vivamus leo turpis, tempus sit amet, tristique vitae, laoreet quis, odio. Proin scelerisque bibendum ipsum. Etiam nisl. Praesent vel dolor. Pellentesque vel magna. Curabitur urna. Vivamus congue urna in velit. Etiam ullamcorper elementum dui. Praesent non urna. Sed placerat quam non mi. Pellentesque diam magna, ultricies eget, ultrices placerat, adipiscing rutrum, sem.

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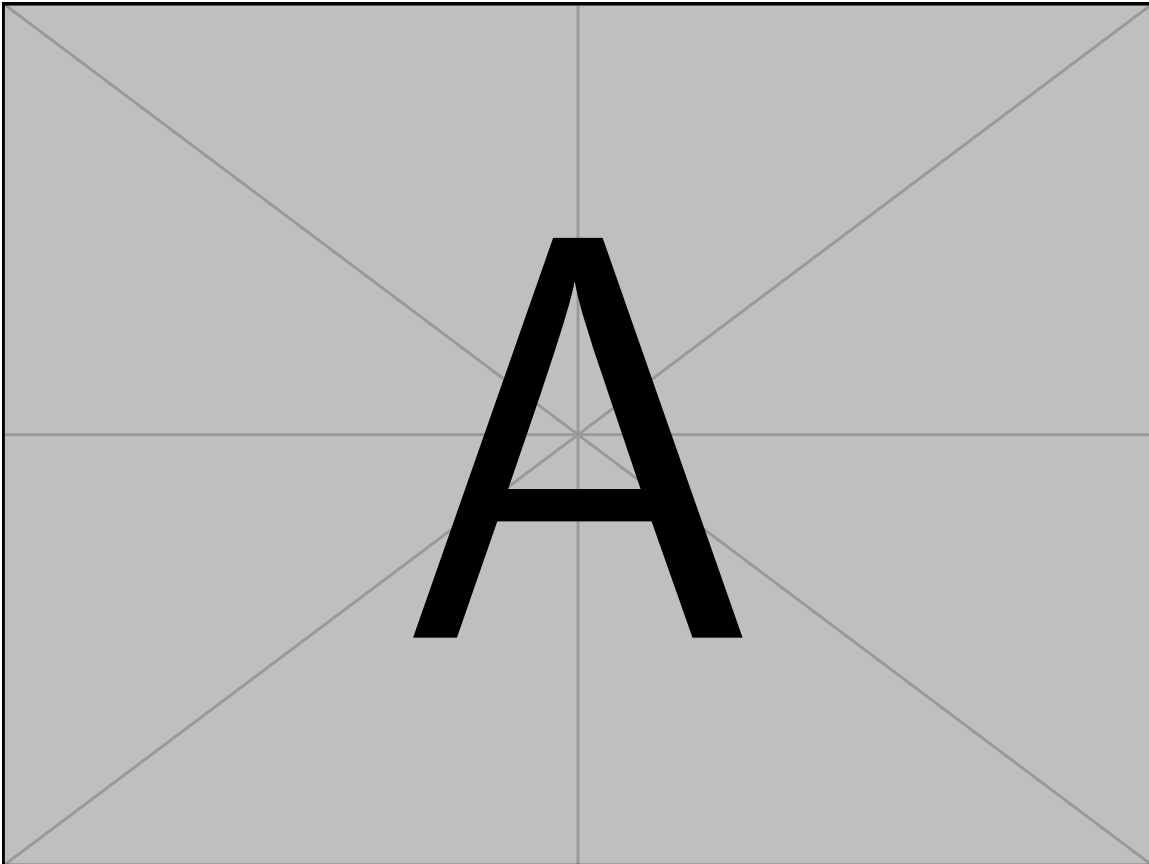


Figure 2.8: Example image ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

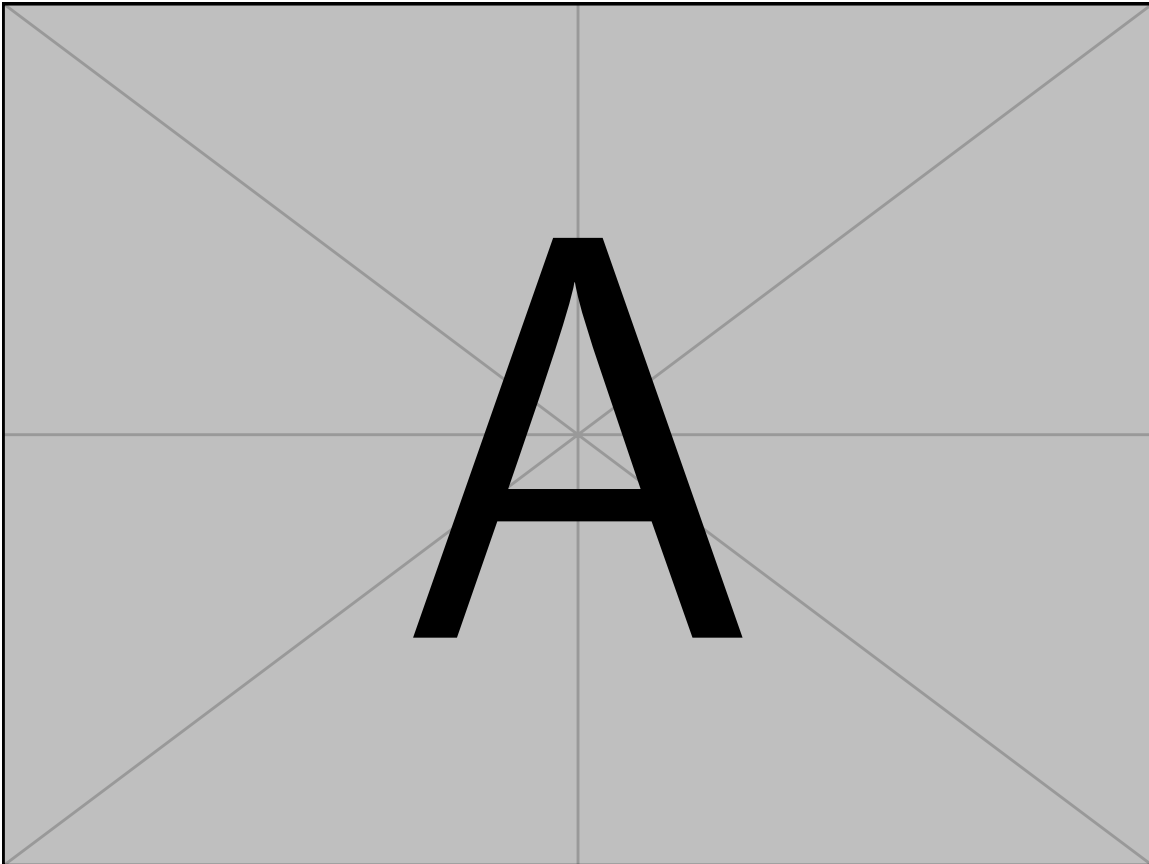


Figure 2.9: Example image ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

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2.6.3 Subsection

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Table 2.2: Example table 2 ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

A	B	C	D (mN)	E (mN)	F (mN)
P	E	12	9.185	9.372	2.459
	P	11	8.566	9.721	3.959
Q	E	6	7.579	7.415	3.797
	P	9	5.463	4.550	2.311
R	E	10	6.712	6.290	2.102
	P	11	7.558	7.829	2.903
S	E	11	16.673	14.650	7.446
	P	12	8.322	8.364	2.535

Table 2.3: Example table 3 ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

A	B	C	D (mN)	E (mN)	F (mN)
P	E	12	9.185	9.372	2.459
	P	11	8.566	9.721	3.959
Q	E	6	7.579	7.415	3.797
	P	9	5.463	4.550	2.311
R	E	10	6.712	6.290	2.102
	P	11	7.558	7.829	2.903
S	E	11	16.673	14.650	7.446
	P	12	8.322	8.364	2.535

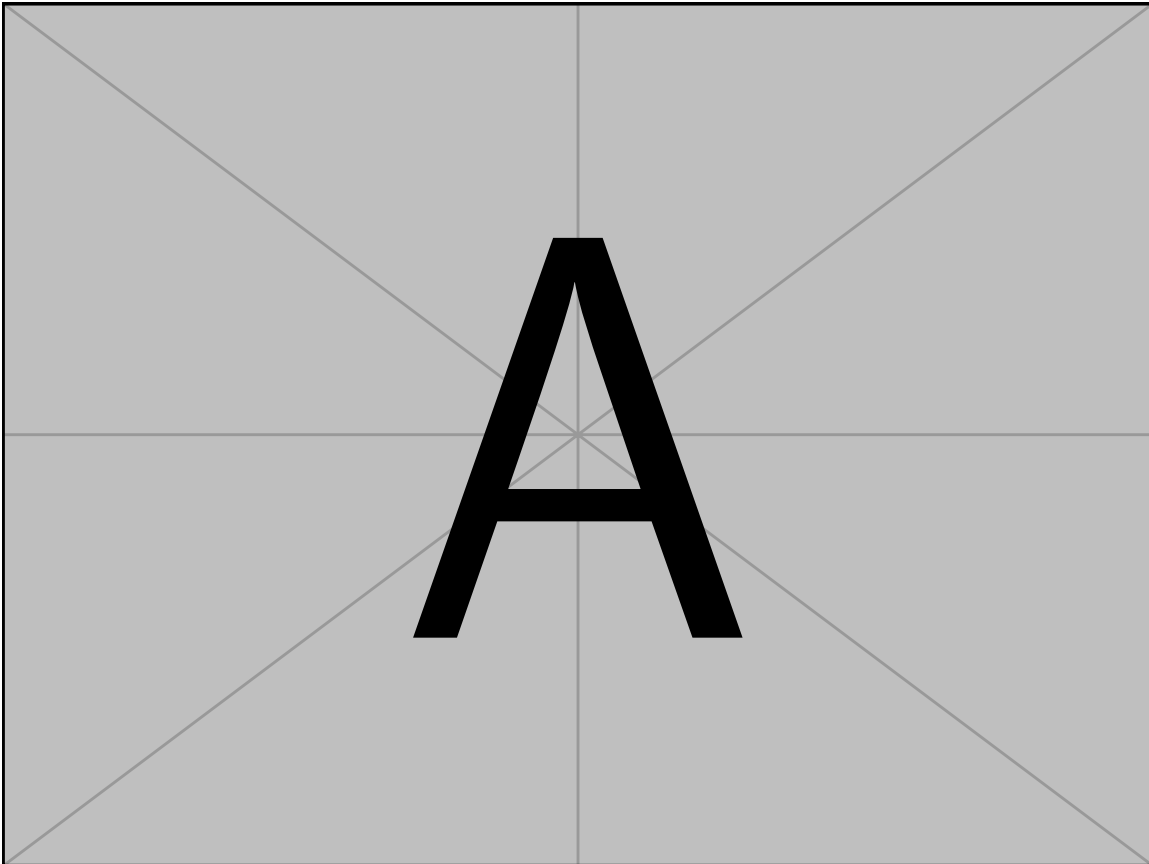


Figure 2.10: Example image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

nonummy sapien. Proin molestie sem vitae urna. Maecenas lorem. Vivamus viverra consequat enim. **Figure 2.10**

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Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum.

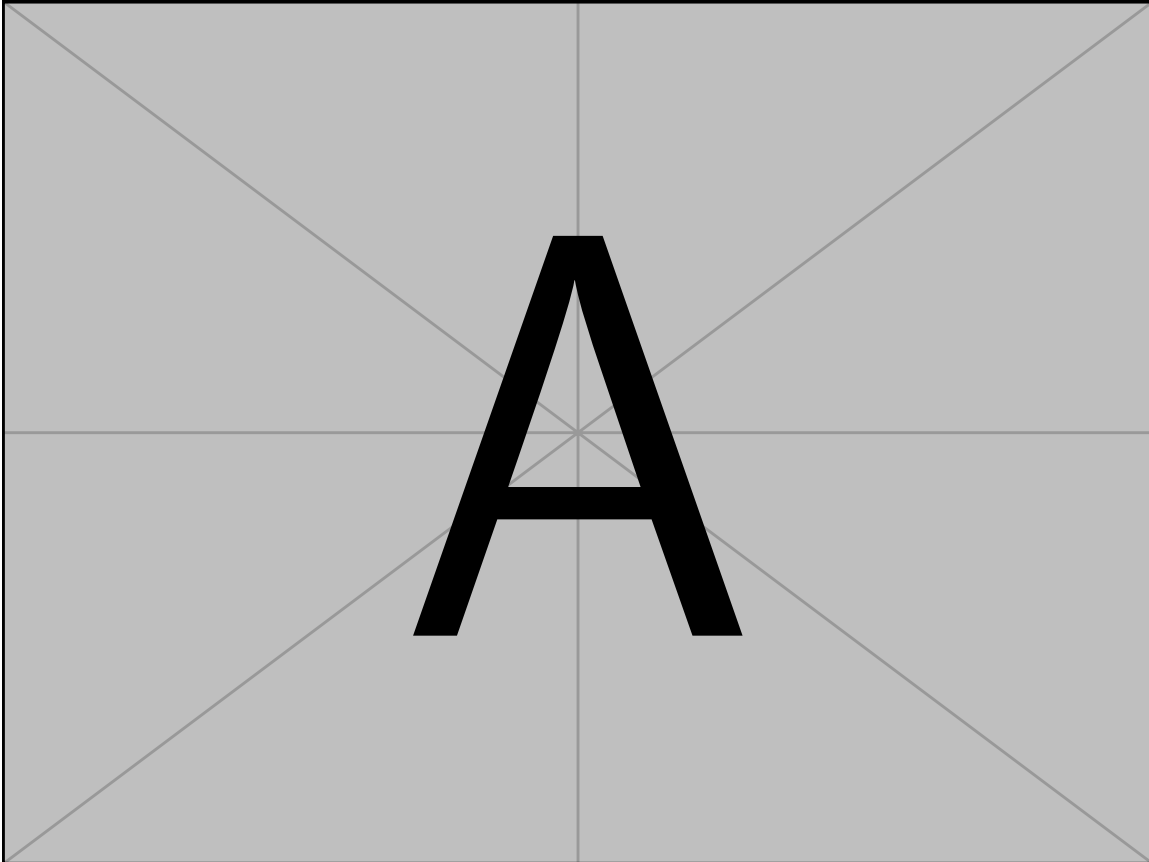


Figure 2.11: Example image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

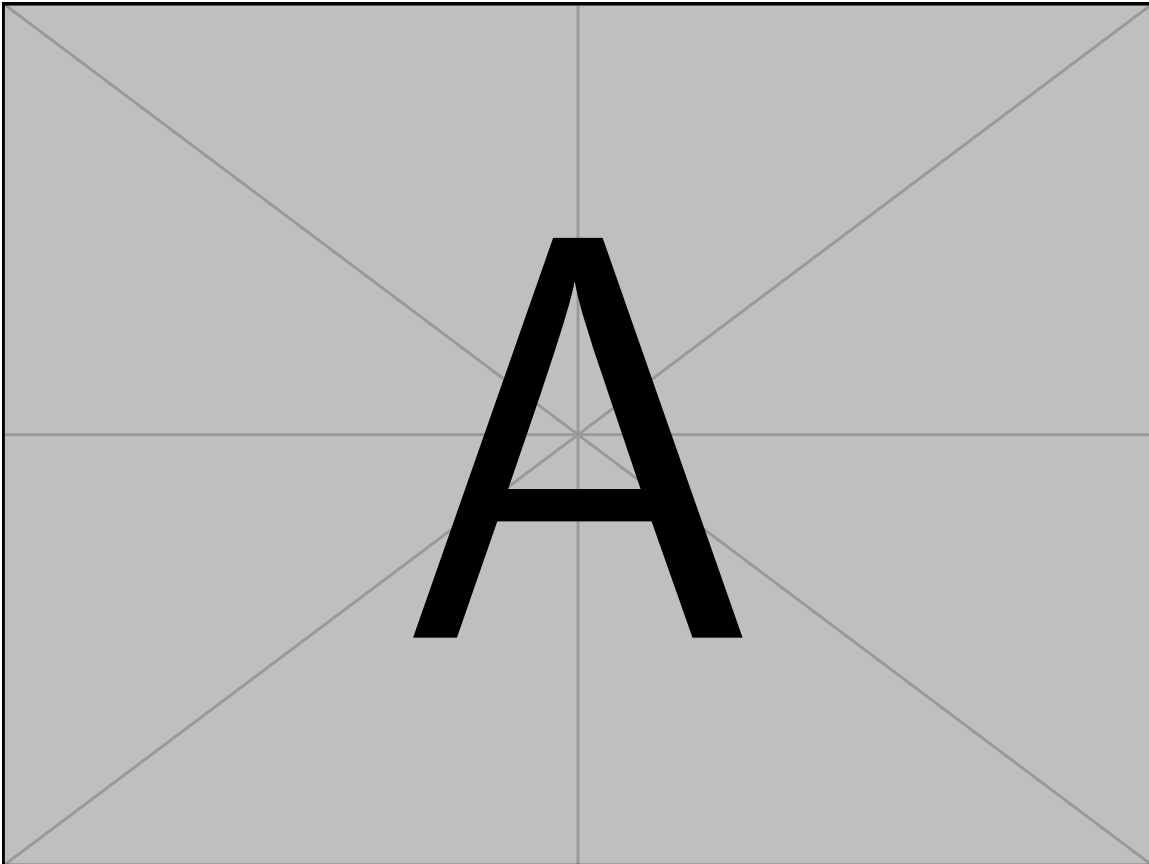


Figure 2.12: Example image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

Etiam vel ipsum. Morbi facilisis vestibulum nisl. Praesent cursus laoreet felis. Integer adipiscing pretium orci. Nulla facilisi. Quisque posuere bibendum purus. Nulla quam mauris, cursus eget, convallis ac, molestie non, enim. Aliquam congue. Quisque sagittis nonummy sapien. Proin molestie sem vitae urna. Maecenas lorem. Vivamus viverra consequat enim. **Figure 2.13**

Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

Etiam vel ipsum. Morbi facilisis vestibulum nisl. Praesent cursus laoreet felis. Integer adipiscing pretium orci. Nulla facilisi. Quisque posuere bibendum purus. Nulla quam mauris, cursus eget, convallis ac, molestie non, enim. Aliquam congue. Quisque sagittis nonummy sapien. Proin molestie sem vitae urna. Maecenas lorem. Vivamus viverra consequat enim. **Table 2.4**

Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

Etiam vel ipsum. Morbi facilisis vestibulum nisl. Praesent cursus laoreet felis. Integer adipiscing pretium orci. Nulla facilisi. Quisque posuere bibendum purus. Nulla quam

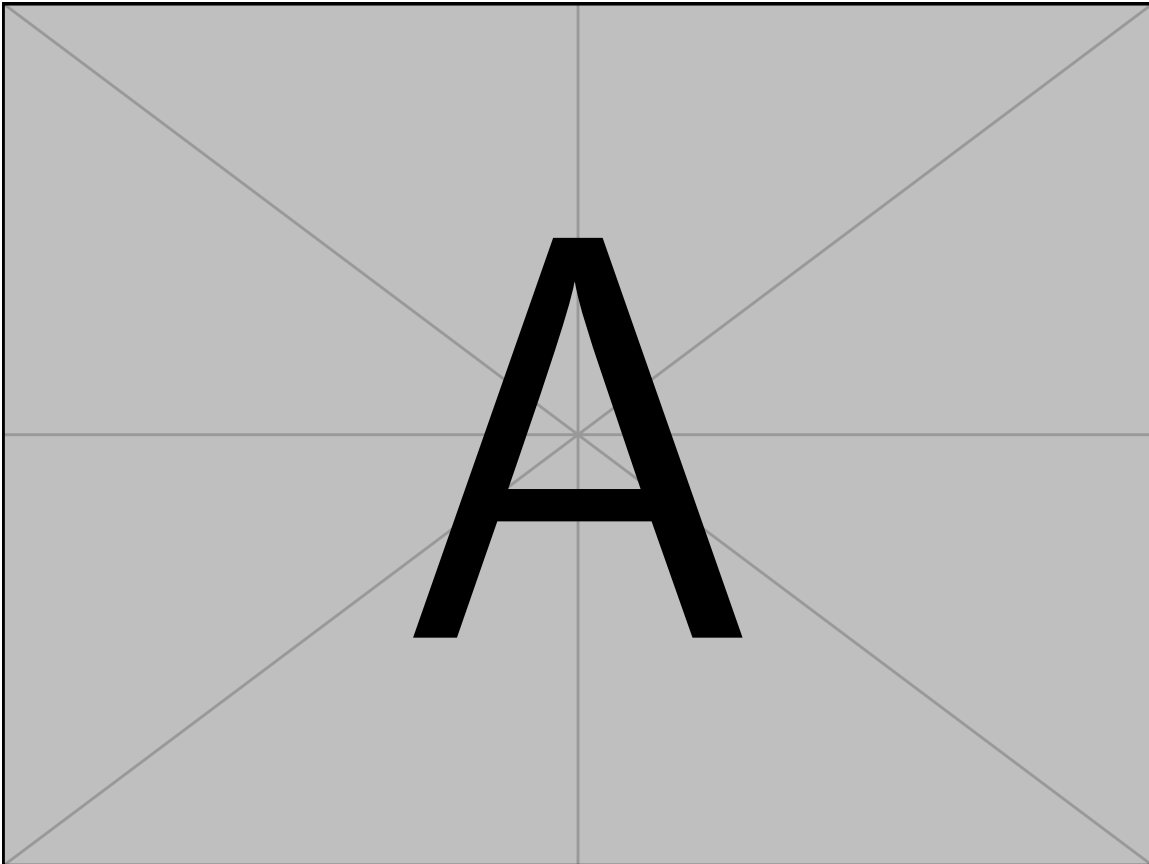


Figure 2.13: Example image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

Table 2.4: Example table 4 ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

A	B	C	D (mN)	E (mN)	F (mN)
P	E	12	9.185	9.372	2.459
	P	11	8.566	9.721	3.959
Q	E	6	7.579	7.415	3.797
	P	9	5.463	4.550	2.311
R	E	10	6.712	6.290	2.102
	P	11	7.558	7.829	2.903
S	E	11	16.673	14.650	7.446
	P	12	8.322	8.364	2.535

mauris, cursus eget, convallis ac, molestie non, enim. Aliquam congue. Quisque sagittis nonummy sapien. Proin molestie sem vitae urna. Maecenas lorem. Vivamus viverra consequat enim. [Table 2.5](#)

2.6.4 SubSection

Aliquam tortor. Morbi ipsum massa, imperdiet non, consectetur vel, feugiat vel, lorem. Quisque eget lorem nec elit malesuada vestibulum. Quisque sollicitudin ipsum vel sem. Nulla enim. Proin nonummy felis vitae felis. Nullam pellentesque. Duis rutrum feugiat felis. Mauris vel pede sed libero tincidunt mollis. Phasellus sed urna rhoncus diam euismod bibendum. Phasellus sed nisl. Integer condimentum justo id orci iaculis varius. Quisque et lacus. Phasellus elementum, justo at dignissim auctor, wisi odio lobortis arcu, sed sollicitudin felis felis eu neque. Praesent at lacus.

Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. [Figures 2.14a to 2.14c](#) [Figures 2.14d to 2.14f](#).

Aliquam tortor. Morbi ipsum massa, imperdiet non, consectetur vel, feugiat vel, lorem. Quisque eget lorem nec elit malesuada vestibulum. Quisque sollicitudin ipsum vel sem. Nulla enim. Proin nonummy felis vitae felis. Nullam pellentesque. Duis rutrum feugiat felis. Mauris vel pede sed libero tincidunt mollis. Phasellus sed urna rhoncus diam euismod bibendum. Phasellus sed nisl. Integer condimentum justo id orci iaculis varius. Quisque et lacus. Phasellus elementum, justo at dignissim auctor, wisi odio lobortis arcu, sed sollicitudin felis felis eu neque. Praesent at lacus.

Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum.

Table 2.5: Example table 5 ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

A	B	C	D (mN)	E (mN)	F (mN)
P	E	12	9.185	9.372	2.459
	P	11	8.566	9.721	3.959
Q	E	6	7.579	7.415	3.797
	P	9	5.463	4.550	2.311
R	E	10	6.712	6.290	2.102
	P	11	7.558	7.829	2.903
S	E	11	16.673	14.650	7.446
	P	12	8.322	8.364	2.535

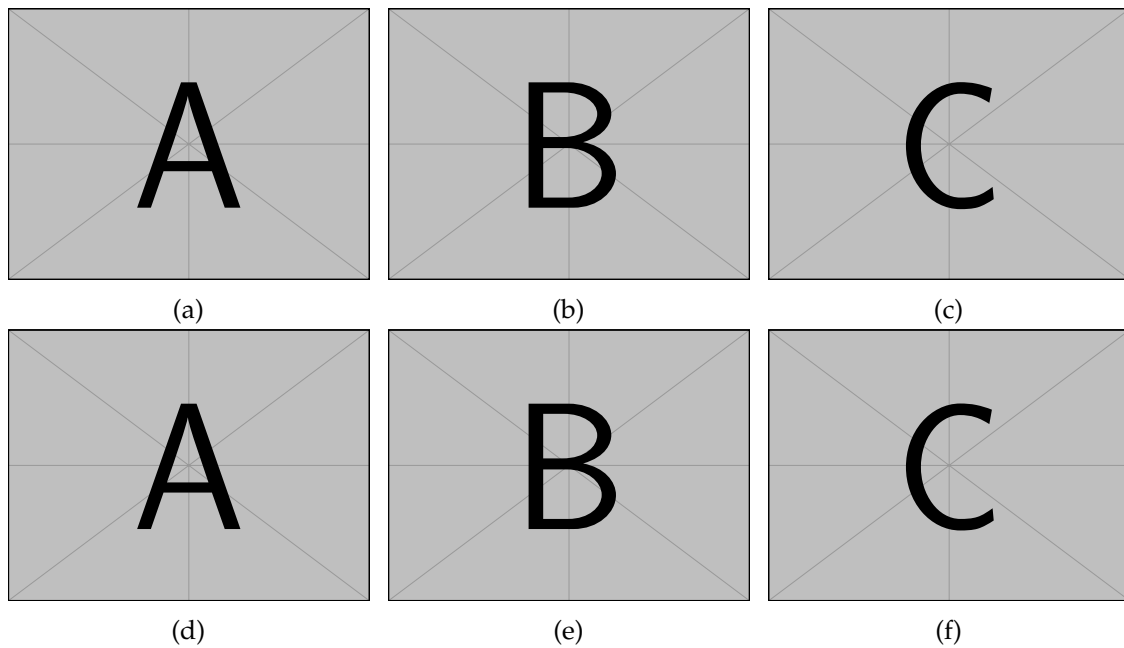


Figure 2.14: This image contains six subfigures. ...((a)-(c)) ... (a). ... (b), ... (c). ((d)-(f)), ... (d), ... (e). ... (f). Example image ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

Etiam vel ipsum. Morbi facilisis vestibulum nisl. Praesent cursus laoreet felis. Integer adipiscing pretium orci. Nulla facilisi. Quisque posuere bibendum purus. Nulla quam mauris, cursus eget, convallis ac, molestie non, enim. Aliquam congue. Quisque sagittis nonummy sapien. Proin molestie sem vitae urna. Maecenas lorem. Vivamus viverra consequat enim.

Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum.

Donec a nibh ut elit vestibulum tristique. Integer at pede. Cras volutpat varius magna. Phasellus eu wisi. Praesent risus justo, lobortis eget, scelerisque ac, aliquet in, dolor. Proin id leo. Nunc iaculis, mi vitae accumsan commodo, neque sem lacinia nulla, quis vestibulum justo sem in eros. Quisque sed massa. Morbi lectus ipsum, vulputate a, mollis ut, accumsan placerat, tellus. Nullam in wisi. Vivamus eu ligula a nunc accumsan congue. Suspendisse ac libero. Aliquam erat volutpat. Donec augue. Nunc venenatis fringilla nibh. Fusce accumsan pulvinar justo. Nullam semper, dui ut dignissim auctor, orci libero fringilla massa, blandit pulvinar pede tortor id magna. Nunc adipiscing justo sed velit tincidunt fermentum.

The \LaTeX code used to create [Figure 2.14](#) is in [Script 6](#).

```

</>      Script 6: ...  $\LaTeX$  to display a figure with two side-by-side images.      </>
1  %-----%
2  \afterpage{
3  \begin{figure}[p]
4      \centering
5      \begin{subfigure}[b]{0.33\textwidth}
6          % A
7          \centering
8          \includegraphics[width=.95\linewidth]
9          {example-image-a} % File path to graphics
10         \subcaption{\label{fig:A}}
11     \end{subfigure}%

```

```

12 \begin{subfigure}[b]{0.33\textwidth}
13   % B
14   \centering
15   \includegraphics[width=.95\linewidth]
16   {example-image-b} % File path to graphics
17   \subcaption{\label{fig:B}}
18 \end{subfigure}%
19 \begin{subfigure}[b]{0.33\textwidth}
20   % C
21   \centering
22   \includegraphics[width=.95\linewidth]
23   {example-image-c} % File path to graphics
24   \subcaption{\label{fig:C}}
25 \end{subfigure}% \
26
27 \begin{subfigure}[b]{0.33\textwidth}
28   % D
29   \centering
30   \includegraphics[width=.95\linewidth]
31   {example-image-a} % File path to graphics
32   \subcaption{\label{fig:D}}
33 \end{subfigure}%
34 \begin{subfigure}[b]{0.33\textwidth}
35   % E
36   \centering
37   \includegraphics[width=.95\linewidth]
38   {example-image-b} % File path to graphics
39   \subcaption{\label{fig:E}}
40 \end{subfigure}%
41 \begin{subfigure}[b]{0.33\textwidth}
42   % F
43   \centering
44   \includegraphics[width=.95\linewidth]
45   {example-image-c} % File path to graphics
46   \subcaption{\label{fig:F}}
47 \end{subfigure}%
48 \caption{This image contains six subfigures. \ldots
49 (\subref{fig:A}-\subref{fig:C}) \ldots \subref{fig:A}. \dots
50 \subref{fig:B}, \ldots \subref{fig:C}. \ldots. \ldots
51 (\subref{fig:D}-\subref{fig:F}), \dots \subref{fig:D}, \ldots
52 \subref{fig:E}. \ldots \subref{fig:F}. Example image \ldots
53 \lipsum[75]}
54 \label{fig:ABCDEF}
55 \end{figure}
56 \clearpage}
57 %-----%

```

2.7 Discussion

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed

a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices

posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi. [4]–[13]

2.8 Conclusion

Aliquam tortor. Morbi ipsum massa, imperdiet non, consectetur vel, feugiat vel, lorem. Quisque eget lorem nec elit malesuada vestibulum. Quisque sollicitudin ipsum vel sem. Nulla enim. Proin nonummy felis vitae felis. Nullam pellentesque. Duis rutrum feugiat felis. Mauris vel pede sed libero tincidunt mollis. Phasellus sed urna rhoncus diam euismod bibendum. Phasellus sed nisl. Integer condimentum justo id orci iaculis varius. Quisque et lacus. Phasellus elementum, justo at dignissim auctor, wisi odio lobortis arcu, sed sollicitudin felis felis eu neque. Praesent at lacus.

Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

2.9 Acknowledgment

Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum.

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CHAPTER 3

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Changes in Vitreoretinal Adhesion With Age and Region in Human and Sheep Eyes

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While several studies have qualitatively investigated age- and region-dependent adhesion between the vitreous and retina, no studies have directly measured the vitreoretinal strength of adhesion. In this study, we developed a rotational peel device and associated methodology to measure the maximum and steady-state peel forces between the vitreous and the retina. Vitreoretinal adhesion in the equator and posterior pole were measured in human eyes from donors ranging 30 to 79 years of age, and in sheep eyes from premature, neonatal, young lamb, and young adult sheep. In human eyes, maximum peel force in the equator (7.24 ± 4.13 mN) was greater than in the posterior pole (4.08 ± 2.03 mN). This trend was especially evident for younger eyes from donors 30 to 39 years of age. After 60 years of age, there was a significant decrease in the maximum equatorial (4.69 ± 2.52 mN, $p = 0.016$) and posterior pole adhesion (2.95 ± 1.25 mN, $p = 0.037$). In immature sheep eyes, maximum adhesion was 7.60 ± 3.06 mN, and did not significantly differ between the equator and posterior pole until young adulthood. At this age, the maximum adhesion in the equator nearly doubled (16.67 ± 7.45 mN) that of the posterior pole, similar to the young adult human eyes. Light microscopy images suggest more disruption of the inner limiting membrane (ILM) in immature sheep eyes compared to adult sheep eyes. Interestingly, in human eyes, ILM disruption was significantly greater in the posterior pole ($p < 0.05$) and in people over 60 years of age ($p < 0.02$). These findings supplement the current discussion surrounding age-related posterior vitreous detachment, and the risk factors and physiological progressions associated with this condition. In addition, these data further our understanding of the biomechanical mechanisms of vitreoretinal adhesion, and can be used to develop age-appropriate computational models simulating retinal detachment, hemorrhaging, or retinal trauma.

Keywords: peel, vitreous, retina, inner limiting membrane, posterior vitreous detachment, retinal detachment

INTRODUCTION

Any disruption to the layers of the retina, particularly the separation of the photosensitive cells from the retinal pigment epithelium, can result in blindness or severe visual impairment. The most common cause of disruption is retinal detachment. Retinal detachment occurs in one of every 10,000 people (Mitry et al., 2010) and does not discriminate between children and adults (Rosner et al., 1987; Fivgas and Capone, 2001). Ocular trauma and age-related vitreous degradation are

common causes of detachment, and the principal mechanism for each of these etiologies is retinal force mediated by adhesion to the vitreous.

Little is quantitatively known about adhesion at the vitreoretinal interface. Sebag (1991) manually peeled the posterior vitreous from the retina in 59 post-mortem eyes from donors with ages spanning 33 weeks gestation to 100 years old. They reported that peeling was “more difficult” in younger ages (20 years old or younger). Additionally, they report disruption of the Müller cells after peeling in 40% of the younger eyes, suggesting vitreoretinal adhesion in the younger group was stronger than adhesion between individual layers of the retina. This study provides evidence for changes in adhesion with age. It also correlates with theories that suggest vitreoretinal adhesion is a function of collagen density and structural integrity (Sebag, 1992; Fivgas and Capone, 2001; Gandorfer et al., 2001, 2002; Bishop et al., 2004; Ponsioen et al., 2008; Mitry et al., 2010). The amount of vitreal collagen present at birth does not change throughout life, so the relative density of collagen in the eye decreases as the eye grows (Balazs and Denlinger, 1982), and degrades with time (Bishop et al., 2004). If adhesion is dependent on collagen density and structure, the decrease and weakening of collagen with age would alter and diminish adhesion at the vitreoretinal interface.

Vitreoretinal adhesion has qualitatively been shown to vary with region. Gandorfer et al. (2001) injected plasmin into the vitreous of 24 porcine eyes and evaluated the vitreoretinal interface using scanning and transmission electron microscopy. Greater dosages and incubation times were required to eliminate and/or separate collagen fibrils on the inner limiting membrane (ILM) of the equator compared to the posterior pole. None of the dosages evaluated were able to completely separate the vitreous cortex from the ILM at the vitreous base. This suggests that vitreoretinal adhesion increases from the posterior pole to the equator to the vitreous base. The exact mechanism of adhesion is not well-established and may be different in the vitreous base compared to the equator or the posterior pole. It is possible the plasmin used in the Gandorfer study was more successful in detaching the vitreous from the retina in the equator and/or posterior pole because of regional adhesion mechanisms rather than adhesive strength.

No studies to date have directly measured adhesive forces at the vitreoretinal interface, but there are several studies that quantified retinal separation at the pigment epithelium (RPE). The earliest series of studies were by Zauberman and deGuillebon (Zauberman and Berman, 1969; DeGuillebon et al., 1971; DeGuillebon and Zauberman, 1972; Zauberman, 1972) in monkey, cat, and rabbit eyes. Both groups excised rectangular specimens from the eye containing retina, choroid, and sclera. The specimens were laid flat in a saline-filled petri dish. A metallic rod was attached to the ILM of the retina and pulled either manually (Zauberman and Berman, 1969), or with a computer-controlled linear actuator (Zauberman, 1972). The adhesive forces between the RPE and choroid were higher in the equator compared to the posterior region (Zauberman and Berman, 1969), and this regional dependence was reported to be greater in younger rabbits (1–2 months old) compared to adult rabbits (DeGuillebon et al., 1971). Additional experiments

report significantly increased RPE adhesion with peel rate (DeGuillebon et al., 1972) and significantly decreased adhesion with post-mortem time (Zauberman and DeGuillebon, 1972). A subsequent study by Endo et al. (1988), however, reported that refrigeration of enucleated eyes delayed deterioration up to at least 18 h.

The limitation of these peel studies is the potential disruption of the interface between the RPE and choroid prior to testing. Sandwich specimens were physically removed from the spherical eye and laid flat for testing. The excision likely damages structures at the cut interface, and straightening the sample likely causes shear forces between the layers which may compromise the interface. To overcome these limitations, Kita et al. (1990) used a bleb technique to estimate adhesion at the RPE. Briefly, a balanced salt solution was slowly injected into the subretinal space to generate retinal separation and a fluid-filled bleb. The choroidal retinal adhesive force was estimated from measured pressure differences between the vitreous and the fluid-filled subretinal space. The accuracy of these calculations is based on the assumption that the fluid-filled bleb is spherical. Previous bleb studies have reported that subretinal injections typically result in blebs with flattened rather than spherical tops (Marmor et al., 1980). The error this may cause in adhesion force estimations is unknown.

The objective of our study was to quantify vitreoretinal adhesive forces in sheep and human eyes, and evaluate how measurements change with age and region of the eye. To achieve this objective, an innovative testing device was created to overcome many of the limitations of the previous retinal adhesion methods. This device allows the retina to be peeled from the vitreous without altering the curvature of the specimens, or requiring dissection of the retina. Using this technique, quantitative vitreoretinal adhesive forces can be directly measured. These forces will be necessary to understand the biomechanics of vitreoretinal adhesion and create numerical tools for predicting retinal detachment.

METHODS

Materials

The adhesive strength between the vitreous and retina was measured in sheep ($n = 43$) and human ($n = 17$) eyes. Sheep eyes were used to investigate differences in adhesion between immature and mature eyes. Sheep eyes were selected because they have a well-defined retinal structure and holangiotic vasculature, and their vitreous composition is similar to human eyes (Balazs and Denlinger, 1982; Sebag, 1993; Ponsioen et al., 2010). Of the sheep eyes, four age groups were compared: adult ($n = 15$, 4–6 years old), young lamb ($n = 10$, 18 weeks old), neonatal ($n = 5$, 1–5 days old), and premature ($n = 13$, 128–136 days gestational age). There are no known human age equivalents for sheep based on ocular anatomy. The young adult sheep used in this study have a human age equivalence of 28–36 years old based on reproductive maturity and life span (Lévy et al., 2017). The immature groups (young lamb, neonatal, and premature) do not have well-established age equivalencies. Sheep brain development peaks *in utero* at ~85 days gestation (Dobbing, 1974). Based on the brain development patterns, our premature and neonatal

groups are estimated to have human equivalent ages of 6–12 and 14–20 months old, respectively. The young lamb group is estimated to have a human equivalent age of a 5–7 years of age. This lamb age equivalency was estimated based on extrapolation of the early brain maturation data and reproductive maturity timelines.

Sheep eyes were removed immediately upon sacrifice and refrigerated *en bloc* in phosphate-buffered saline (PBS) until testing. Adult human eyes (30–80 years old) were purchased from the Utah Lions Eye Bank in PBS and refrigerated until time of testing. Left and right eyes for all sheep and human subjects were collected and tested within 24 h of death. All studies were reviewed by the University of Utah IRB and IACUC compliance boards and determined to be exempt from regulation.

Testing was performed in the equatorial and posterior pole regions for each eye. The order in which samples were tested (right/left, equator/posterior pole) was randomly selected. Extraocular tissue and the optic nerve were removed from the globe prior to all dissections. For equatorial peels, a cut through the sclera, leaving the choroid, retina, and vitreous intact, was made anteriorly from the small opening at the optic nerve head to the equatorial region, ending ~15 mm posterior to the cornea (Cut 1 in **Figure 1A**). A second cut was made perpendicular to the initial cut, and along the equatorial region of the eye, ~25 mm in length (Eq. Cut in **Figure 1A**). Third and fourth cuts were made to create an 8 × 25 mm rectangular window of choroid (**Figure 1B**). Forceps were used to carefully pull away the choroid and expose the underlying retinal pigment epithelium.

For posterior peels, an initial cut was made similar to the equatorial peels (Cut 1 in **Figure 1A**). A circumferential cut was made using forceps and dissection scissors around the globe along the posterior cut line (Pos. Cut in **Figure 1A**), and the posterior sclera was removed entirely from the globe. This provided better visualization and access to the retina in the posterior pole. The choroid was removed using forceps and dissection scissors. The posterior retinal testing region was always oriented at an angle to avoid the fovea (**Figure 1C**).

Peel Test Setup and Protocol

A peel test system was created to test vitreoretinal adhesion with minimal dissection and disruption to the vitreoretinal

interface. This was achieved by keeping the retina and vitreous in their natural configuration, and rotating the eye as the retina was peeled away from the vitreous. The prepared eye with a window of exposed retina was placed onto a flexible membrane (Dragon Skin, Smooth-On, Macungie, PA) molded to cup the eye (**Figure 2A**). The eye and membrane were loaded into a custom 3D-printed holder with a rectangular opening that lined up with the exposed retina. Air was pumped into the cavity beneath the flexible membrane to enforce a spherical shape at the vitreoretinal interface. Two different sizes of membranes and eye holders were designed. The large size (diameter = 30 mm) was used to hold adult and young lamb sheep eyes. The small size (diameter = 20 mm) was used for neonatal and preterm sheep and human eyes.

A plastic L-shaped tab was connected to an Instron Universal Testing Instrument (Model No. 5943, Instron, Norwood, MA) where load measurements were made with a 5 N uniaxial load cell (Model No. 2530-5N, Instron, Norwood, MA). A thin layer of cyanoacrylate adhesive was applied to the bottom surface of the tab (5.0 × 4.5 mm) and lowered until it was in contact with the retina (**Figure 2B**). The retina was scored on both sides of the tab as well as one end of the peel region to ensure a clean rectangular peel shape throughout the duration of the test. The tab was raised at a quasistatic rate of 0.02 mm/s in accordance with other previous peel test literature (DeGuillebon and Zauberman, 1972; Zauberman and DeGuillebon, 1972; ASTM, 2016). The eye holder rotated simultaneously using a pulley system connected to the Instron crosshead. This rotation was critical for maintaining a constant perpendicular angle of peel during testing. Tests lasted anywhere from 5 to 12 min depending on the length of the steady-state peel. A Logitech web cam (Logitech C920 HD Pro, Logitech, Newark, CA) recorded video of each peel test. Optical coherence tomography (Envisu R2200, Leica Microsystems, Wetzlar, Germany) imaging was used to verify the glue between the tab and the retina did not penetrate deep into the retina and affect adhesion measurements (**Figure 2C**).

Following rotational peel tests, 2 mm square sections of peeled retina not directly attached to the tab were removed to characterize damage to the vitreoretinal interface. Specimens were placed in a 1% buffered formaldehyde and 1.25%

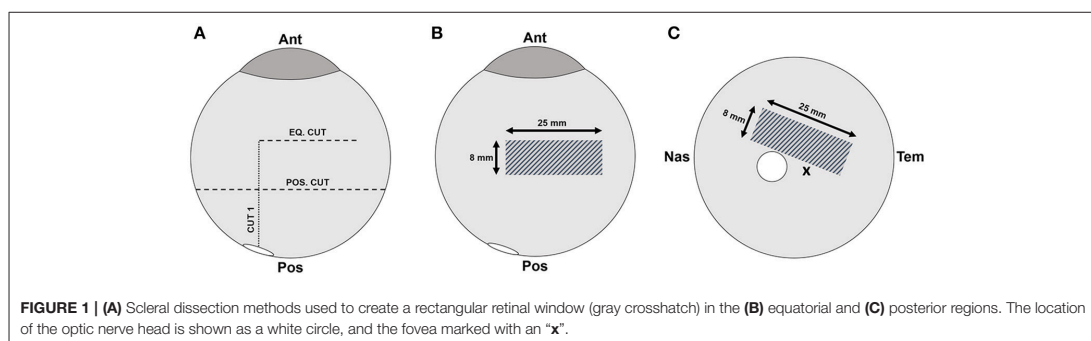
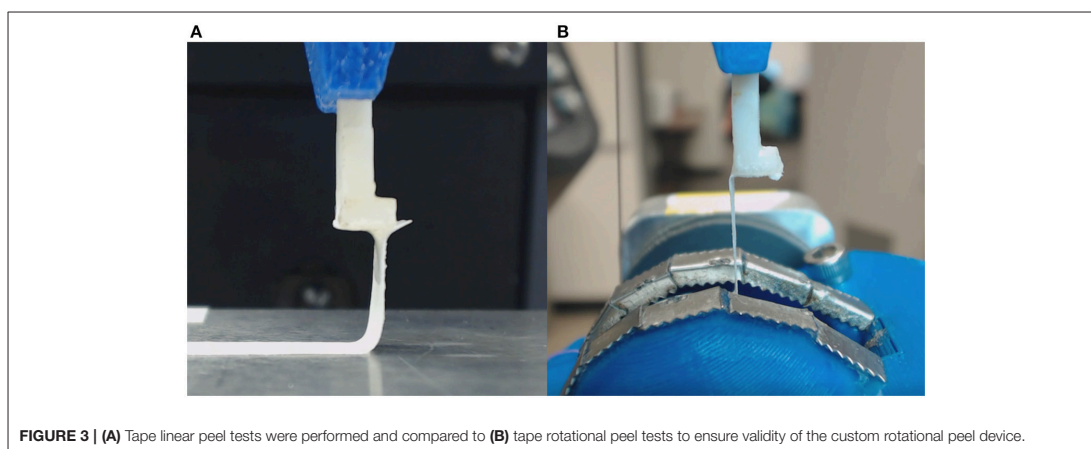
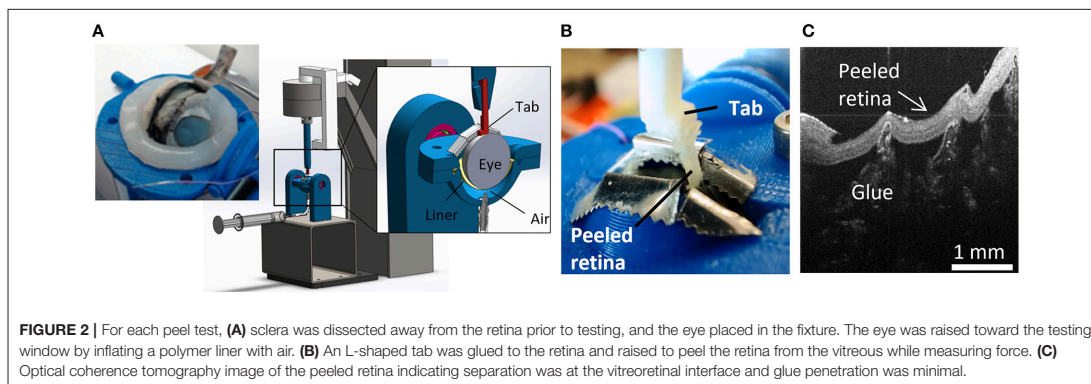


FIGURE 1 | (A) Scleral dissection methods used to create a rectangular retinal window (gray crosshatch) in the **(B)** equatorial and **(C)** posterior regions. The location of the optic nerve head is shown as a white circle, and the fovea marked with an "X".



glutaraldehyde solution for 24 h. For processing, samples were placed in a 0.1 M sodium cacodylate buffer rinse twice for 5 min while being agitated. Samples were then placed in a 1:1 mixture of diluted osmium tetroxide OsO_4 (4% in dH_2O) and 0.2 M sodium cacodylate buffer and agitated for 1 h. The samples were rinsed with DI water to remove excess osmium, and then placed in a 4% uranyl acetate solution, and agitated for 1 h. The samples were then dehydrated in increasing percentages of ethanol alcohol (50, 70, 95, and 100%) and then placed in acetone. Processed specimens were infiltrated using unpolymerized resin plastic and cured at an elevated temperature in an oven overnight. Specimens were cut to 0.5 μm thick slices, stained with toluidine blue, and imaged on an upright microscope (Olympus CX41, Olympus, Center Valley, PA).

Peel Test Validation

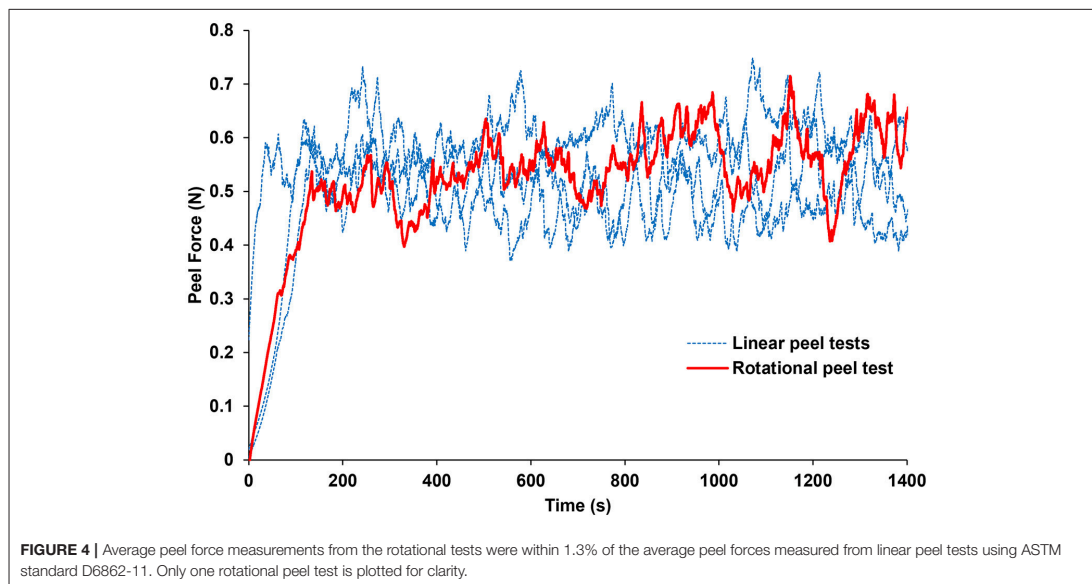
The novel rotational peel system was validated by measuring adhesion between metal and tape (Daigger, Vernon Hills, IL) and comparing measurements in the rotational system to measurements from linear peel testing using ASTM standard

D6862-11 (**Figure 3A**; ASTM, 2016). For the rotational test, tape was adhered to an aluminum ball bearing and placed inside the eye holder (**Figure 3B**). The tape was glued to the tab similar to the retinal experiments and followed the protocol described in section Peel Test Setup and Protocol. The linear peel test setup was identical to the rotational test, however it differed by adhering the tape to a flat aluminum surface (**Figure 3A**). After gluing the tab to the tape, the aluminum plate was horizontally actuated as the tab moved upward to maintain a 90° peel angle. The adhesive force over time for the rotational ($n = 6$) and linear ($n = 3$) peel tests were compared.

Data Analysis

In any peel test, a maximum force is required to initiate a peel, and a steady-state peel force maintains the peel. In this study, these attributes were extracted through careful examination of videos of each peel test in conjunction with the force-time data.

The maximum peel force was defined as the maximum force measured prior to separation between the retina and the vitreous. The period of steady-state peel was defined as the time period



of relatively constant force after the vitreous separated from the retina, leaving vitreous in contact at the base of the peel. A video showing a typical peel test is provided as **Supplemental Data**. The steady-state peel force was calculated as the average force across the steady-state peel period. Retinal samples that detached from the L-shaped tab or tore before steady-state peeling were excluded from analysis.

A two-way ANOVA with repeated measures was performed to evaluate the effect of region and age on the maximum and steady-state peel force in the sheep eyes and human eyes. Repeated measures were used because regional data was collected from the same eyes. To perform this test in humans, donor ages were binned into the 4, 5, 6, 7, or 8th decade of life. Tukey-Kramer *post-hoc* tests were selected to evaluate pairwise comparisons within each effect. A linear regression was also performed in the human eyes to see if the maximum and steady-state peel force significantly decreased with age. The linear regression analysis was executed separately for each region (equator, posterior pole).

To identify significant differences in mechanisms of failure, the light microscopy images of the peeled retina were rated according to the following criteria: 0–ILM cleanly separated with no disruption or evidence of traction; 1–ILM cleanly separated, but ILM is undulated or there is evidence of traction on the ILM; 2–ILM cleanly separated, with the exception of 1–2 small localized disruptions (typically around vessels); 3–ILM torn and disrupted. A chi-square test was performed on these scores to identify significant differences between region and age. A logistic regression was also used to determine if the maximum and steady-state peel forces were predictive of failure type (i.e., 0, 1, 2, or 3).

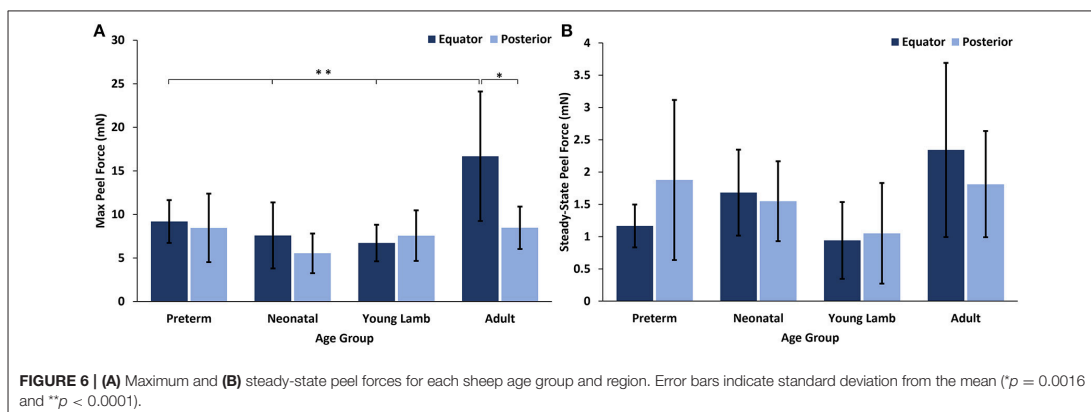
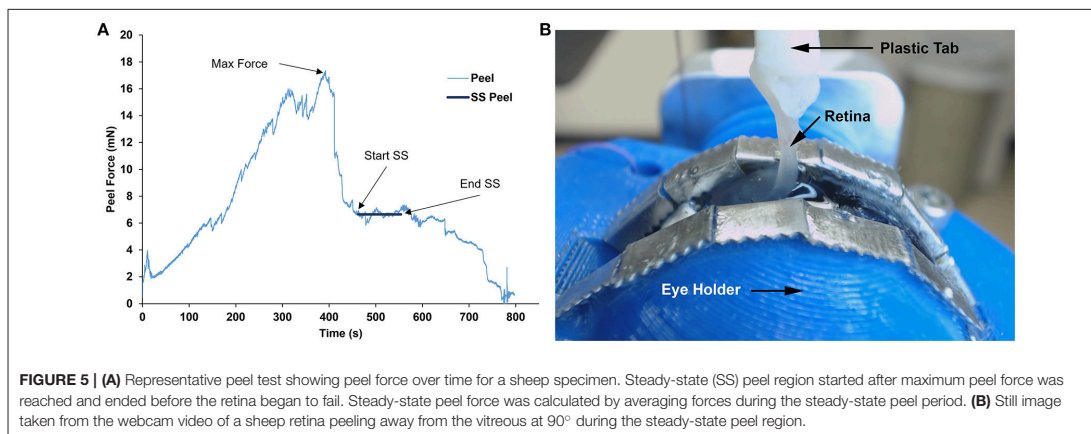
For all statistical tests, p -values < 0.05 were considered significant.

RESULTS

The forces measured from the linear and rotational tape peel tests did not exhibit a definitive peak force (**Figure 4**), so steady-state peel force was calculated as the average of the data after the initial ramp up period. The resulting linear and rotational steady-state peel forces were 0.534 ± 0.062 and 0.527 ± 0.075 N, respectively, validating the device and methodology. All human and sheep peel tests exhibited a distinct maximum peel force (**Figure 5A**) followed by a steady-state peel region (**Figure 5B**). Decreases in force after the steady-state period were due to defects in the retina causing it to prematurely tear, retinal thinning or stretching during particularly long peel tests, or manual cutting by the test observer to end the test.

Effect of Age and Region in Sheep Eyes

No significant differences with region were seen for either the max or steady-state peel force except for the adults which had significantly higher max peel force in the equatorial region (16.67 ± 8.46 mN) compared to the posterior region (8.46 ± 2.43 mN, $p = 0.0016$, **Figure 6**). Maximum peel force in the equator was also significantly higher in the adult compared to the younger ages (7.96 ± 2.81 mN, $p < 0.0001$). In most premature eyes, the steady-state adhesion in the posterior pole (1.88 ± 1.24 mN) was greater than the equator (1.12 ± 0.33 mN), but this finding was not statistically significant.



Effect of Age and Region in Human Eyes

At all ages, the maximum peel forces in the equator (7.16 ± 4.08 mN) were greater than those in the posterior pole (4.08 ± 2.03 mN, **Figure 7A**), but this regional difference was only significant in the youngest adult ages ($p < 0.03$). With age groups defined by decade of life, there was no significant difference in maximum adhesion in the equator or posterior pole with age. This finding was confirmed by the linear regression with age. However, when maximum peel force was plotted against age, there was a noticeable decrease in equatorial vitreoretinal adhesion after 60 years of age from 8.76 ± 4.22 to 4.50 ± 2.00 mN (**Figure 7B**). This decrease was found to be significant when evaluated with a Student's *t*-test ($p < 0.01$). Steady-state peel force was significantly affected by age ($p < 0.006$), region ($p < 0.0001$), and their interaction ($p < 0.001$). Specifically, vitreoretinal adhesion in the equator of the youngest adults (7.44 ± 2.34 mN, 30–39 years old) was significantly greater than the posterior pole in that age group (3.25 ± 1.27 mN, $p < 0.002$) and significantly greater than

the equatorial adhesion in the other age groups ($p < 0.015$, **Figure 8**).

Locations of Failure

Inspection of light microscopy images in the sheep revealed generally clean separation at the vitreoretinal interface (**Figure 9A**). Occasional disruption or failure of the ILM was observed (**Figure 9B**), especially in the presence of blood vessels (**Figure 9C**) and in immature eyes (i.e., premature, neonatal, and young lamb). Retinal stretching without ILM disruption was often seen in the nerve fiber layer, ganglion cell layer, or the outer plexiform layer. These observations were not different between the equator and posterior pole. In the human eyes, large disruption of the ILM occurred in the posterior pole (**Figure 9D**), and was significantly different than the failure location in the equator ($p < 0.05$) which exhibited a clean separation (**Figure 9E**), oftentimes with indication of tractional pulling (**Figure 9F**). ILM disruption in the posterior pole was significantly greater in eyes from donors > 60 years of

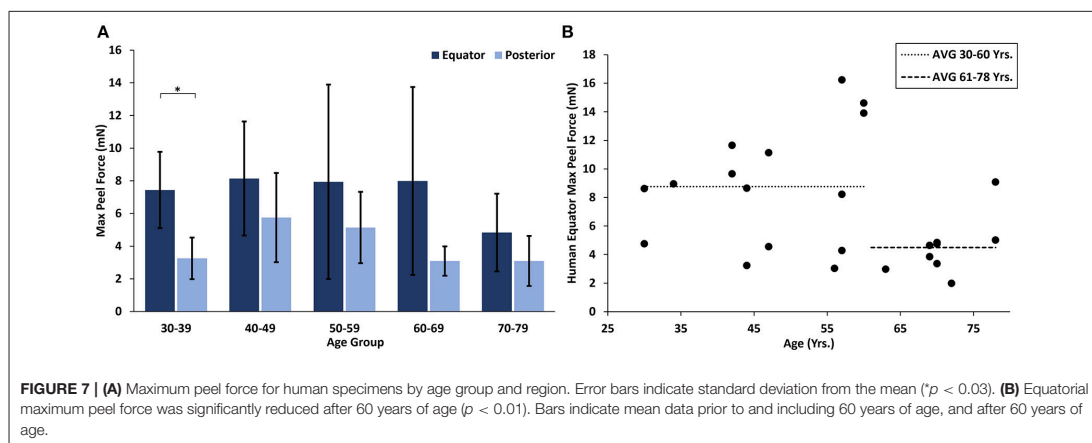


FIGURE 7 | (A) Maximum peel force for human specimens by age group and region. Error bars indicate standard deviation from the mean ($p < 0.03$). **(B)** Equatorial maximum peel force was significantly reduced after 60 years of age ($p < 0.01$). Bars indicate mean data prior to and including 60 years of age, and after 60 years of age.

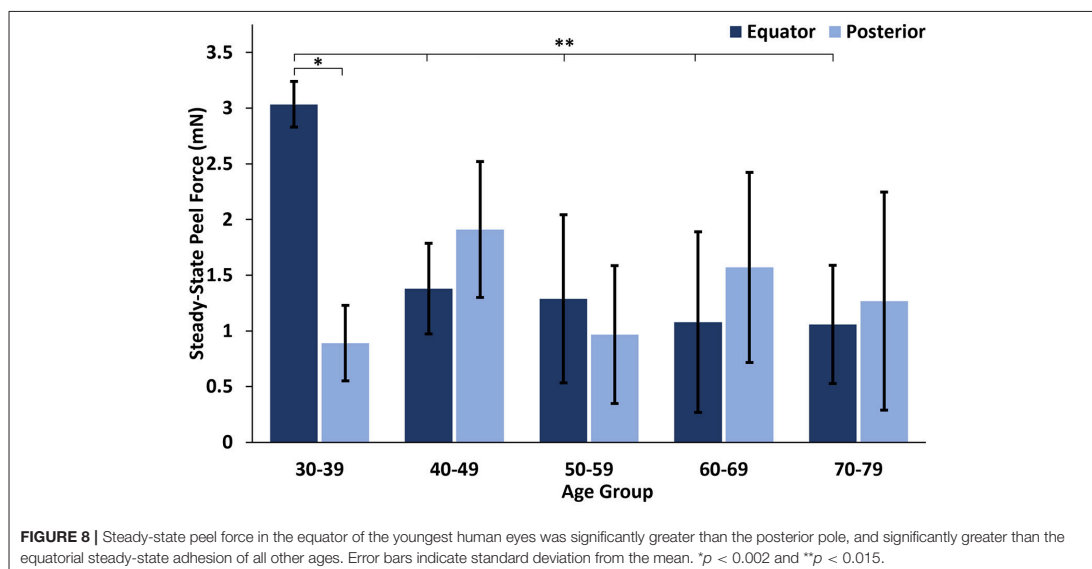


FIGURE 8 | Steady-state peel force in the equator of the youngest human eyes was significantly greater than the posterior pole, and significantly greater than the equatorial steady-state adhesion of all other ages. Error bars indicate standard deviation from the mean. $*p < 0.002$ and $**p < 0.015$.

age ($p < 0.02$). No significant differences in failure location were found with gender, and ILM disruption was not predicted by the maximum or steady-state peel forces.

DISCUSSION

In this study, we developed a novel rotational peel test system to measure the strength of adhesion at the vitreoretinal interface. We used the device to quantify age- and region-dependent vitreoretinal adhesion in human and sheep eyes. These data are critical to improving biomechanical understanding of the vitreoretinal interface. They can be implemented

into computational models to investigate posterior vitreous detachment, or to simulate traumatic ocular injury. Further, the peel test system and associated data can be used to evaluate the effectiveness of chemical compounds to assist in surgical separation of the retina and vitreous.

In both sheep and human eyes, there was an interesting distinction between the maximum force of vitreoretinal adhesion in the equator and posterior pole that was highly dependent on the maturity of the animal. In premature, neonatal, and young lamb eyes, there were no regional differences. By the time the sheep developed into young adults (~28–36 years human age equivalent), the equatorial vitreoretinal adhesion significantly increased while adhesion in the posterior pole

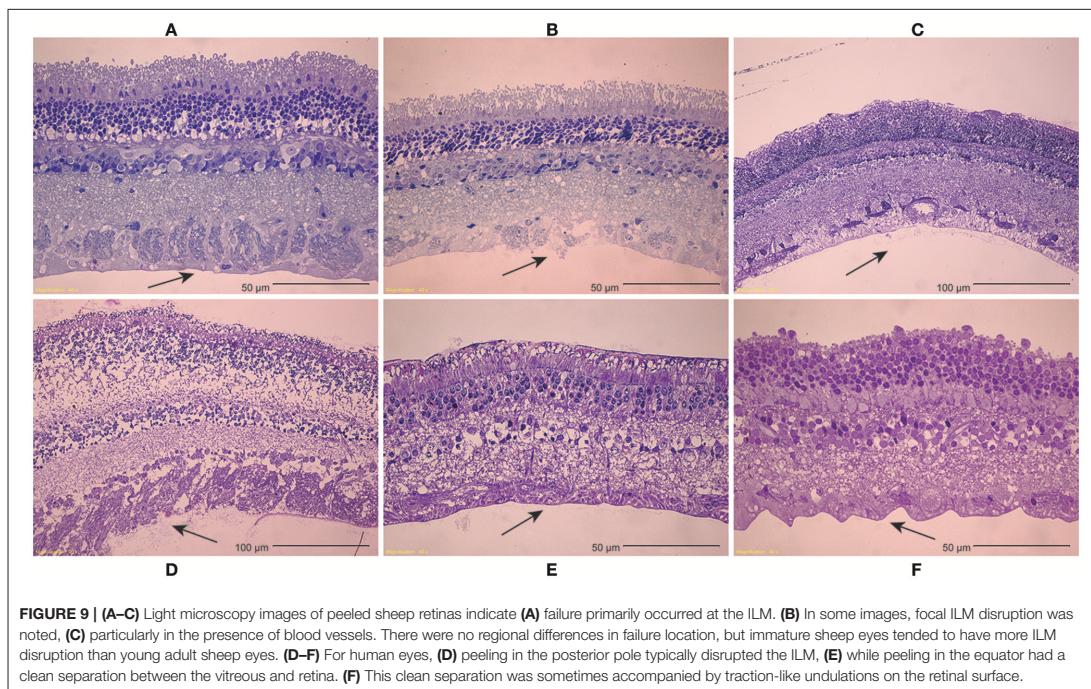


FIGURE 9 | (A–C) Light microscopy images of peeled sheep retinas indicate **(A)** failure primarily occurred at the ILM. **(B)** In some images, focal ILM disruption was noted, **(C)** particularly in the presence of blood vessels. There were no regional differences in failure location, but immature sheep eyes tended to have more ILM disruption than young adult sheep eyes. **(D–F)** For human eyes, **(D)** peeling in the posterior pole typically disrupted the ILM, **(E)** while peeling in the equator had a clean separation between the vitreous and retina. **(F)** This clean separation was sometimes accompanied by traction-like undulations on the retinal surface.

remained unchanged from the immature sheep eyes. This may be due to posterior extension of the vitreous base and ILM thickening with age. Wang et al. investigated the anteroposterior length of the vitreous base in 58 pairs of human eyes from subjects spanning ages of 8–96 years old (Wang et al., 2003). They report a continual posterior extension of the length of the vitreous base until ~80 years old, at which time the length decreases. A similar study has not been performed in sheep, but a posterior extension of the vitreous base with age would explain the increased equatorial adhesion in the adult sheep eyes compared to immature sheep eyes.

Similar to the sheep eyes, the maximum peel force in the equator of the human eyes was greater than in the posterior pole. This was only significant in the youngest age group (30–39 years old), but all binned age groups younger than 70 years of age had higher average adhesion in the equator than in the posterior pole. One interesting finding from our dataset was a significant decrease in equatorial maximum peel force in eyes from human subjects > 60 years of age (Figure 7B). This suggests the existence of age-related changes that reduce equatorial adhesion, and overshadow any increased adhesion due to vitreous base extension. The distinct drop-off in equatorial max peel force around 60 years of age corresponds with the timeline of vitreous liquefaction (Fos, 1972; Balazs and Denlinger, 1982; Sebag, 1987, 1989; Uchino et al., 2001) and may be protective to the retina by facilitating posterior vitreous detachment (PVD) before retinal tearing or retinal detachment occurs. In PVD,

vitreoretinal separation is typically thought to begin near the macula and progress anteriorly (Kakehashi et al., 1997, 2014). As liquefaction occurs, increased traction is placed on the retina at locations of strong adhesion. The decreased equatorial adhesion after 60 years of age, a time when PVD is most prevalent, reduces the risk of retinal tearing or detachment in the equator. Further to this point, the steady-state peel force in our study was similar in both the posterior pole and the equator for all ages except the youngest age group (30–39 years old). This suggests that for most adults, PVD can gradually develop anteriorly into the equatorial region with minimal resistance and risk for retinal tearing. However, in young ages, there will be an increased risk for retinal tearing or detachment. This may explain why severe myopes, who have an increased disposition to liquefaction at young ages, have an increased risk for retinal detachment (Akiba, 1993).

Our study is the first quantitative measurement of vitreoretinal adhesion, but other groups have qualitatively evaluated adhesion at the vitreoretinal interface (Sebag, 1992; Marmor et al., 1994; Gandorfer et al., 2001). Their observations of changes in adhesion with age or region correlate with our findings. Sebag (1992) microscopically examined vitreoretinal adhesion in the posterior pole in human eyes from donors aged from 33 weeks of gestation to 94 years. He reported disruption to Müller's cells during peeling in 6 of the 15 eyes from donors < 20 years old, suggesting young adults and children have stronger posterior pole adhesion than older adults. In sheep eyes,

we found no significant difference in posterior pole adhesion between immature and adult sheep. The young adult sheep in our study correspond to 26–38 years old for humans. We visually observed minimal to no vitreous liquefaction during dissection of the eyes, similar to the visually observed levels of liquefaction in our youngest group of human eyes (30–39 years old). If we had used older adult sheep, we may have seen distinctions in the posterior pole adhesion similar to Sebag.

Microscopic examination of peeled sheep retinas suggested generally clean separation at the ILM, regardless of age or region. Occasionally, the ILM was torn in immature eyes, regardless of region. In adult sheep, the ILM was never torn, but the nerve fiber layer was often stretched and occasionally disrupted locally around blood vessels. There was a single premature specimen with failure occurring in the ganglion cell layer, which is similar to Sebag. We obtained light microscopy specimens from 37% of our sheep peel tests. A more extensive microscopic analysis might correlate more closely with observations by Sebag.

In human adult peeled retinas, there was significant distinction between failure in the equator and posterior pole. The peeled retina in the equator was generally smooth with some undulation or traction-like peaks on the surface of the ILM, while many of the posterior peeled retinas exhibited complete disruption of the ILM. This was surprising given that adhesion in the posterior pole is significantly lower than the equator. We hypothesize that numerous collagen penetrations in the posterior pole create large disruptions of the ILM when pulled, and that there is less collagen penetration in the equator where adhesion is thought to be dominated by adhesive proteins acting as an extracellular glue. Failure of this “glue” would result in cleaner separation. The traction-like characteristics may be caused by sparse penetration of collagen fibrils. Interestingly, ILM disruption in the posterior pole was significantly greater in eyes from donors older than 60 years of age. Because the adhesive strength is weak at this age, we hypothesize that the disruption of the ILM is an indication of decreased retinal structural integrity. Regardless, these data show adhesive strength cannot be inferred solely from locations of damage. Mechanism of adhesion and changes in retinal structural integrity with age likely contribute to patterns of failure.

Gandorfer et al. evaluated the effect of plasmin in different regions of porcine eyes (Gandorfer et al., 2001). After the same dosage and incubation time (2 U/0.1 mL plasmin, 60 min), they report a bare ILM in the posterior pole, sparse collagen fibrils in the equator, and a dense network of collagen fibrils at the vitreous base. This may suggest that adhesion is greater anteriorly to posteriorly, but different mechanisms of adhesion may occur in different regions of the eye, and may be affected by plasmin differently. Plasmin is known to digest fibrin and laminin, which are more prominent in the posterior pole compared to the equator (Mitry et al., 2010). There is some indirect digestion of collagen, but the extent is unknown. Future clarification is still needed to elucidate the role of glycoproteins in adhesion of the vitreoretinal interface at the vitreous base, equator, and posterior pole.

Several studies have quantitatively measured adhesion between the neurosensory layer and retina pigment epithelium (RPE) (Zauberman and Berman, 1969; Lincoff et al., 1970; DeGuillebon et al., 1971, 1972; DeGuillebon and Zauberman, 1972; Zauberman, 1972; Zauberman and DeGuillebon, 1972; Zauberman et al., 1972; Owczarek et al., 1975; Kain, 1984). Similar to our results, these studies report significantly greater adhesion in the equator compared to the posterior pole. Zauberman and Berman (1969) reported 1.18–2.45 mN in the equator compared to 0.59–0.88 mN in the posterior pole in cats. DeGuillebon et al. (1971) reported 0.77–1.41 mN in the equator compared to 0.86–1.206 mN in the posterior pole in rabbits. One exception to this is a study by DeGuillebon et al. (1972) that found increasing peel rates increased RPE adhesion in the posterior pole compared to the equator. The rates used in the present study are quasistatic, and suitable for PVD investigations. Additional vitreoretinal adhesion studies at higher rates will need to be performed to understand region and age-related differences associated with ocular trauma.

Retinal detachment or tearing can occur due to vitreoretinal traction, so adhesion at the vitreoretinal interface is likely greater than adhesion at the RPE in healthy young adults. No studies have measured RPE adhesion in sheep or in humans, making comparison of our measurements with the literature challenging. Kita and Marmor (1992) used subretinal injections to calculate posterior RPE adhesion in young adult primates (3.8–7.9 kg). They report average adhesive forces of 140 ± 3 dynes/cm using a subretinal bleb technique. Without a reported bleb circumference, it is impossible to convert their measurements to mN and compare to our study. However, they state primate adhesive forces were 140% greater than that of rabbits, and an earlier study by the same group (Kita et al., 1990) reported 1.979 ± 0.22 mN (converted using reported bleb circumferences). This results in an approximate primate RPE adhesion of 2.771 ± 0.31 mN, and is 1.7 times lower than the average adhesion human eyes from donors 30–60 years of age in our study. Of note, the RPE adhesion measured in primates was only 10% lower than the maximum posterior peel force in our oldest age group (70–79 years old). None of the eyes we tested had PVD, so this oldest age group likely had greater vitreoretinal adhesion than those at risk for PVD.

In standard peel tests, a thin membrane is typically peeled from a solid surface. In these studies, we peeled a thin membrane (retina) from a gel (vitreous). This resulted in deformation of both materials prior to and during peeling. The maximum peel forces measured in this study were defined as the maximum force before clear separation of the vitreous from the retina. With this definition, the maximum peel force may incorporate some retinal stretching or separation from the scored retinal edges in addition to the peeling force. During steady-state peeling, the retina also experienced some deformation, however, careful examination of video in conjunction with the peel force data provided confidence that peeling, and not retinal deformation, was the primary contributor to the steady-state measurements. A computational simulation of the peel tests is planned for a future study to separate tissue adhesion and vitreous deformation in the maximum peel force measurements.

The data collected in this study was on the low end of the load cell limit. Because of this, we had the load cell carefully calibrated at its reported lower limit of 9 mN. The uncertainty measurement at this limit was 0.002 gf, or 0.0196 mN, and decreased with decreasing load. The maximum peel force data in our study ranged from 4 to 15 mN, which is near the lower limit of the load cell. The steady state peel forces were lower than the maximum peel forces (1–3 mN), but were still on the same order of magnitude as the calibrated limit, and still two orders of magnitude larger than the uncertainty measurements. It is possible the load cell limits contributed to the variability in the steady-state measurements, but we have strong confidence in the conclusions and trends of the study.

Vitreoretinal adhesion to large blood vessels is thought to be greater than adhesion in regions without blood vessels. Our observations of ILM tearing surrounding blood vessels support this notion. Further, we observed steady-state peel forces drop after passing a blood vessel. For this study, we extracted steady-state values from regions without the blood vessels in order to maintain a consistent comparison across all ages and regions. A comprehensive and focused assessment of the effect of blood vessels on adhesion will be performed in a future study.

CONCLUSION

We developed a novel device to quantify vitreoretinal adhesion in the equator and posterior pole of human and sheep eyes. Maximum vitreoretinal adhesion in adult human eyes (30–79 years old) was greater in the equator than in the posterior pole, especially at young ages (30–39 years old). After 60 years of age, there was a significant drop in equatorial adhesion that may be protective to the retina by facilitating vitreous detachment during liquefaction. In immature (premature, neonatal, and young lamb) and mature (young adult) sheep eyes, there was no significant difference in posterior vitreoretinal adhesion, but maximum equatorial adhesion in mature eyes was 2 times greater than immature eyes. This may be caused by the extension of the vitreous base during development. These data are the first quantitative measurements of vitreoretinal adhesion, and

will be useful in the development of computational models for simulating posterior vitreous detachment or ocular trauma. The methods and technology developed for this study can be used to evaluate mechanisms of adhesion, and assess the efficacy of enzymes to remove or reduce vitreoretinal adhesion for surgical interventions.

DATA AVAILABILITY

All data used in this manuscript is available via doi: 10.7278/S5BK19H3 located within the University of Utah Research Data Repository (<https://hive.utah.edu>).

AUTHOR CONTRIBUTIONS

CC performed testing, sectioning, preliminary analysis and manuscript writing. JC assisted with all aspects of the data analysis and manuscript writing. BC was responsible for the study conception and design, data interpretation, and manuscript editing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fbioe.2018.00153/full#supplementary-material>

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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3.8 PDF Import

Using the \LaTeX package `pdfpages`, you can import PDFs into your PDF. An example of this is used to import a previously published journal article in [Script 7](#). There are function keywords that allow you to add sections to the table of contents, list of figures, and the list of tables.

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13     1,section,1,Introduction,chp3I,
14     2,section,1,Methods,chp3M,
15     2,subsection,2,Materials,chp3M_1,
16     3,subsection,2,Peel Test Setup and Protocol,chp3M_2,
17     4,subsection,2,Peel Test Validation,chp3M_3,
18     4,subsection,2,Data Analysis,chp3M_4,
19     5,section,1,Results,chp3R,
20     5,subsection,2,Effect of Age and Region in Sheep Eyes,chp3R_1,
21     6,subsection,2,Effect of Age and Region in Human Eyes,chp3R_2,
22     6,subsection,2,Locations of Failure,chp3R_3,
23     7,section,1,Discussion,chp3D,
24     10,section,1,Conclusion,chp3C,
25     10,section,1,References,chp3Ref},
26 addtolist={
27     3,figure,{(A) Scleral dissection methods used to create a rectangular
28         retinal window (gray crosshatch) in the (B) equatorial and (C)
29         posterior regions. The location of the optic nerve head is shown as a
30         white circle, and the fovea marked with an ``x''},3fig1,
31     4,figure,{For each peel test, (A) sclera was dissected away from the
32         retina prior to testing, and the eye placed in the fixture. The eye was
33         raised toward the testing window by inflating a polymer liner with air.
34         (B) An L-shaped tab was glued to the retina and raised to peel the
35         retina from the vitreous while measuring force. (C) Optical coherence
36         tomography image of the peeled retina indicating separation was at the
37         vitreoretinal interface and glue penetration was minimal.},3fig2,
38     4,figure,{(A) Tape linear peel tests were performed and compared to (B)
39         tape rotational peel tests to ensure validity of the custom rotational
40         peel device.},3fig3,
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41 5,figure,{Average peel force measurements from the rotational tests were
42 within 1.3\% of the average peel forces measured from linear peel tests
43 using ASTM standard D6862-11. Only one rotational peel test is plotted
44 for clarity.},3fig4,
45 6,figure,{Representative peel test showing peel force over time for a
46 sheep specimen. Steady-state (SS) peel region started after maximum
47 peel force was reached and ended before the retina began to fail.
48 Steady-state peel force was calculated by averaging forces during the
49 steady-state peel period. (B) Still image taken from the webcam video
50 of a sheep retina peeling away from the vitreous at 90 $\circ$  during
51 the steady-state peel region.},3fig5,
52 6,figure,{(A) Maximum and (B) steady-state peel forces for each sheep age
53 group and region. Error bars indicate standard deviation from the mean
54 ( $p = 0.0016$  and  $p < 0.0001$ ).},3fig6,
55 7,figure,{(A) Maximum peel force for human specimens by age group and
56 region. Error bars indicate standard deviation from the mean ( $p <
57 0.03$ ). (B) Equatorial maximum peel force was significantly reduced
58 after 60 years of age ( $p < 0.01$ ). Bars indicate mean data prior to
59 and including 60 years of age, and after 60 years of age.},3fig7,
60 7,figure,{Steady-state peel force in the equator of the youngest human
61 eyes was significantly greater than the posterior pole, and
62 significantly greater than the equatorial steady-state adhesion of all
63 other ages. Error bars indicate standard deviation from the mean.  $p
64 < 0.002$  and  $p < 0.015$ .},3fig8,
65 8,figure,{(A-C) Light microscopy images of peeled sheep retinas indicate
66 (A) failure primarily occurred at the ILM. (B) In some images, focal
67 ILM disruption was noted, (C) particularly in the presence of blood
68 vessels. There were no regional differences in failure location, but
69 immature sheep eyes tended to have more ILM disruption than young adult
70 sheep eyes. (D-F) For human eyes, (D) peeling in the posterior pole
71 typically disrupted the ILM, (E) while peeling in the equator had a
72 clean separation between the vitreous and retina. (F) This clean
73 separation was sometimes accompanied by traction-like undulations on
74 the retinal surface.},3fig9},
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CHAPTER 4

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4.1 Abstract

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4.2 Introduction

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4.3 Methods

4.3.1 Subsection

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4.3.2 Subsection

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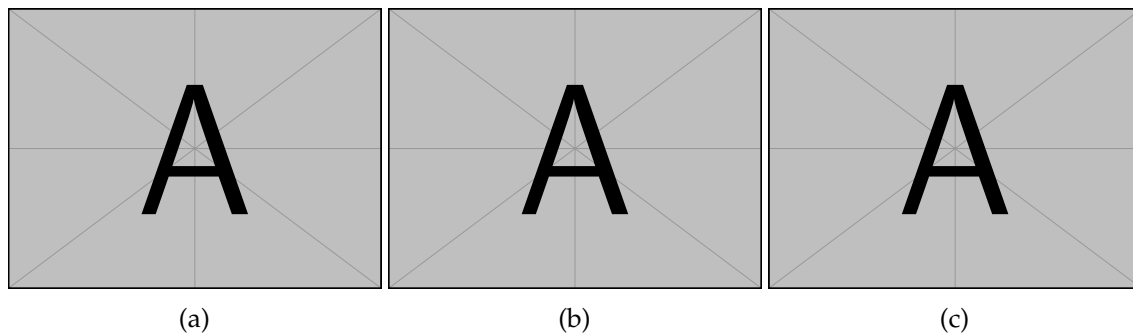


Figure 4.1: Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. ... (a) ... (b) ... (c) ...

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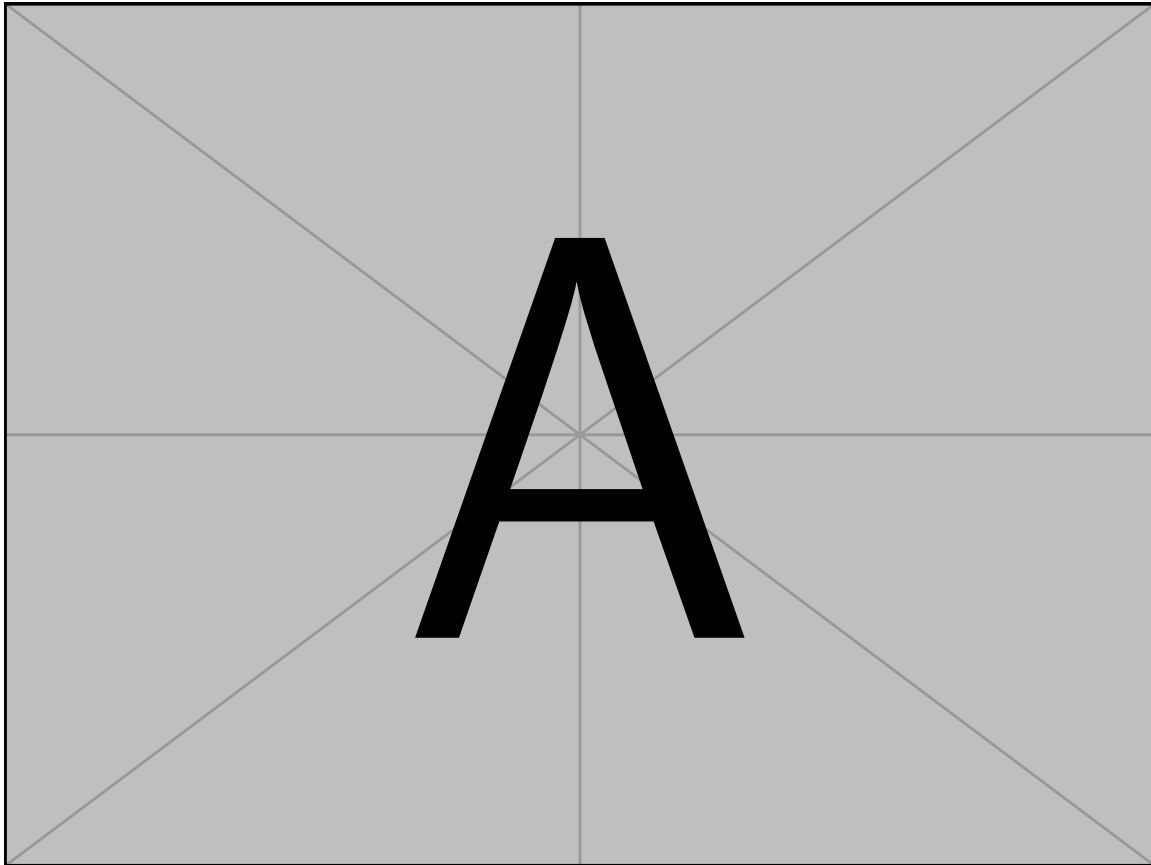
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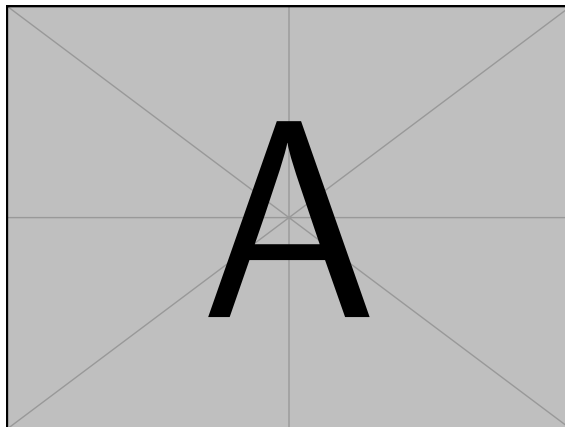
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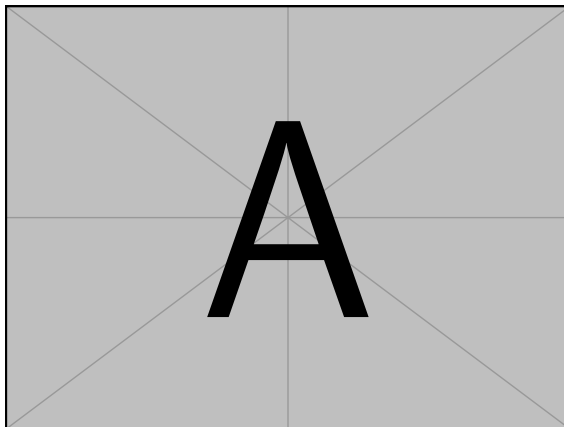
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(a)



(b)



(c)

Figure 4.2: Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. (a) ... (b) ... (c) ...

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4.3.2.1 Chemistry Formulations

For chemistry formulas use the following \LaTeX commands from the `chemfig` package:

An example is seen here:

```
\chemfig{OsO_4} (4\% in \emph{d}\chemfig{H_2O}) \longrightarrow OsO_4 (4\% in dH_2O)
```

4.3.3 Subsection

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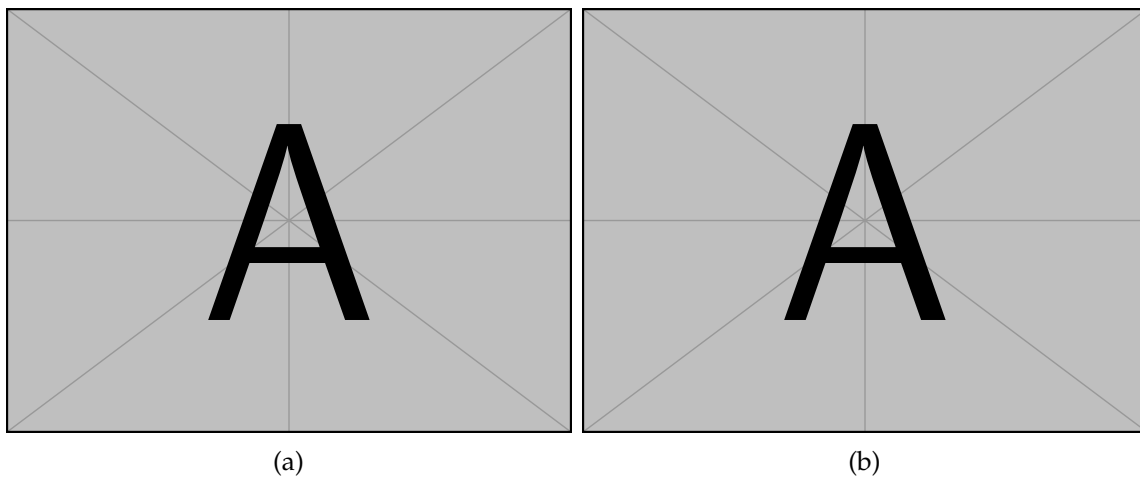


Figure 4.3: Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. (a) ... (b)

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4.3.4 Subsection

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4.4 Results

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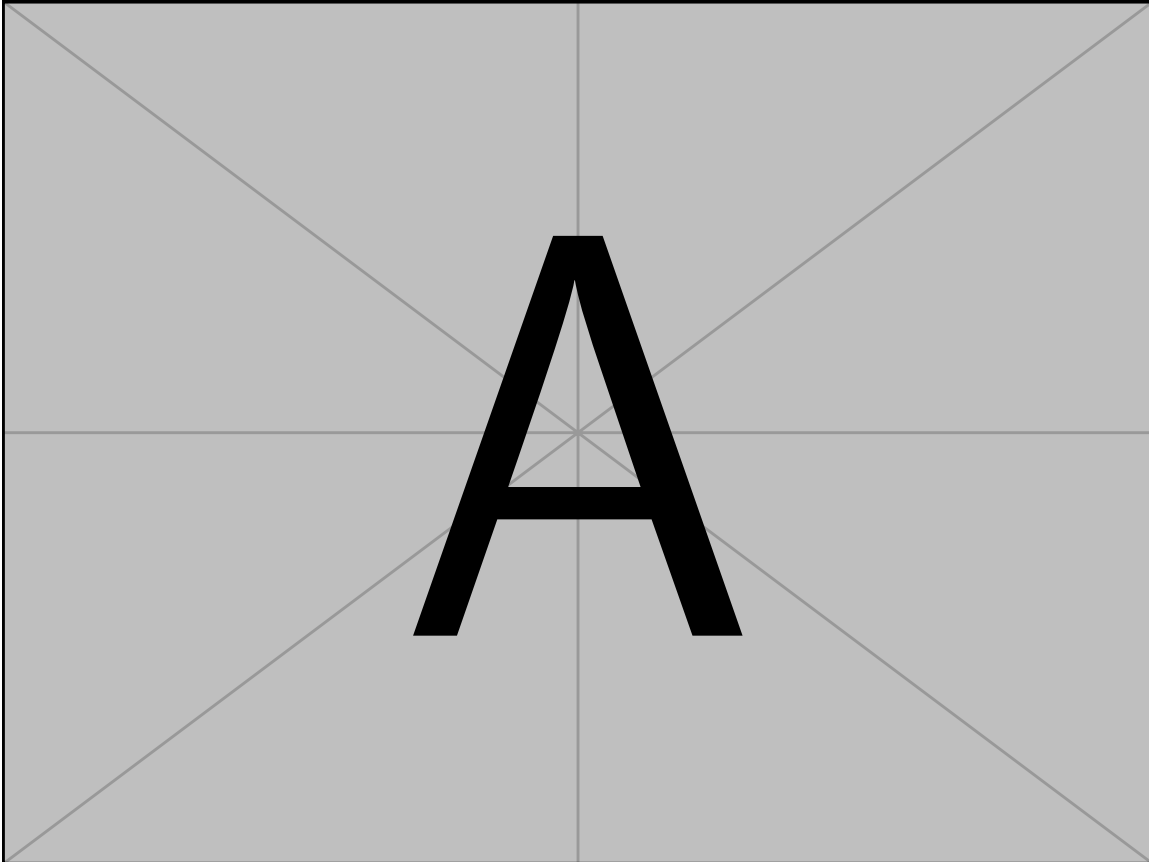


Figure 4.4: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

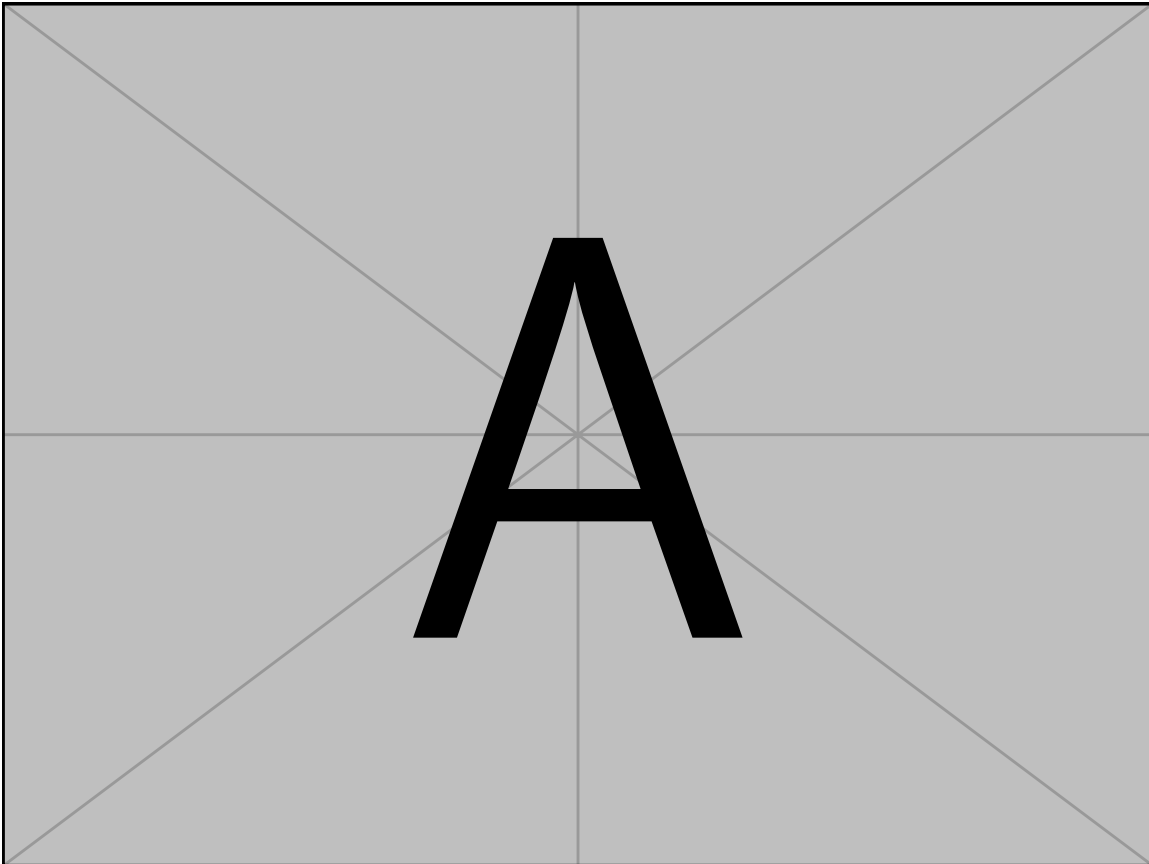


Figure 4.5: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

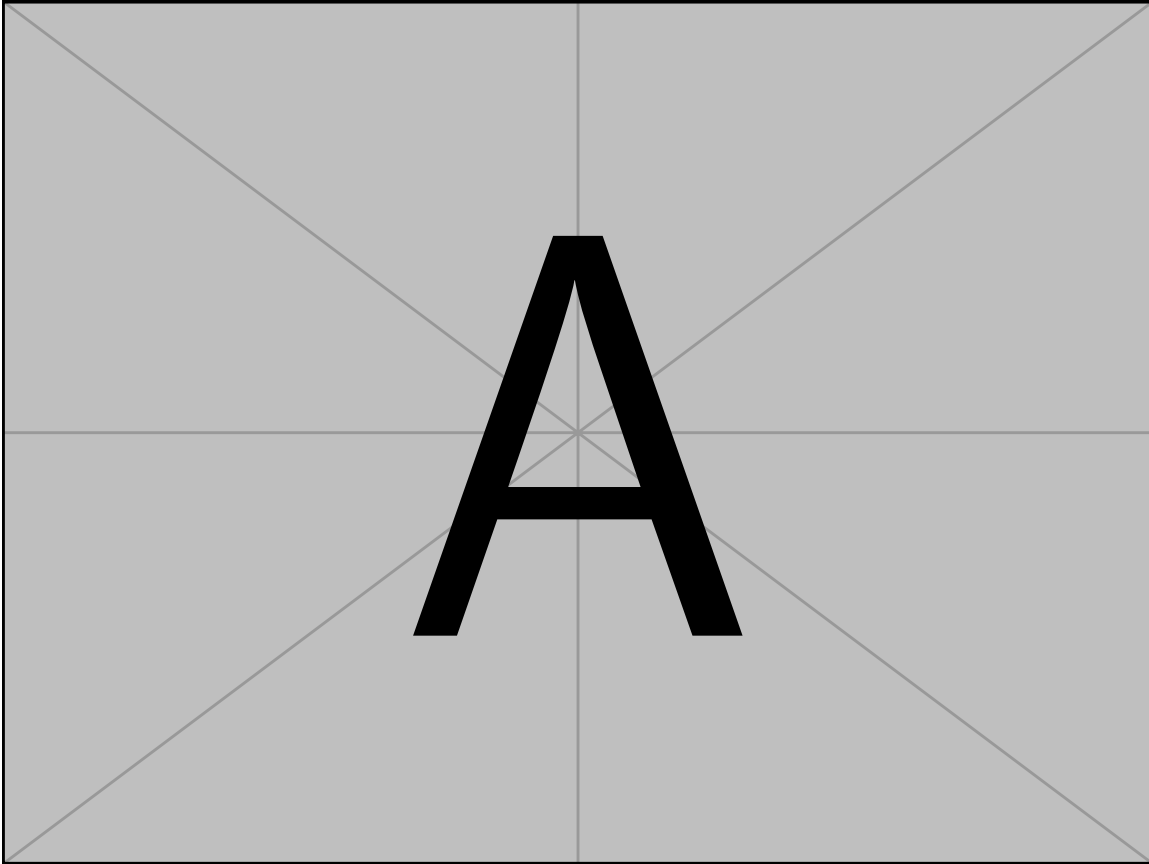


Figure 4.6: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

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4.4.1 Subsection

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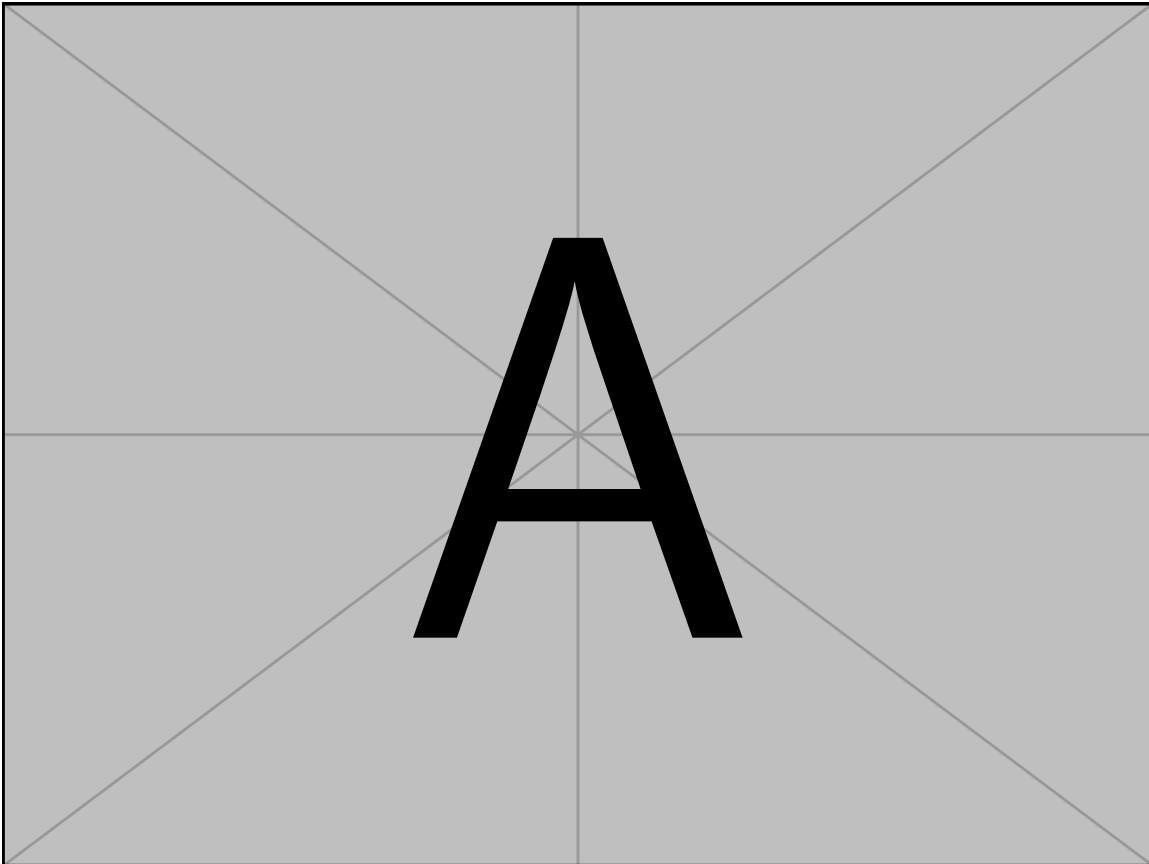


Figure 4.7: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

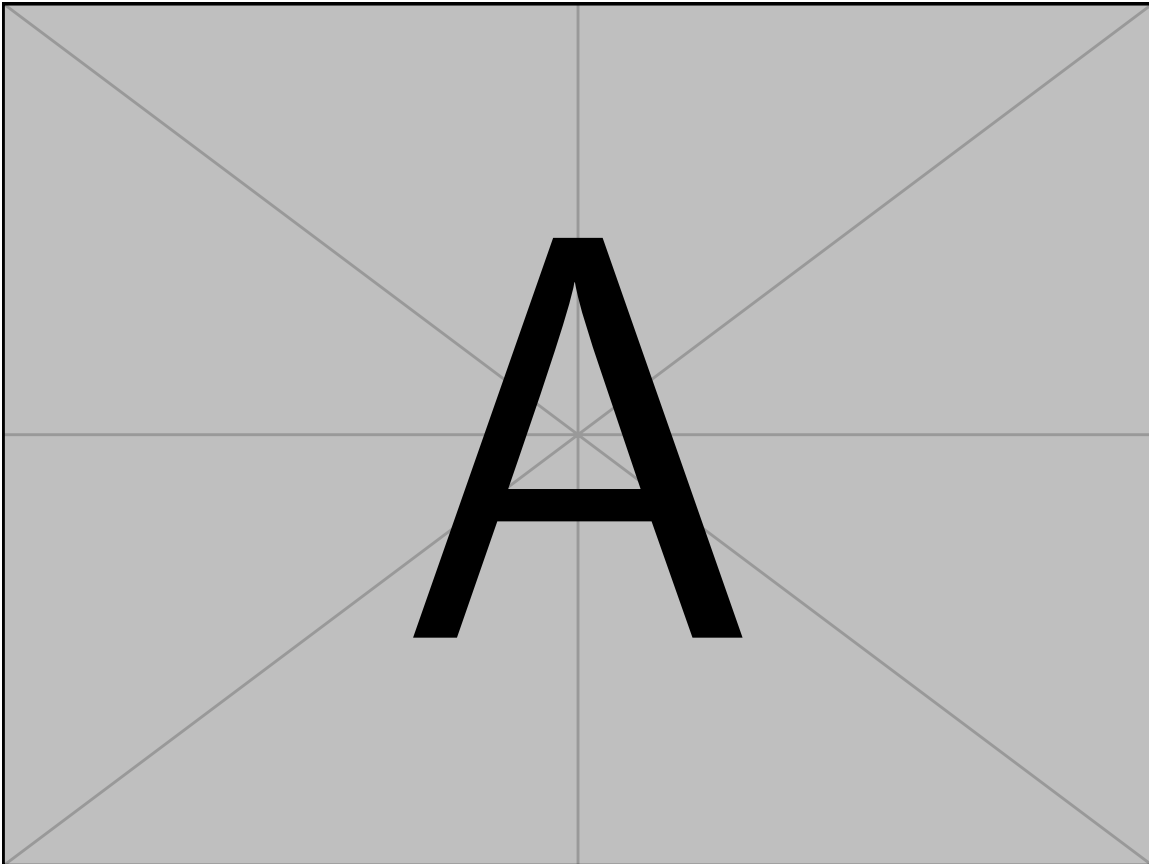


Figure 4.8: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

Table 4.1: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

xx	xx	xx	xx (mN)	xx (mN)	xx (mN)
xx	xx	12	9.185	9.372	2.459
	xx	11	8.566	9.721	3.959
xx	xx	6	7.579	7.415	3.797
	xx	9	5.463	4.550	2.311
xx	xx	10	6.712	6.290	2.102
	xx	11	7.558	7.829	2.903
xx	xx	11	16.673	14.650	7.446
	xx	12	8.322	8.364	2.535

Table 4.2: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

xx	xx	xx	xx (mN)	xx (mN)	xx (mN)
xx	xx	8	1.166	1.166	0.333
	xx	10	1.878	1.730	1.241
xx	xx	6	1.682	1.478	0.664
	xx	9	1.548	1.507	0.618
xx	xx	9	0.941	0.994	0.596
	xx	10	1.052	0.900	0.780
xx	xx	10	2.285	2.162	1.324
	xx	8	1.812	1.755	0.822

nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

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4.4.2 Subsection

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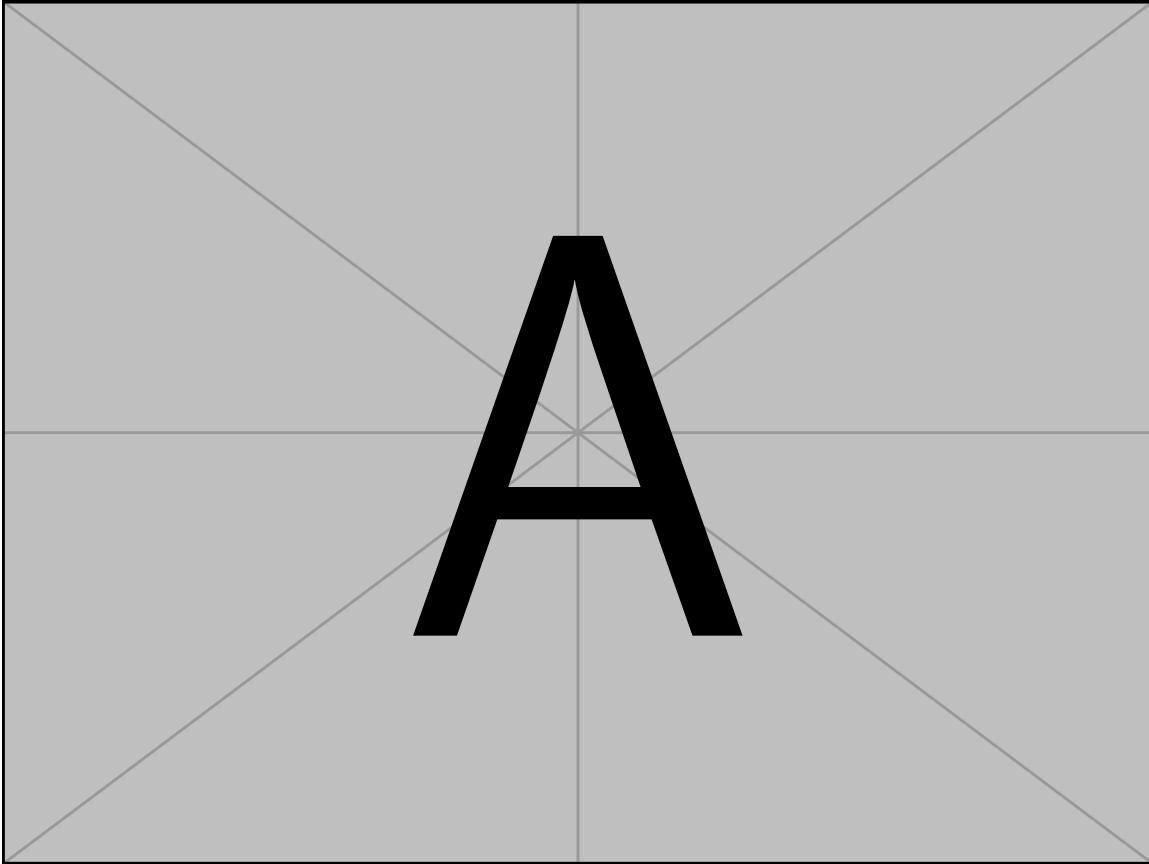


Figure 4.9: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

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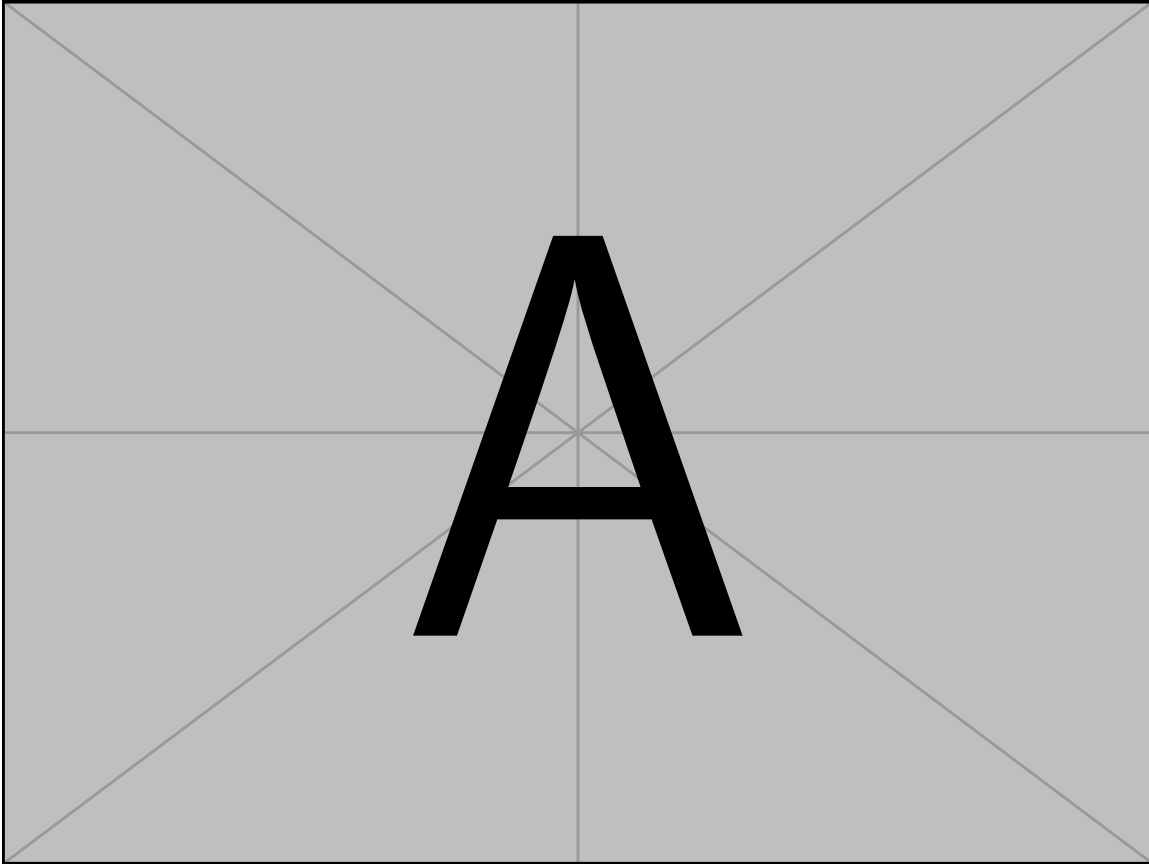


Figure 4.10: ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

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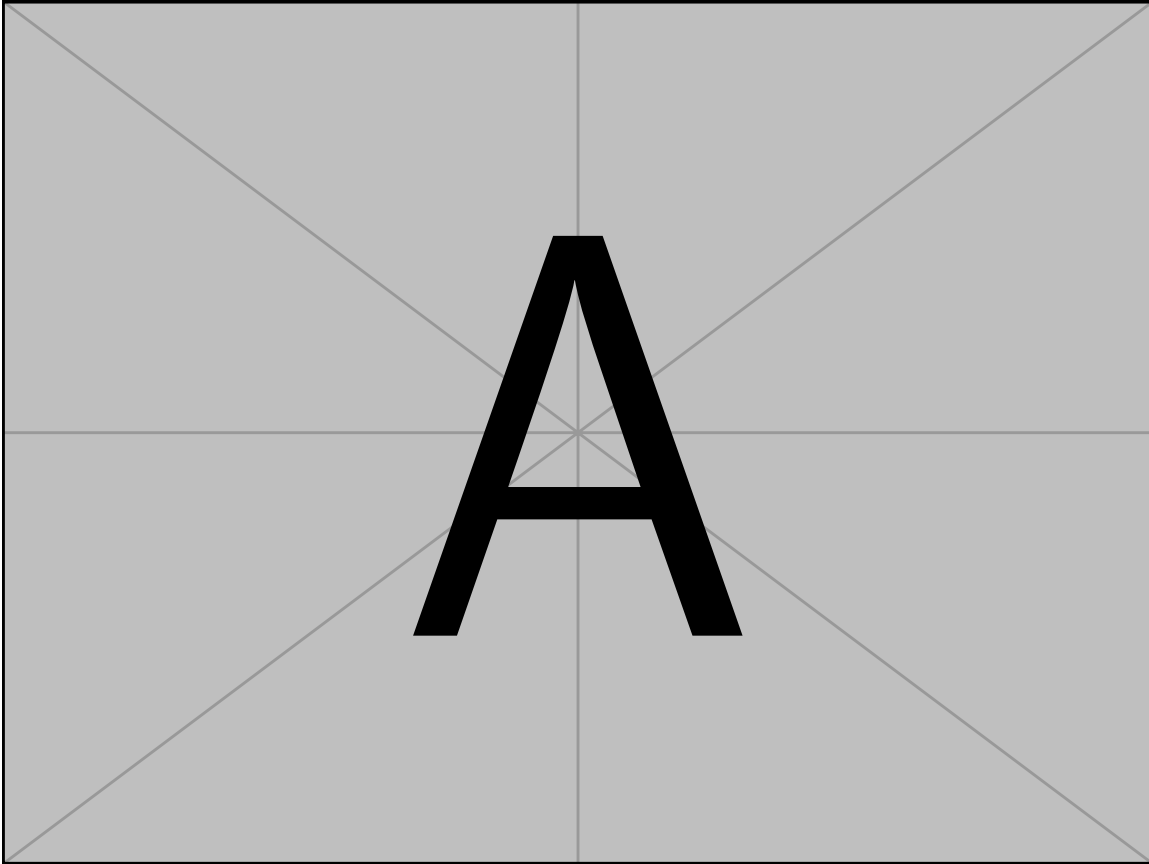


Figure 4.11: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

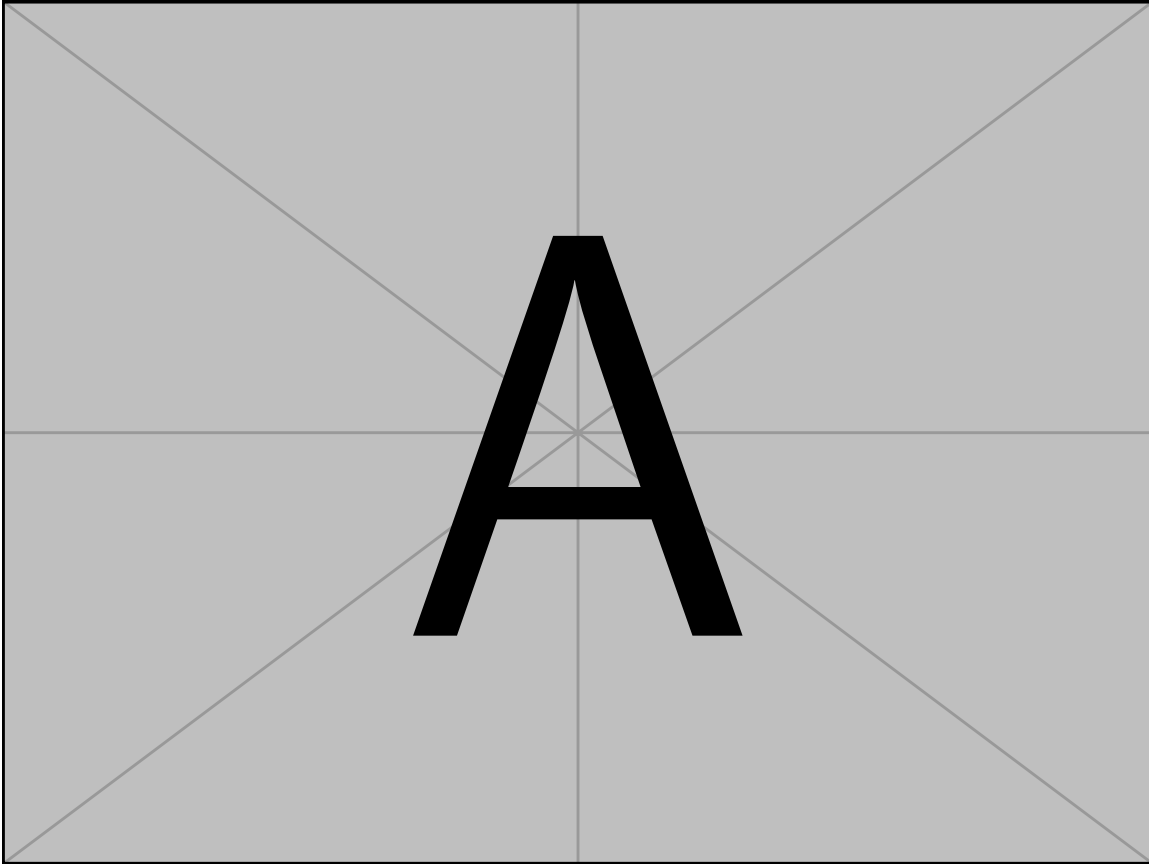


Figure 4.12: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

Table 4.3: ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

xx (yr.)	xx	xx	mean (mN)	median (mN)	std (mN)
30-39	xx	3	7.440	8.620	2.335
	xx	4	3.249	3.287	1.271
40-49	xx	6	8.143	9.149	3.492
	xx	4	5.753	4.722	2.732
50-59	xx	4	7.939	6.248	5.954
	xx	7	5.139	5.549	2.183
60-69	xx	5	7.991	4.637	5.752
	xx	5	3.087	2.908	0.894
70-79	xx	6	4.835	4.789	2.382
	xx	6	3.092	2.716	1.534

Table 4.4: ... Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

xx (yr.)	xx	xx	mean (mN)	median (mN)	std (mN)
30-39	xx	2	3.034	3.034	0.205
	xx	4	0.891	0.845	0.339
40-49	xx	5	1.380	1.424	0.407
	xx	4	1.910	1.740	0.610
50-59	xx	4	1.288	1.231	0.754
	xx	6	0.967	0.996	0.619
60-69	xx	4	1.079	0.865	0.811
	xx	4	1.570	1.177	0.853
70-79	xx	6	1.059	1.144	0.530
	xx	5	1.269	0.863	0.978

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Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel,

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4.4.3 Subsection

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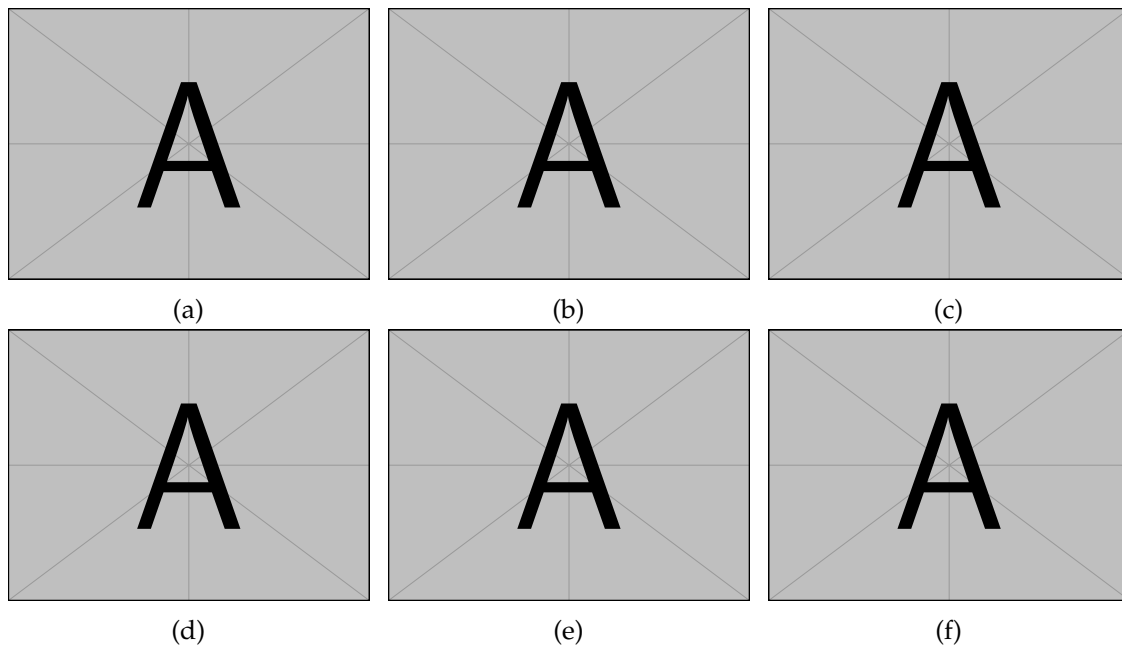


Figure 4.13: ... Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. ((a)-(c)) ... (a)... (b) ... (c) ... ((d)-(f)) ... (d) ... (e) ... (f).

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Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. (Figure 4.13d) Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. ($p < 0.05$, Figure 4.13e) Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique

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4.5 Discussion

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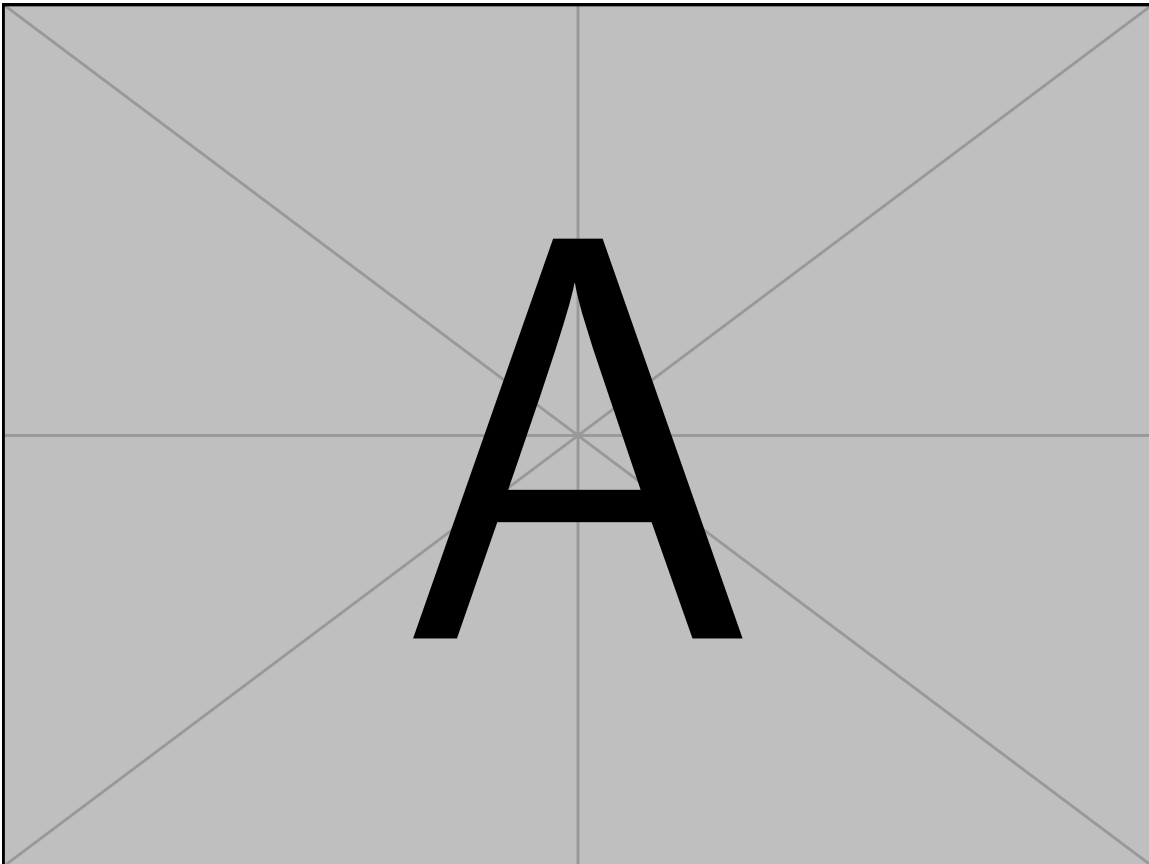


Figure 4.14: ... Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

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	xx	xx	xx
0	xx	6	
	xx	5	
1	xx	6	
	xx	7	
2	xx	4	
	xx	1	
3	xx	1	
	xx	8	

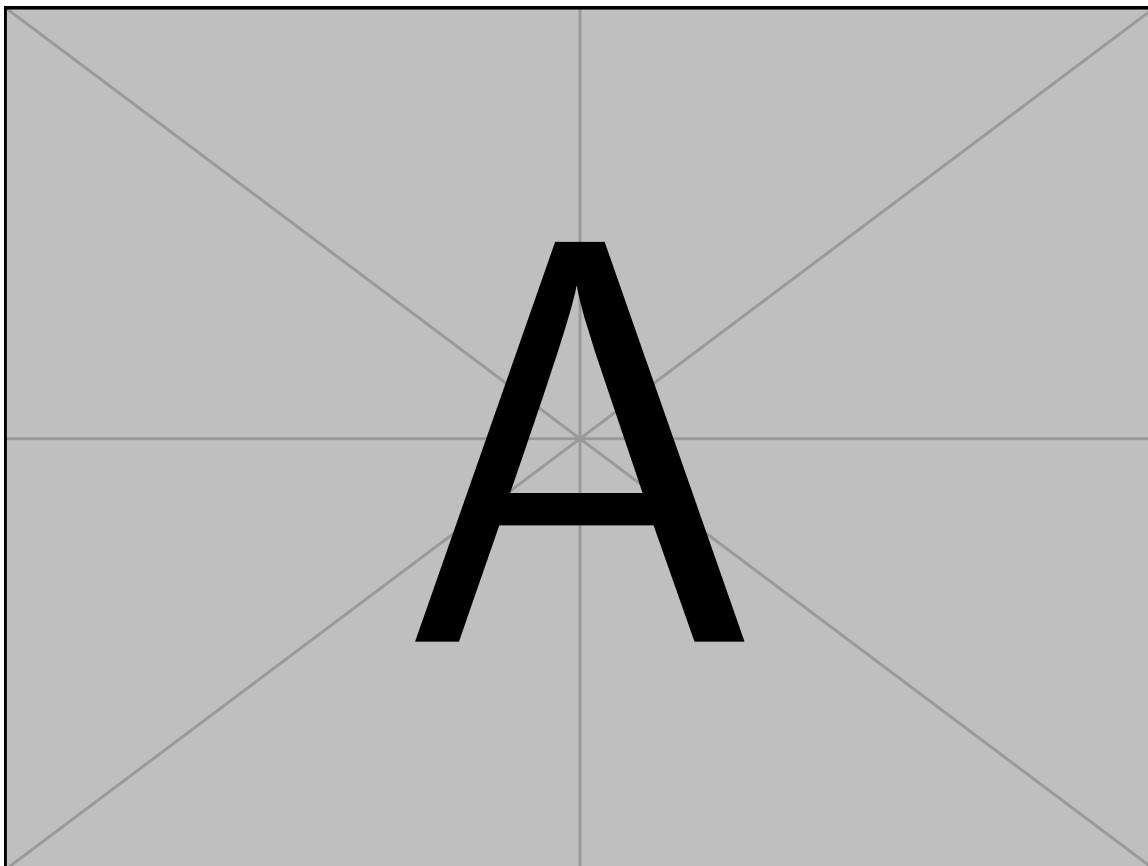


Figure 4.15: ...Pellentesque interdum sapien sed nulla. Proin tincidunt. Aliquam volutpat est vel massa. Sed dolor lacus, imperdiet non, ornare non, commodo eu, neque. Integer pretium semper justo. Proin risus. Nullam id quam. Nam neque. Duis vitae wisi ullamcorper diam congue ultricies. Quisque ligula. Mauris vehicula.

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Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. [35], [36].

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tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

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4.6 Conclusion

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4.7 Acknowledgment

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CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Summary of Key Findings

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5.1.1 Chapter 2

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5.1.2 Chapter 3

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5.1.3 Chapter 4

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wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. **Chapter 4** Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

5.2 Conclusion

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neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. [44]. Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci. [45], [46] Vivamus sit amet pede. Duis interdum, nunc eget rutrum dignissim, nisl diam luctus leo, et tincidunt velit nisl id tellus. In lorem tellus, aliquet vitae, porta in, aliquet sed, lectus. Phasellus sodales. Ut varius scelerisque erat. In vel nibh eu eros imperdiet rutrum. Donec ac odio nec neque vulputate suscipit. Nam nec magna. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nullam porta, odio et sagittis iaculis, wisi neque fringilla sapien, vel commodo lorem lorem id elit. Ut sem lectus, scelerisque eget, placerat et, tincidunt scelerisque, ligula. Pellentesque non orci.

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5.3 Future Work

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APPENDIX A
CODE SCRIPT EXAMPLES

A.1 Example Cross product codes

Find cross products using [Scripts 8 to 11](#).

A.1.1 c

```

</> Script 8: ... c to solve cross products. </>
1  #include <stdio.h>
2  #include <math.h>
3
4  typedef struct{
5      float i,j,k;
6      }Vector;
7
8  Vector vecAdd(Vector a, Vector b)
9  {
10     Vector c = {a.i + b.i, a.j + b.j, a.k + b.k};
11     return c;
12 }
13
14 Vector vecSubtract(Vector a, Vector b)
15 {
16     Vector c = {a.i - b.i, a.j - b.j, a.k - b.k};
17     return c;
18 }
19
20 float dotProduct(Vector a, Vector b)
21 {
22     return a.i*b.i + a.j*b.j + a.k*b.k;
23 }
24
25 float vecMag(Vector a)
26 {
27     return pow(a.i*a.i + a.j*a.j + a.k*a.k, 0.5);
28 }
29
30 Vector crossProduct(Vector a,Vector b)
31 {
32     Vector c = {a.j*b.k - a.k*b.j,
33                a.k*b.i - a.i*b.k,
34                a.i*b.j - a.j*b.i};
35     return c;
36 }
37
38 void printVector(Vector a)
39 {
40     printf("( %f, %f, %f)\n", a.i, a.j, a.k);
41 }
42
43 int main(){
44     double F, t, r, m_x;
45
46     // Part-a using scalar
47     F = 100;
48     t = 60*M_PI/180;

```

```

49     r = 250;
50
51     m_x = -F*sin(t)*r;
52
53     // Part-b vector approach
54     Vector o = {0, 0, 0};
55     Vector R = {0, 250, 0};
56     Vector f = {0, F*cos(t), -F*sin(t)};
57
58     // Unit vector
59     Vector x = {1, 0, 0};
60
61     // Position vector
62     Vector d = vecSubtract(R, o);
63
64     // Calculate moment
65     Vector M = crossProduct(R, f);
66
67     // Vector magnitude
68     float m;
69     m = vecMag(M);
70
71     printf("\n Part a (Scalar approach)\n %f (N-mm)\n", m_x);
72     printf("\n Part b (Vector approach)\n r x F = "); printVector(M);
73     printf("\n Magnitude = %f (N-mm)\n ", m);
74     printf("\n Magnitude of M about x-axis = %f (N-mm)\n", dotProduct(M, x));
75     return 0;
76 }

```

A.1.2 Fortran

```

</> Script 9: ... Fortran to solve cross products. </>
1     module cross_product
2     implicit none
3     contains
4     FUNCTION cross(a, b)
5         REAL, DIMENSION(3) :: cross
6         REAL, DIMENSION(3), INTENT(IN) :: a, b
7         cross(1) = a(2) * b(3) - a(3) * b(2)
8         cross(2) = a(3) * b(1) - a(1) * b(3)
9         cross(3) = a(1) * b(2) - a(2) * b(1)
10    END FUNCTION cross
11    end module cross_product
12
13    PROGRAM HW3_Prob_2
14        use cross_product
15        IMPLICIT NONE
16        REAL, DIMENSION(3) :: r, f
17        REAL, DIMENSION(3) :: m
18        ! Part a
19        r = [2.0, 5.0, 11.0] ! ft
20        f = [0.0, 44.0, -60.0] ! lbs
21        m = cross(r, f) ! Cross product
22        print*, "Part a ---- r x F = "
23        write (*, *) m, "lb-ft"

```

```

24
25     ! Part b
26     r = [1.4, 3.0, 5.7] ! m
27     f = [13.0, 25.0, -8.0] ! N
28     m = cross(r, f) ! Cross product
29     print*, "Part b ---- r x F = "
30     write (*, *) m, "N-m"
31
32     ! Part c
33     r = [-10.0, 15.0, -5.0] ! m
34     f = [500.0, -250.0, -300.0] ! N
35     m = cross(r, f) ! Cross product
36     print*, "Part c ---- r x F = "
37     write (*, *) m, "N-m"
38     END PROGRAM HW3_Prob_2

```

A.1.3 Matlab

```

</> Script 10: ... Matlab to solve cross products. </>
1 clear all
2 clc
3
4 % Part A
5 r_a = [2, 5, 11]; % ft
6 F_a = [0, 44, -60]; % lbs
7
8 r_x_F_a = cross(r_a, F_a);
9
10 fmt = ['r X F: [' , repmat('%g, ', 1, numel(r_x_F_a)-1), '%g] lb-ft\n'];
11 fprintf(fmt, r_x_F_a)
12
13 % Part B
14 r_b = [1.4, 3, 5.7]; % m
15 F_b = [13, 25, -8]; % kN
16
17 r_x_F_b = cross(r_b, F_b);
18
19 fmt = ['r X F: [' , repmat('%g, ', 1, numel(r_x_F_b)-1), '%g] kN-m\n'];
20 fprintf(fmt, r_x_F_b)
21
22 % Part C
23 r_c = [-10, 15, -5]; % m
24 F_c = [500, -250, -300]; % N
25
26 r_x_F_c = cross(r_c, F_c);
27
28 fmt = ['r X F: [' , repmat('%g, ', 1, numel(r_x_F_c)-1), '%g] N-m\n'];
29 fprintf(fmt, r_x_F_c)

```

A.1.4 Python

```

</> Script 11: ... Python to solve cross products. </>
1 import numpy as np
2
3 # Part A
4 r_a = np.array([2, 5, 11]) # ft
5 F_a = np.array([0, 44, -60]) # lbs
6
7 r_x_F_a = np.cross(r_a, F_a)
8
9 print('r X F:', r_x_F_a, 'lb-ft')
10
11 # Part B
12 r_b = np.array([1.4, 3, 5.7]) # m
13 F_b = np.array([13, 25, -8]) # kN
14
15 r_x_F_b = np.cross(r_b, F_b)
16
17 print('r X F:', r_x_F_b, 'kN-m')
18
19 # Part C
20 r_c = np.array([-10, 15, -5]) # m
21 F_c = np.array([500, -250, -300]) # N
22
23 r_x_F_c = np.cross(r_c, F_c)
24
25 print('r X F:', r_x_F_c, 'N-m')

```

A.2 Additional Example codes

A.2.1 Matlab

```

</> Script 12: ... Matlab to solve a problem. </>
1 clear all
2 clc
3
4 % Part A
5 r_a = 2; % ft
6 F_a = 8; % lbs
7
8 M_a = -r_a*F_a;
9
10 fprintf('M: %f lb-ft\n', M_a)
11
12 % Part B
13 r_b = 1.5; % ft
14 F_b = 20; % lbs
15
16 M_b = -r_b*F_b;
17
18 fprintf('M: %f lb-ft\n', M_b)
19

```

```

20 % Part C
21 r_c_1 = 4; % m
22 F_c_1 = 75; % N
23
24 r_c_2 = 1.5; % m
25 F_c_2 = 50; % N
26
27 M_c = -r_c_1*F_c_1 + -r_c_2*F_c_2;
28
29 fprintf('M: %f N-m\n', M_c)

```

A.3 Code Highlighting Using `minted`

A.3.1 Highlighting Function

To use the code highlighting function that renders scripts for publication with line numbers/language specification/file path and more, please see the following function:

```

% The "\codeFromFile" function is used in the following manner:
\codeFromFile
  {language}           % Programming language
  {\subfix{path}}     % File path
  {Header}            % Script heading info
  {label}             % LaTeX label for cross referencing
  {fontsize}         % Fontsize
  {backgroundcolor}  % Text background color
  {mintedStyle}      % Minted text style (default)

```

A.3.2 Code Highlighting Example

Here is the text to display the code used to highlight \LaTeX code in [Script 13](#).

```

\section{Scripting language to call scripts}
\subsection{\texttt{\hologo{LaTeX}}}
  \codeFromFile{LaTeX}
  {\subfix{code/LaTeX/exampleCode.tex}}
  {\ldots \hologo{LaTeX} to call other scripts.}
  {exampleCode}
  {\footnotesize}
  {latexcodebg}
  {default}

```

- Lines 1-8 in [Script 13](#) refer to [Script 8](#)
- Lines 10-17 in [Script 13](#) refer to [Script 9](#)
- Lines 19-26 in [Script 13](#) refer to [Script 10](#)

- Lines 28–35 in [Script 13](#) refer to [Script 11](#)

A.3.3 L^AT_EX Script

```

</> Script 13: ... LATEX to call other scripts using the codeFromFile function. </>
1  \subsection{\texttt{c}}
2     \codeFromFile{c}
3     {\subfix{code/c/HW3-4_58.c}}
4     {\ldots \texttt{c} to solve cross products.}
5     {ex1}
6     {\footnotesize}
7     {ccodebg}
8     {default}
9
10 \subsection{\texttt{Fortran}}
11    \codeFromFile{fortran}
12    {\subfix{code/fortran/HW3-Problem_2.f}}
13    {\ldots \texttt{Fortran} to solve cross products.}
14    {ex2}
15    {\footnotesize}
16    {fortrancodebg}
17    {default}
18
19 \subsection{\texttt{Matlab}}
20    \codeFromFile{matlab}
21    {\subfix{code/matlab/HW3-2_cross_product.m}}
22    {\ldots \texttt{Matlab} to solve cross products.}
23    {ex3}
24    {\footnotesize}
25    {matlabcodebg}
26    {default}
27
28 \subsection{\texttt{Python}}
29    \codeFromFile{LaTeX}
30    {\subfix{code/python/HW3-2_cross_Product.py}}
31    {\ldots \texttt{Python} to solve cross products.}
32    {ex4}
33    {\footnotesize}
34    {pythoncodebg}
35    {default}

```

APPENDIX B

EQUATIONS

B.1 Supporting relationships

The mass-energy equivalence is described by the famous equation

$$E = mc^2 \tag{B.1}$$

discovered in 1905 by Albert Einstein. In natural units ($c = 1$), the formula expresses the identity

$$E = m \tag{B.2}$$

APPENDIX C
TISSUE PROCESSING

C.1 Electron Microscopy Preparation

C.1.1 Tissue Processing

Tissue Processing Dehydration to Plastic

Christopher Creveling, Graduate Student *

June 6th, 2018

Abstract

Tissue preparation in the electron microscopy lab to use TEM to look at the vitreo-retinal interface in eyes.

§1 Introduction

This document is intended to be used to process tissue from formalin to embedded plastic to be used on the transmission electron microscope (TEM) to identify the orientation of collagen fibers.

§1.1 Sorting

Begin first by sorting the tissue in two piles of tissue that was peeled and tissue that was adjacent to the peeled region. Then write down the identification ID # on the paper to keep the proper vial straight during the tissue process.

§1.1.1 Identification ID

Sheep #, L/R, E/P, P/A

For example, *UL-15A-B Left Equator Peel* can be reduced to *UL15LEP*

§2 Dehydration

First place samples in glass vials. Use forceps if it is required to remove excess waste from the container. Properly label the samples from before section 1.1.1 and place the label on the vial. Before adhering the label to the vial, write down the number of specimens in the vial to ensure that the specimens don't get lost during the process. Use tape to ensure that the label will not be removed from the vial during the process.

*N. Chandler was with the Electron Microscopy Facility, University of Utah, Salt Lake City, UT, 84112 USA e-mail: (see <http://www.bioscience.utah.edu/molecular-biology/core-facilities.php>).

§2.1 Buffer Rinse

Remove the fixative from the existing vial using the micropipette. Be sure not to suck out the tissue. Then fill the vial with buffer - 0.1M Sodium Cacodylate buffer.

§2.1.1 Agitation

Put the sample vials in the rotating agitator for 5 minutes.

§2.2 Buffer Rinse

Remove the buffer from section 2.1 and replace with new buffer - 0.1M Sodium Cacodylate buffer.

§2.2.1 Agitation

Put the sample vials in the rotating agitator again for 5 minutes.

§2.3 Osmium dilution

During the previous agitation step in section 2.2.1 dilute the osmium tetroxide OsO_4 (4% in dH_2O) with 0.2 M Sodium Cacodylate buffer in a 1:1 mixture. Be sure to filter the Osmium tetroxide with a millipore filter to remove any excess particulate that would otherwise result in artifacts inside the tissue.

§2.4 Osmium rinse

Remove the 0.1M Sodium cacodylate buffer from the vials and replace with the diluted Osmium from section 2.3. Use just enough diluted Osmium to cover the tissue.

§2.4.1 Agitation

Put the sample vials back in the rotating agitator again for one hour.

§2.5 DI water rinse

Remove the diluted Osmium tetroxide from the vials and rinse with DI water. The DI water will be filtered¹. This step is done to remove excess osmium.

§2.5.1 Agitation

Put the sample vials back in the rotating agitator again for 5 minutes.

§2.6 Uranyl Acetate rinse

Remove the DI water from the vials and replace with Saturated 4% Aqueous Uranyl Acetate. The Uranyl Acetate also needs to be filtered using a millipore filter^{note1} on a 10 ml syringe.

§2.6.1 Agitation

Put the sample vials back in the rotating agitator again for one hour.

¹The millipore filter is used to remove any excess particulate that would otherwise result in artifacts inside the tissue.

§3 Final acetone dehydration step

The final step of the dehydration process is to replace all of the moisture in the tissue from H_2O to pure acetone. This is done with a series of rinses in various percentages of alcohol with the last set of rinses in acetone. **Note - if there is not enough alcohol mixtures in the hood then you will need to make more. When making the dilutions, use the graduated cylinder that is in the sink and mix the highest concentrations first to ensure that the percentages of alcohol is correct. Start with 95 then 70 then 50 etc. Also be sure that the ethanol containers are covered to prevent evaporation during each step of the dehydration process.

§3.1 50% Ethanol Alcohol

Remove the urinal acetate from the vial in section 2.6 to the appropriate container. Next use the micropipette and fill the vial with 50% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.1.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.2 70% Ethanol Alcohol

Remove the 50% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 70% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.2.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.3 95% Ethanol Alcohol

Remove the 70% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 95% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.3.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.4 95% Ethanol Alcohol

Remove the 95% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 95% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.4.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.5 100% Ethanol Alcohol

Remove the 95% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 100% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.5.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.6 100% Ethanol Alcohol

Remove the 100% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 100% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.6.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.7 100% Ethanol Alcohol

Remove the 100% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 100% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.7.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.8 100% Ethanol Alcohol

Remove the 100% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with 100% Ethanol Alcohol; ensure that the tissue specimen is well covered.

§3.8.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.9 Acetone

Remove the 100% Ethanol Alcohol from the vial. Next use the micropipette and fill the vial with acetone; ensure that the tissue specimen is well covered.

§3.9.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.10 Acetone

Remove the acetone from the vial. Next use the micropipette and fill the vial with acetone; ensure that the tissue specimen is well covered.

§3.10.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.11 Acetone

Remove the acetone from the vial. Next use the micropipette and fill the vial with acetone; ensure that the tissue specimen is well covered.

§3.11.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§3.12 Acetone

Remove the acetone from the vial. Next use the micropipette and fill the vial with acetone; ensure that the tissue specimen is well covered.

§3.12.1 Agitation

Put the sample vials in the rotating agitator again for 10 minutes.

§4 Infiltration

Once the tissue samples have been completely dehydrated and all moisture in the sample has been replaced with acetone, the next step is to infiltrate with plastic. This will allow the tissue to be embedded and then cut using the Ultramicrotomes. This will also take a few steps that still incorporate various mixtures of acetone and plastic.

§4.1 Acetone & Plastic

The first step is to remove the acetone from the vial using a micropipette and replacing it with a 1:1 mixture of acetone and plastic. Again, as mentioned before, the vial does not need to be filled up to the brim, just enough to thoroughly allow plastic to infiltrate the tissue.

§4.1.1 Agitation

Put the sample vials in the rotating agitator again for one hour.

§4.2 Acetone & Plastic Overnight Option**

If you are to finish the process for the day and return the next, then perform the following option, if not skip to section 4.3. First remove the 1:1 mixture from section 4.1 and replace with a 3:1 mixture of plastic to acetone and let it sit overnight.

§4.3 Acetone & Plastic

If you are to finish the process the same day then skip section 4.2. First remove the 1:1 mixture from section 4.1 and replace with a 3:1 mixture of plastic to acetone.

§4.3.1 Agitation

Put the sample vials in the rotating agitator again for one hour.

§4.4 Pure Plastic

First remove the 3:1 mixture from either section 4.2 or 4.3 and replace with pure plastic.

§4.4.1 Agitation

Put the sample vials in the rotating agitator again for one hour.

§4.4.2 Vacuum

Place all of the vials with the lids removed inside the vacuum chamber. Turn the pump on to remove air from the chamber. This will remove all air from the samples that has been embedded inside the tissue and will allow the infiltration of plastic to fully take affect. Let the samples sit inside the vacuum chamber for one hour.

§4.5 Pure Plastic

Remove the pure plastic from section 4.4 and replace with pure plastic again.

§4.5.1 Agitation

Put the sample vials in the rotating agitator again for one hour.

§4.5.2 Vacuum

Place all of the vials with the lids removed inside the vacuum chamber. Turn the pump on to remove air from the chamber. This will remove all air from the samples that has been embedded inside the tissue and will allow the infiltration of plastic to fully take affect. Let the samples sit inside the vacuum chamber for one hour.

§5 Embedding

The next step is to embed the plasticized tissue into the mold. Before forgoing with this process, a list of all of the specimens will need to be created on Excel to print and cut out. For example if there are five specimens in the same vial, make a list of sample names with the specimen ID (A), specimen ID (B), ... specimen ID (E). Next, grab a razor blade and a wooden stir stick. Simply use the razor blade to shave away wood from the stir stick to make a flat surface. The flat surface will be used to transfer specimens from the vials to the mold. Place the printed out label inside the mold and set the mold inside the oven to let it bake the specimens to cure the plastic.

§6 Cutting

After the plastic has cured, remove the specimen to be cut and use the microtome to shave away thin layers to be used for TEM.

§7 Grid Staining

Once thin sections have been placed on grids from section 6 the grids will need to be stained to increase the contrast for TEM. Two chemicals will be Uranyl Acetate and Lead Citrate.

§7.1 Preparation

Using the square petri-dish and wax from the cupboard cut the wax to fit the inside the petri-dish. Clean the wax with alcohol and DI water to remove any impurities on the wax that would alter the grid samples. This will also prevent the drops from coagulating together on the wax. Simply rinse the wax to clean it off.

§7.2 Chemical Prep

After the wax has been cleaned and cut remove the saturated Uranyl Acetate and Reynold's Lead Citrate from the refrigerator. Grab two small 1 ml syringes from the drawer and fill up each syringe with either UA or Lead Citrate. Then place one small filter on the end of the syringe filled with UA and two filters on the syringe filled with Lead Citrate.

§7.3 UA Stain

Using the 1 ml syringe with a single filter place a droplet of UA for each grid that you need to stain evenly spaced on the wax pad. Use the forceps and remove the grids from the grid holder and place on top of the UA droplet. Be sure to place the grid shiny side down to allow the UA to stain the specimen.

§7.4 Timer - 18 minutes

Set the timer for 18 minutes. During this time fill up enough 30 ml syringes with DI water for rinsing both UA and Lead Citrate. You will need approximately 10 ml per sample per rinse. Place a large filter on the end of the syringe.

§7.5 Staging Area

Grab a small round petri dish and insert two filter papers to absorb the water following the rinse. Use a pen or pencil to mark the paper to help organize the order of specimens to prevent a mix up.

§7.6 First Rinse

After 18 minutes, pick up the grid with forceps and rinse with 10 ml of DI water. Hold the forceps at a 60° angle from the horizontal and drip the water down the curved section of the forceps. After the rinse, place the specimens inside the round petri dish to remove excess DI water. Once all of the specimens have been placed on the filter paper, a few sodium hydroxide crystals will need to be placed inside the square petri dish. The NaOH will help prevent any sort of moisture from interfering with the grid during the staining process. Next, use the other 1 ml syringe with Lead Citrate and place drops on the wax pad following the same procedure mentioned before in section 7.3.

§7.7 Lead Citrate Rinse

Using the forceps, grip the grid and place it on top of the Lead Citrate droplet with the shiny side down which allows the grid to be stained. Set the timer for eight minutes.

§7.8 Second Rinse

After eight minutes have passed, repeat the same step as in 7.6. Once the grids have completely dried, place them back in the grid holder and they are ready for the TEM.

§7.9 Cleanup

Dispose of the petri dish in the unwanted UA container.

§8 Transmission Electron Microscopy

Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through it.

§8.1 TEM

Head over to the TEM and begin imaging!

#	Step	Instruction	Time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	Dehydration	0.1 M Sodium Cacodylate buffer	A* 5 minutes								
2	Dehydration	0.1 M Sodium Cacodylate buffer	A* 5 minutes								
3	Fix	4% OsO_4 with 0.2 M Sodium Cacodylate buffer (1:1 filtered)	A* 60 minutes								
4	Rinse	DI water rinse	A* 5 minutes								
5	Stain	Saturated 4% Aqueous Uranyl Acetate (filtered)	A* 60 minutes								
6	Dehydration	50% Ethanol	A* 10 minutes								
7	Dehydration	70% Ethanol	A* 10 minutes								
8	Dehydration	95% Ethanol	A* 10 minutes								
9	Dehydration	95% Ethanol	A* 10 minutes								
10	Dehydration	100% Ethanol	A* 10 minutes								
11	Dehydration	100% Ethanol	A* 10 minutes								
12	Dehydration	100% Ethanol	A* 10 minutes								
13	Dehydration	100% Ethanol	A* 10 minutes								
14	Dehydration	Acetone	A* 10 minutes								
15	Dehydration	Acetone	A* 10 minutes								
16	Dehydration	Acetone	A* 10 minutes								
17	Dehydration	Acetone	A* 10 minutes								
18	Infiltration	1:1 Plastic to Acetone	A* 60 minutes								
19	Infiltration	3:1 Plastic to Acetone	A* 60 minutes								
20	Infiltration	Pure Plastic	A* 60 minutes								
21	Vacuum	Vacuum	V* 60 minutes								
22	Infiltration	Pure Plastic	A* 60 minutes								
23	Vacuum	Vacuum	V* 60 minutes								
24	Embedding	Embedding	Limitless								

Table 1: Simplified instructions to check off the steps during the tissue processing by hand. A* indicates Agitation, and V* indicates Vacuum.

Station #	Step	Instruction	Time	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
1	-	-	-	-	-	-	-
2	Dehydration	0.1 M Sodium Cacodylate buffer	A* 10 minutes				
3	Fix	4% OsO ₄ with 0.2 M Sodium Cacodylate buffer (1:1 filtered)	A* 60 minutes				
4	Rinse	DI water rinse	A* 10 minutes				
5	Stain	Saturated 4% Aqueous Uranyl Acetate (filtered)	A* 60 minutes				
6	Dehydration	50% Ethanol	A* 10 minutes				
7	Dehydration	70% Ethanol	A* 10 minutes				
8	Dehydration	95% Ethanol	A* 10 minutes				
9	Dehydration	95% Ethanol	A* 10 minutes				
10	Dehydration	100% Ethanol	A* 10 minutes				
11	Dehydration	100% Ethanol	A* 10 minutes				
12	Dehydration	100% Ethanol	A* 10 minutes				
13	Dehydration	100% Ethanol	A* 10 minutes				
14	Dehydration	Acetone	A* 10 minutes				
15	Dehydration	Acetone	A* 10 minutes				
16	Dehydration	Acetone	A* 10 minutes				
17	Dehydration	Acetone	A* 10 minutes				
18	Infiltration	1:1 Plastic to Acetone	A* 60 minutes				
19	Infiltration	3:1 Plastic to Acetone	A* 60 minutes				
20	Infiltration	Pure Plastic	A* & V* 60 minutes				
21	Infiltration	Pure Plastic	A* & V* 60 minutes				
22	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-

Table 2: Simplified instructions to check and make sure the automatic tissue processor is set up at the correct stations. Each vial should be filled with 20 ml when processing. Be sure to check the program on the automatic tissue processor; it should be marked by program #2. A* indicates Agitation, and V* indicates Vacuum.

C.1.2 Tissue Processing

Tissue Processing Dehydration to Plastic

Christopher Creveling, Graduate Student *

June 8th, 2018

Abstract

Tissue preparation in the electron microscopy lab to prepare the EMBED 812 for tissue processing.

§1 Introduction

This document is intended to be used to process tissue from formalin to embedded plastic to be used on the transmission electron microscope (TEM) to identify the orientation of collagen fibers.

§2 Embed 812

§2.1 Personal Protective Equipment

Begin first by grabbing a lab coat and then use paper towels and acetone to clean off the scale used for measuring out the mass of various resin mixtures.

§2.2 Recipe for EMBED 812

Remove the four chemicals for the EMBED 812 resin from the cabinet by using the WPE-147. Where W.P.E. is the Weight per Epoxide Equivalent).

Ingredient	Unit
EMBED 812 Resin	51.80 g
DDSA	26.68 g
NMA	21.67 g
BDMA	2.5 ml

Table 1: Simplified instructions to check and make sure the automatic tissue processor is set up at the correct stations. Each vial should be filled with 20 ml when processing. Be sure to check the program on the automatic tissue processor; it should be marked by program #2.

*N. Chandler was with the Electron Microscopy Facility, University of Utah, Salt Lake City, UT, 84112 USA e-mail: (see <http://www.bioscience.utah.edu/molecular-biology/core-facilities.php>).

§3 Lab Equipment

Grab one (400 ml) Tripore container along with four clean pipettes.

§4 EMbed 812

Balance the scale with the Tripore container and pour in 51.80 g of EMbed 812 Resin. Clean the bottle and cap with Kimwipes and throw out the pipette. Grab a strip of Parafilm to stretch over the cap to ensure an air-tight seal.

§5 DDSA

Balance the scale after 51.80 g of EMbed 812 Resin has been added to the Tripore container. Add 26.68 g of DDSA to the container by first underpouring and then using a pipette to add the rest of the DDSA. Clean the bottle and cap with Kimwipes and throw out the pipette. Grab a strip of Parafilm to stretch over the cap to ensure an air-tight seal.

§6 NMA

Balance the scale after 26.68 g of DDSA has been added to the Tripore container. Add 21.67 g of NMA to the container by first underpouring and then using a pipette to add the rest of the NMA. Clean the bottle and cap with Kimwipes and throw out the pipette. Grab a strip of Parafilm to stretch over the cap to ensure an air-tight seal.

§7 Stir

Move the Tripore container inside the hood. Add a stirbar to the Tripore container containing EMbed 812 Resin, DDSA, and NMA to stir the mixture for 10 minutes in the hood.

§8 BDMA

In the hood, while the Tripore container is being stirred, use a graduated micropipette and obtain 2.5 ml of BDMA. The BDMA is used as the accelerant for polymerization.

§9 Stir

Stir the Tripore container containing EMbed 812 Resin, DDSA, NMA, and BDMA mixture for 10 minutes in the hood. The mixture should turn orange after the BDMA has been added.

§10 Parafilm

Using Parafilm wrap, ensure that each chemical lid has been wrapped to keep an air-tight seal.

§11 Syringe

Grab eight syringes and caps from the cupboards and prepare them for filling up with the resin. Place the newly filled resin syringes in the freezer.

§12 Clean-up

Clean the magnetic stirbars with acetone. Be sure to put vinyl liners inside the gloves.

§13 Embed

Embed the tissue samples!

C.2 MatLab Least Squares

```
</> Script 14: Matlab script that performs a least squares regression calculation. </>  
1 function [A] = Least_Squares(A)  
2 % Calculate the slope and y-intercept using matrix math  
3 % x & y are the coordinates of points  
4 x = A(:,1);  
5 y = A(:,2);  
6 Z = ones(length(x),2);  
7 Z(:,2) = x;  
8 % Calculate the matrix inverse for the constants of the regression  
9 A = inv(Z'*Z)*(Z'*y);  
10 return  
11 end
```

C.3 Additional Scripts

Additional scripts used for analysis: https://gitlab.com/SkiEngineer/phd_dissertation_code/-/tree/master/AppendixB.

Part I

Organization of Thesis/Dissertation

(Not included in actual document)

APPENDIX D
THESIS/DISSERTATION
ORGANIZATION

To setup your Thesis/Dissertation, take advantage of the \LaTeX package `subfiles` which allows you to break apart your document into various sections and compile them individually for editing purposes:

```

</> Script 15: ... $\LaTeX$  script used to setup the document. </>
1 % The class file specifying the document structure
2 \documentclass{./LaTeX/tex/latex/MastersDoctoralThesis}
3
4 \input{StudentInfo.tex}
5
6 \input{./LaTeX/tex/latex/codeHighlighting.tex} % Code highlighting
7
8 %-----%
9 %                               References
10 %-----%
11
12 \addbibresource{\subfix{Chapter1/bib_files/bibliography.bib}}
13 \addbibresource{\subfix{Chapter2/bib_files/bibliography.bib}}
14 \addbibresource{\subfix{Chapter3/bib_files/bibliography.bib}}
15 \addbibresource{\subfix{Chapter4/bib_files/bibliography.bib}}
16 \addbibresource{\subfix{Chapter5/bib_files/bibliography.bib}}
17
18 \raggedbottom
19 \begin{document}
20
21   \frontMatter
22
23   %-----%
24   %                               Thesis Title, Copyright, Approval
25   %-----%
26
27   \begin{center}
28     \thesisTitle
29     \copyrightpage
30     \dissertationapproval
31   \end{center}
32
33   %-----%
34   %                               Abstract
35   %-----%
36
37   \abstractPage
38
39   %-----%
40   %                               Dedication
41   %-----%
42
43   \dedicationPage
44
45   %-----%
46   %                               Frontispiece image (Image of importance relevance)
47   %-----%
48
49   \frontispiecePage

```

```

50
51 %-----%
52 %           Epigraph page (Inspirational quote)
53 %-----%
54
55 \epigraphPage
56
57 %-----%
58 %           LIST OF CONTENTS/FIGURES/TABLES PAGES
59 %-----%
60
61 \tableOfContents
62
63 %-----%
64 %           Notation and Symbols
65 %-----%
66
67 \NotationSymbolsPage
68
69 %-----%
70 %           Acknowledge
71 %-----%
72
73 \AcknowledgementPage
74
75 %-----%
76 %           Thesis/Dissertation Content (Chapters etc.)
77 %-----%
78
79 \mainMatter
80
81 \subfile{\subfix{Chapter1/Chapter1}}
82 \subfile{\subfix{Chapter2/Chapter2}}
83 \subfile{\subfix{Chapter3/Chapter3}}
84 \subfile{\subfix{Chapter4/Chapter4}}
85 \subfile{\subfix{Chapter5/Chapter5}}
86
87 %-----%
88 %           List of items to work on (Editing phase)
89 %-----%
90
91 %\listoftodos
92
93 %-----%
94 %           APPENDICES
95 %-----%
96
97 \backMatter % Que to tell LaTeX that the following "chapters" are Appendices
98
99 % Include the appendices of the thesis as separate files from the
100 % Appendices folder
101 % Uncomment the lines as you write the Appendices
102
103 \subfile{\subfix{AppendixA/AppendixA}}
104 \subfile{\subfix{AppendixB/AppendixB}}
105 \subfile{\subfix{AppendixC/AppendixC}}
106
107 %-----%

```

```

108      %                               BIBLIOGRAPHY
109      %-----%
110
111      % Comment out because each chapter displays references/
112      % or comment out the individual references and keep the final bibliography
113      % \finalBibliography
114
115 \end{document}

```

D.1 Student Info Setup

Script 16 is used to specify student-specific information.

```

</>      Script 16: ...LaTeX script used for Student-Specific Info.      </>
1  \author           {Full Name}
2  \title            {Thesis/Dissertation Title}
3  \thesistype       {dissertation} % thesis/dissertation - variable to switch between
   → 3 and 5 committee members
4  \degreeAchieved   {Doctor of Philosophy}
5  \department       {Department of xx}
6  \departmentLink   {}
7  \submitdate       {Month Year}
8  \copyrightyear    {\the\year{}}
9
10 \abstractString   {The usability of dissertation abstracts depends largely on
11 their content. Many journals within the medical community have settled on a
12 seven sentence structure, which is also gaining acceptance in the social
13 sciences, education and business. In it, the purpose of the study and
14 methodological choices are outlined succinctly, allowing the reader or
15 researcher to quickly scan and evaluate a number of studies to easily choose
16 ones that meet their particular demands. The structure contains variations on
17 the following seven sentence stems: "The purpose of this study is..." "The
18 scope of this study..." "The methodology..." "The Findings..." "Conclusions
19 reached are ..." "Limitations of this study include..." "This study
20 contributes..." Abstracts of dissertation proposals contain the same seven
21 concepts, substituting data collection and analysis in place of findings and
22 conclusions. Abstracts are limited in the United States by the UMI to 350
23 words.\\indent More info here.}
24
25 \dedication        {Most books at the library will have a dedication page.
26 Normally, this page includes quotes like "For my mother" or "For Lucy who never
27 gave up on me." A dissertation dedication is the same concept. In this part of
28 the dissertation, the student must use a sentence or a paragraph to dedicate
29 their text. They may want to use the dedication to recognize an individual who
30 inspired them to go to college or someone who helped with the dissertation.
31 Dedicating the dissertation to someone is a way to honor them. After putting so
32 much work into this paper, it is a chance for the student to recognize the
33 people who influenced the process.}
34
35 \frontispiece       {example-image-a} %
36
37 \epigraphQuote      {\`Quote"}
38 \epigraphAuthor     {Famous Individual}
39
40 \Acknowledgement{The dissertation acknowledgements section is where you thank

```

```

41 those who have helped and supported you during the research and writing
42 process. This includes both professional and personal acknowledgements. \ldots
43 \\ \indent More acknowledgement info can be found here:
44 \url{https://www.scribbr.com/dissertation/acknowledgements/}.}
45
46 \NotationAndSymbols{
47 \begin{tabularx}{\textwidth}{lX}
48   \toprule
49   x      & \emph{Var} & & - the variable `x'. \\
50   y      & \emph{y}   & & - the variable `y'. \\
51   m      & \emph{Slope} & & - The slope is one of the essential characteristics of a
   \rightarrow line and helps us measure the rate of change. The slope of a straight line is
   \rightarrow the ratio of the change in  $y$  to the change in  $x$ , also called the rise
   \rightarrow over run. \\
52    $\vec{F}$  & \emph{Force} & & - Force vector. \\
53    $\pi$  & \emph{Pi} & & - The number  $\pi$  is a mathematical constant. It is
   \rightarrow defined as the ratio of a circle's circumference to its diameter, and it also
   \rightarrow has various equivalent definitions. It appears in many formulas in all areas
   \rightarrow of mathematics and physics. \\
54   \bottomrule
55 \end{tabularx}
56 }
57
58 \approvaldepartment {Dept.} % Your department goes here
59
60 \graduateDean {Graduate School Dean} % Dean's name
61 \departmentChair {Department Chair}
62 \departmentChairTitle {Chair}
63 \deptmentCollegeSchool {Department} % College/Department/school
64
65 \committeeChair {Graduate Advisor} % Graduate Advisor
66 \advisorTitle {Associate Professor, Associate Chair}
67
68 \committeeMemberII {Committee member 2}
69 \committeeMemberIII {Committee member 3}
70 \committeeMemberIIII {Committee member 4}
71 \committeeMemberIIIII {Committee member 5}
72
73 \chairDateApproved {mm/dd/\the\year{}}
74 \committeeMemberIIDateApproved {mm/dd/\the\year{}}
75 \committeeMemberIIIDateApproved {mm/dd/\the\year{}}
76 \committeeMemberIIIIIDateApproved {mm/dd/\the\year{}}
77 \committeeMemberIIIIIDateApproved {mm/dd/\the\year{}}

```

D.2 Individual Chapter 1 Setup

</>

Script 17: ...*LaTeX* script used for chapter 1.

</>

```

1 %%% -*-LaTeX-*-
2 \documentclass[../Dissertation]{subfiles}
3
4 \doublespacing
5 \graphicspath{{Chapter1/Media/}{Media/}} % Graphics path for images
6
7 \begin{document}

```



```

8
9   % Needs to be capitalized (University Rules) and title width is no longer
10  % than 4.5 inches. Specify custom line breaks using "\protect\\\" for both
11  % the Chapter title page and the table of contents page
12  \chapter{\uppercase{Introduction}}\label{chp:1}
13
14  % If there is no text between the chapter and the first section, then we
15  % need to reduce the spacing with a negative skip. Otherwise, comment out
16  % the following line
17  \vspace{-2ex}
18
19  \subfile{0_Overview}
20  \subfile{1_Background}
21  \subfile{2_Aims}
22  \subfile{3_Impact}
23
24  % bibliography
25  \printbibliography[segment=\therefsegment,heading=references]
26
27 \end{document}

```

D.3 Individual Chapter 2 Setup

```

</> Script 18: ... $\LaTeX$  script used to import a chapter. </>
1  %% -*-LaTeX*-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5  %\graphicspath{{Chapter2/Media/}{Media/}} % Graphics path for images
6
7  \begin{document}
8
9   % Needs to be capitalized (University Rules) and title width is no longer
10  % than 4.5 inches. Specify custom line breaks using "\protect\\\" for both
11  % the Chapter title page and the table of contents page
12  \chapter[\uppercase{Multiline Title}]{\uppercase{Multiline
13  \protect\\ Title}}\label{chp:2}
14
15  \lipsum[1] % random text after the chapter title.
16
17  % If there is no text between the chapter and the first section, then we
18  % need to reduce the spacing with a negative skip. Otherwise, comment out
19  % the following line
20  % \vspace{-2ex}
21
22  \subfile{0_Abstract}
23  \subfile{1_Introduction}
24  \subfile{2_Methods}
25  \subfile{3_Results}
26  \subfile{4_Discussion}
27  \subfile{5_Conclusion}
28  \subfile{6_Acknowledgment}
29
30  % bibliography

```

```

31 \printbibliography[segment=\therefsegment,heading=references]
32
33 \end{document}

```

D.4 Individual Chapter 3 Setup

</> Script 19: ...*LaTeX* script used to import a chapter. </>

```

1  %%% -*-LaTeX-*-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5  %\graphicspath{{Chapter3/Media/}{Media/}} % Graphics path for images
6
7  \begin{document}
8
9      % Needs to be capitalized (University Rules) and title width is no longer
10     % than 4.5 inches. Specify custom line breaks using "\protect|" for both
11     % the Chapter title page and the table of contents page
12     \chapter[\uppercase{Previously published article}]{\uppercase{Previously
13     ↪ published article}}\label{chp:3}
14
15     % If there is no text between the chapter and the first section, then we
16     % need to reduce the spacing with a negative skip. Otherwise, comment out
17     % the following line
18     %\vspace{-0.5\UofUDoubleSpace}
19
20     Research published: C. J. Creveling, J. Colter, and B. Coats, ``Changes in
21     Vitreoretinal Adhesion With Age and Region in Human and Sheep Eyes," Front.
22     Bioeng. Biotechnol., vol. 6, no. 153, pp. 1-11, Oct. 2018.
23
24     % \subfile{\subfix{Chapter3/0_Abstract}}
25     % \subfile{\subfix{Chapter3/1_Introduction}}
26     % \subfile{\subfix{Chapter3/2_Methods}}
27     % \subfile{\subfix{Chapter3/3_Results}}
28     % \subfile{\subfix{Chapter3/4_Discussion}}
29     % \subfile{\subfix{Chapter3/5_Conclusion}}
30     % \subfile{\subfix{Chapter3/6_Acknowledgment}}
31
32     \subfile{./code/PDFdocument}%Chapter3/
33
34     \section{PDF Import}
35     Using the \hologo{LaTeX} package
36     \href{https://ctan.org/pkg/pdfpages?lang=en}{\texttt{pdfpages}}, you can
37     import PDFs into your PDF. An example of this is used to import a
38     previously published journal article in \cref{code:PDF}. There are
39     function keywords that allow you to add sections to the table of
40     contents, list of figures, and the list of tables.
41
42     \mintinline{LaTeX}{addtotoc={<page
43     ↪ number>,<section>,<level>,<heading>,<label>}}
44
45     \mintinline{LaTeX}{addtolist={<page number>,<type>,<heading>,<label>}}
46
47     \codeFromFile{LaTeX}

```

```

46     {./Chapter3/code/PDFdocument.tex} %
47     {\ldots \hologo{LaTeX} to import a PDF and add contents to the Table of
48     Contents, List of Figures, and List of Tables.}
49     {PDF}
50     {\footnotesize}
51     {\latexcodebg}
52     {default}
53
54     % bibliography
55     \printbibliography[segment=\therefsegment,heading=references]
56
57 \end{document}

```

D.5 Individual Chapter 4 Setup

</> Script 20: ... \LaTeX script used to import a chapter. </>

```

1  %%% -*-LaTeX-*-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5  \graphicspath{{Chapter4/Media/}{Media/}} % Graphics path for images
6
7  \begin{document}
8
9     % Needs to be capitalized (University Rules) and title width is no longer
10    % than 4.5 inches. Specify custom line breaks using "\protect\\" for both
11    % the Chapter title page and the table of contents page
12    \chapter[\uppercase{This Is Another Multi-Line Title That Needs To Have An
13    \protect\\Inverted Pyramid Shape Where Each Line Is Not Wider Than 4.6
14    in.}]{\uppercase{This Is Another Multi-Line Title That \protect\\Needs To
15    Have An Inverted \protect\\Pyramid Shape Where Each \protect\\Line Is Not
16    Wider \protect\\Than 4.6 in.}}\label{chp:4}
17
18
19    % If there is no text between the chapter and the first section, then we
20    % need to reduce the spacing with a negative skip. Otherwise, comment out
21    % the following line
22    \vspace{-2ex}
23
24    \subfile{0_Abstract}
25    \subfile{1_Introduction}
26    \subfile{2_Methods}
27    \subfile{3_Results}
28    \subfile{4_Discussion}
29    \subfile{5_Conclusion}
30    \subfile{6_Acknowledgment}
31
32    % bibliography
33    \printbibliography[segment=\therefsegment,heading=references]
34
35 \end{document}

```

D.6 Individual Chapter 5 Setup

```

</> Script 21: ... $\LaTeX$  script used to import a chapter. </>
1  %% -LaTeX-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5  \graphicspath{{Chapter5/Media/}{Media/}} % Graphics path for images
6
7  \begin{document}
8
9      % Needs to be capitalized (University Rules) and title width is no longer
10     % than 4.5 inches. Specify custom line breaks using "\protect\\" for both
11     % the Chapter title page and the table of contents page
12     \chapter{\uppercase{Conclusions and future work}}\label{chp:5}
13
14     % If there is no text between the chapter and the first section, then we
15     % need to reduce the spacing with a negative skip. Otherwise, comment out
16     % the following line
17     \vspace{-2ex}
18
19     \subfile{0_Summary_of_key_findings}
20     \subfile{1_Chapter2_summary}
21     \subfile{2_Chapter3_summary}
22     \subfile{3_Chapter4_summary}
23     \subfile{4_Conclusion}
24     \subfile{5_Future_Work}
25
26     % bibliography
27     \printbibliography[segment=\therefsegment,heading=references]
28
29 \end{document}

```

D.7 Individual Appendix A Setup

```

</> Script 22: ... $\LaTeX$  script used to import an appendix. </>
1  %% -LaTeX-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5
6  \begin{document}
7
8  \chapter{Code Script Examples}\label{AppendixA}
9
10     % If there is no text between the chapter and the first section, then we
11     % need to reduce the spacing with a negative skip. Otherwise, comment out
12     % the following line
13     \vspace{-0.5\UofUDoubleSpace}
14
15 \section{Example Cross product codes}
16     Find cross products using
17     \cref{code:ex1,code:ex2,code:ex3,code:ex4}.

```

```

18
19 \subsection{\texttt{c}}
20   \codeFromFile{c}
21   {\subfix{code/c/HW3-4_58.c}}
22   {\ldots \texttt{c} to solve cross products.}
23   {ex1}
24   {\footnotesize}
25   {ccodebg}
26   {default}
27
28 \subsection{\texttt{Fortran}}
29   \codeFromFile{fortran}
30   {\subfix{code/fortran/HW3-Problem_2.f}}
31   {\ldots \texttt{Fortran} to solve cross products.}
32   {ex2}
33   {\footnotesize}
34   {fortrancodebg}
35   {default}
36
37 \subsection{\texttt{Matlab}}
38   \codeFromFile{matlab}
39   {\subfix{code/matlab/HW3-2_cross_product.m}}
40   {\ldots \texttt{Matlab} to solve cross products.}
41   {ex3}
42   {\footnotesize}
43   {matlabcodebg}
44   {default}
45
46 \subsection{\texttt{Python}}
47   \codeFromFile{python}
48   {\subfix{code/python/HW3-2_cross_Product.py}}
49   {\ldots \texttt{Python} to solve cross products.}
50   {ex4}
51   {\footnotesize}
52   {pythoncodebg}
53   {default}
54
55 \section{Additional Example codes}
56
57 \subsection{\texttt{Matlab}}
58   \codeFromFile{matlab}
59   {\subfix{code/matlab/HW3-problem_1.m}}
60   {\ldots \texttt{Matlab} to solve a problem.}
61   {HW3-problem_1}
62   {\footnotesize}
63   {matlabcodebg}
64   {default}
65
66 \section{Code Highlighting Using
67 \href{https://ctan.org/pkg/minted?lang=en}{\texttt{minted}}}
68 \subsection{Highlighting Function}
69   To use the code highlighting function that renders scripts for publication
70   with line numbers/language specification/file path and more, please see the
71   following function:
72
73   {\singlespacing
74   \begin{minted}{LaTeX}
75   % The "\codeFromFile" function is used in the following manner:

```

```

76 \codeFromFile
77   {language}           % Programming language
78   {\subfix{path}}     % File path
79   {Header}            % Script heading info
80   {label}             % LaTeX label for cross referencing
81   {fontsize}          % Fontsize
82   {backgroundcolor}  % Text background color
83   {mintedStyle}      % Minted text style (default)
84 \end{minted}
85 }
86
87 \subsection{Code Highlighting Example}
88 Here is the text to display the code used to highlight \hologo{LaTeX} code in
89 \cref{code:exampleCode}.
90
91 {\singlespacing
92 \begin{minted}{LaTeX}
93 \section{Scripting language to call scripts}
94 \subsection{\texttt{\hologo{LaTeX}}}
95   \codeFromFile{LaTeX}
96   {\subfix{code/LaTeX/exampleCode.tex}}
97   {\ldots \hologo{LaTeX} to call other scripts.}
98   {exampleCode}
99   {\footnotesize}
100  {latexcodebg}
101  {default}
102 \end{minted}
103 }
104
105 \begin{itemize}
106   \item Lines \texttt{1-8} in \cref{code:exampleCode} refer to
107     \cref{code:ex1}
108   \item Lines \texttt{10-17} in \cref{code:exampleCode} refer to
109     \cref{code:ex2}
110   \item Lines \texttt{19-26} in \cref{code:exampleCode} refer to
111     \cref{code:ex3}
112   \item Lines \texttt{28-35} in \cref{code:exampleCode} refer to
113     \cref{code:ex4}
114 \end{itemize}
115
116
117 \subsection{\hologo{LaTeX} Script}
118 \codeFromFile{LaTeX}
119 {\subfix{code/LaTeX/exampleCode.tex}}
120 {\ldots \hologo{LaTeX} to call other scripts using the
121 \texttt{codeFromfile} function.} % \mintinline{LaTeX}{\codeFromFile}
122 {exampleCode}
123 {\footnotesize}
124 {latexcodebg}
125 {default}
126
127 \end{document}

```

D.8 Individual **Appendix B** Setup

```

</> Script 23: ...LaTeX script used to import an appendix. </>
1  %% -LaTeX-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5
6  \begin{document}
7
8      \chapter{Equations}\label{AppendixB}
9
10     \section{Supporting relationships}
11     The mass-energy equivalence is described by the famous equation
12
13     \begin{equation}
14         E=mc^2
15     \end{equation}
16
17     \noindent discovered in 1905 by Albert Einstein.
18     In natural units ( $\hbar = 1$ ), the formula expresses the identity
19
20     \begin{equation}
21         E=m
22     \end{equation}
23
24 \end{document}

```

D.9 Individual **Appendix C** Setup

```

</> Script 24: ...LaTeX script used to import an appendix. </>
1  %% -LaTeX-
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5
6  \begin{document}
7
8  \chapter{Tissue Processing}\label{AppendixC}
9
10     % Space used to make space between chapter title and section header the
11     % correct spacing
12     \vspace{-0.5\baselineskip}
13
14     \includepdf[
15     pages={1},
16     pagecommand={\section{Electron Microscopy Preparation}\subsection{Tissue
17     ↪ Processing}},
18     scale=0.8]
19     {\subfix{procedures/TissueProcessing/Release/TissueProcessing}}
20
21     % Because the page created new subsections for each page
22     \includepdf[pages={2-},

```

```

22 pagecommand={},
23 scale=0.8]
24 {\subfix{procedures/TissueProcessing/Release/TissueProcessing}}
25
26 \includepdf[pages={1},
27 pagecommand={\subsection{Tissue Processing}},
28 scale=0.8]
29 {\subfix{procedures/ResinPrep/Release/ResinPreparation}}
30
31 % Because the page created new subsections for each page
32 \includepdf[
33 pages={2-},
34 pagecommand={},
35 scale=0.8]
36 {\subfix{procedures/ResinPrep/Release/ResinPreparation}}
37
38 \section{MatLab Least Squares}
39 \codeFromFile{matlab}
40 {\subfix{Matlab/Least_Squares.m}}
41 {Matlab script that performs a least squares regression calculation.}
42 {leastSquares}{\footnotesize}{matlabcodebg}{default}
43
44 %\section{Ridge Detection Input Parameters}
45 % \codeFromFile{matlab}
46 % {\subfix{Matlab/Sigma_Selector.m}}
47 % {Matlab script that determine ridge detection parameters using TEM images.}
48 % {ridgeDetectionParams}{\footnotesize}{matlabcodebg}{default}
49
50 %\section{Analyze Ridge Detection Output}
51 % \codeFromFile{matlab}
52 % {\subfix{Matlab/RidgeDetectionAnalysis.m}}
53 % {Matlab script that analyzes ridge detection output from TEM images.}
54 % {ridgeDetectionAnalysis}{\footnotesize}{matlabcodebg}{default}
55
56 %\section{Human Data Analysis}
57 % \codeFromFile{python}
58 % {\subfix{Python/HumanDataStatisticsPaper2.py}}
59 % {Python script analyzes human data, performs statistics, and creates
60 % figures.}
61 % {humanTEMDataAnalysis}{\footnotesize}{pythoncodebg}{default}
62
63 \section{Additional Scripts}
64 Additional scripts used for analysis:
65 \href{http://gitlab.com/SkiEngineer/phd_dissertation_code/-/tree/master/AppendixB}
66 {\texttt{https://gitlab.com/SkiEngineer/\linebreak
67 phd\_dissertation\_code/-/tree/master/AppendixB}}.
68
69 \end{document}

```

D.10 How To Use This Thesis/Dissertation L^AT_EX Template?

In order to take advantage of the whole functionality of L^AT_EX to compile your Thesis/Dissertation, it is recommended to use a Linux system. This can be done on Microsoft

Windows using the Linux subsystem `Ubuntu`. The alternative is to use `Overleaf` which takes care of all of the package installation requirements.

D.10.1 Overleaf Template

To get started using the Overleaf template (Figure D.1), click the following link: [University of Utah Thesis/Dissertation Template](#). You can begin writing as soon as you add the project to your “cloud”. Be sure to check that the “Recompile” option is set to “off” or else it will recompile each time you change `.tex` files. When you want to compile hit the button or press “`Ctrl + S`” (Figure D.2). The benefit of using overleaf is that you do not have get \LaTeX installed on your local machine and you can preview the finished project on the same screen. Just be careful when your project has a lot of figures and references that it will take time to compile when you press “`Ctrl + S`” to compile.

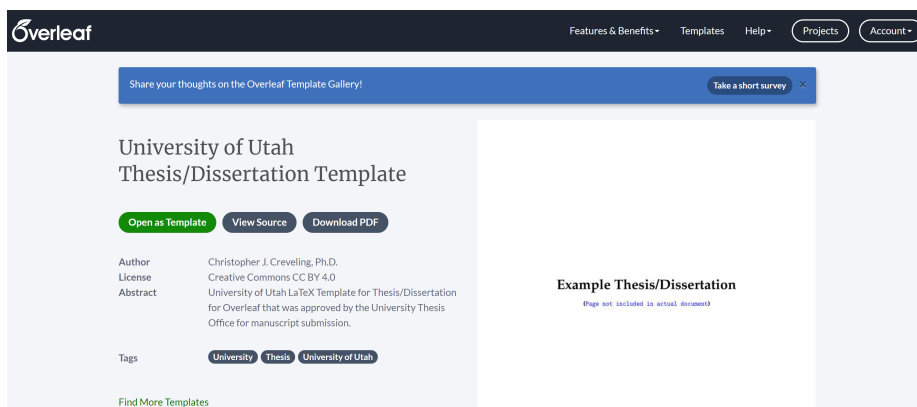


Figure D.1: Overleaf project template.

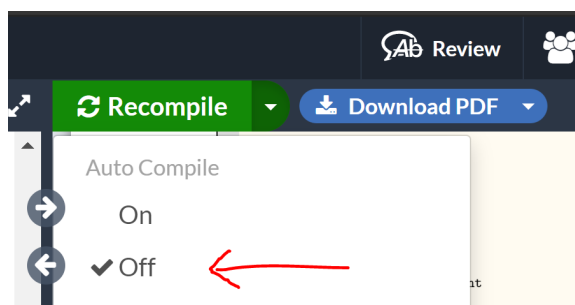


Figure D.2: Overleaf autocompile option.

D.10.2 Steps to Get Writing using Linux

The primary advantage using this method to write your thesis/dissertation is that you can write when you are offline. Another benefit of using this method is the files are on your local machine, you can open files as much as you'd like and you only compile/update when you specify.

Below are the steps you will need to take to get your thesis/dissertation working on your local machine:

1. Enable the Linux subsystem for Windows (Figure D.3)

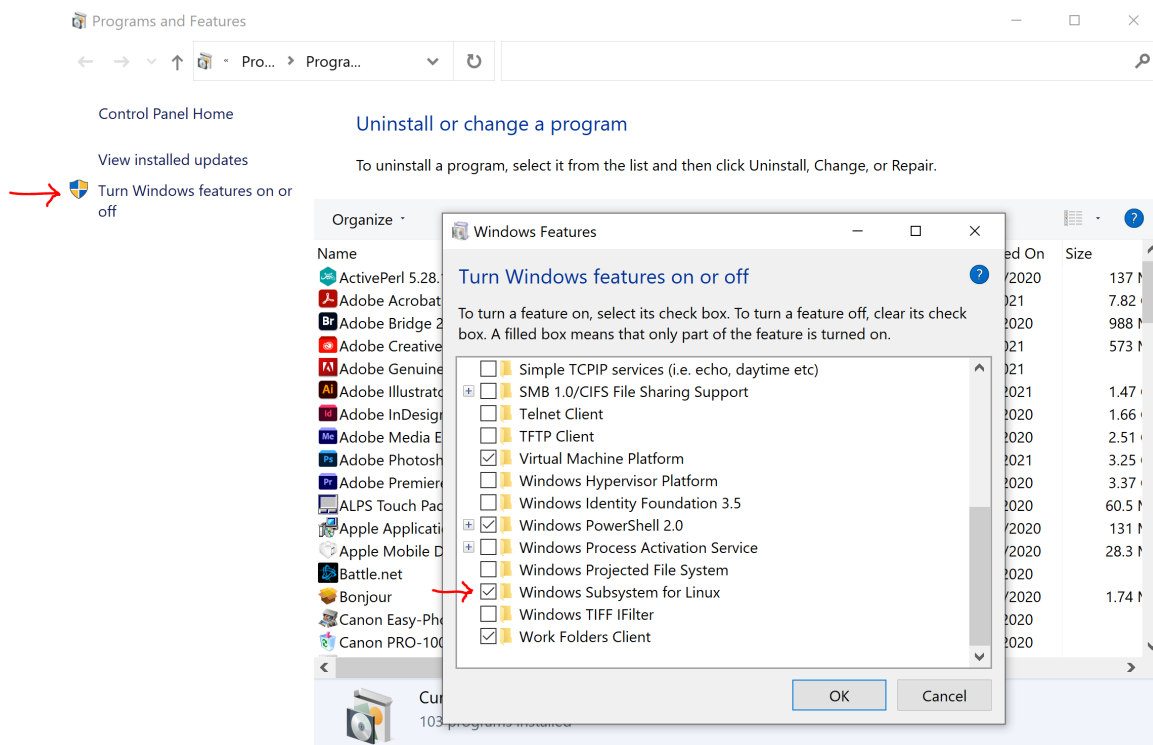


Figure D.3: Enable Windows Subsystem for Linux

2. Download the Ubuntu application from the Microsoft App store (Figure D.4)

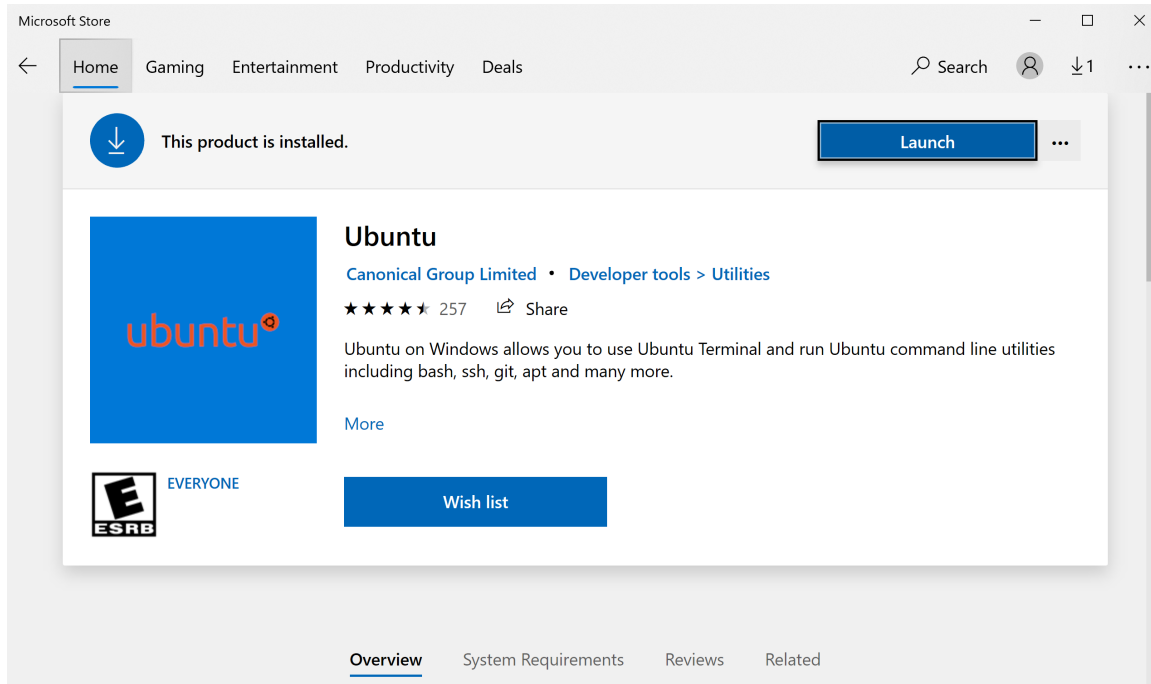


Figure D.4: Download Ubuntu

3. Create a [GitLab](https://gitlab.com) account to pull files. (You will learn how to do version control once you get your Thesis/Dissertation setup). There is a fabulous link to learn the basics of Git: <https://docs.gitlab.com/ee/gitlab-basics/start-using-git.html>
4. Initialize Ubuntu on your local machine and establish the connection to your own repository.

```
git config --global user.name "your_username"
git config --global user.email "your_email_address@example.com"
```

5. Clone the Thesis/Dissertation template to your local machine from the following link: <https://gitlab.com/SkiEngineer/uofuthesistemplate.git>. (Figures D.5 and D.6).

```
git clone https://gitlab.com/SkiEngineer/uofuthesistemplate.git
```

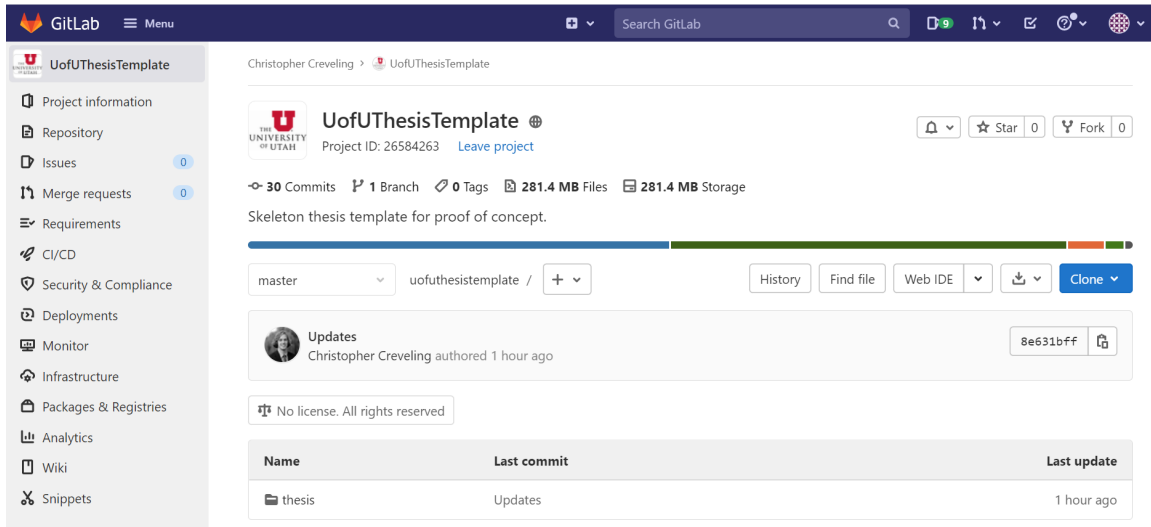


Figure D.5: GitLab main screen.

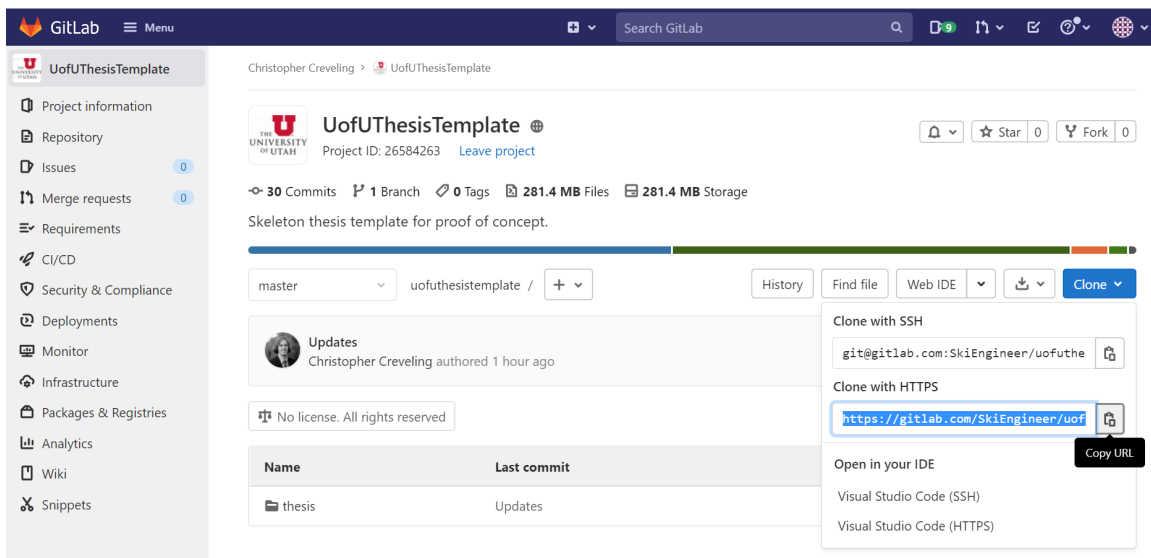


Figure D.6: Clone repository.

- In GitLab, create a new project titled: "new_awesome_project" (*This will be the name of your Thesis/Dissertation*). This is where you are going to put the Thesis/Dissertation template and make changes. Create a new local directory titled: "new_awesome_project". Navigate inside the newly created folder and clone this "new" repository to your local machine. See [Figure D.6](#) for details.

```
git clone https://gitlab.com/SkiEngineer/new_awesome_project.git
```

- Navigate to the "uofuthesistemplate" template folder directory and copy the files to your own Thesis/Dissertation folder on your local machine in the subsystem directory.

```
cd ..
cd uofuthesistemplate
cp -r thesis ../new_awesome_project
```

(Figure D.7).

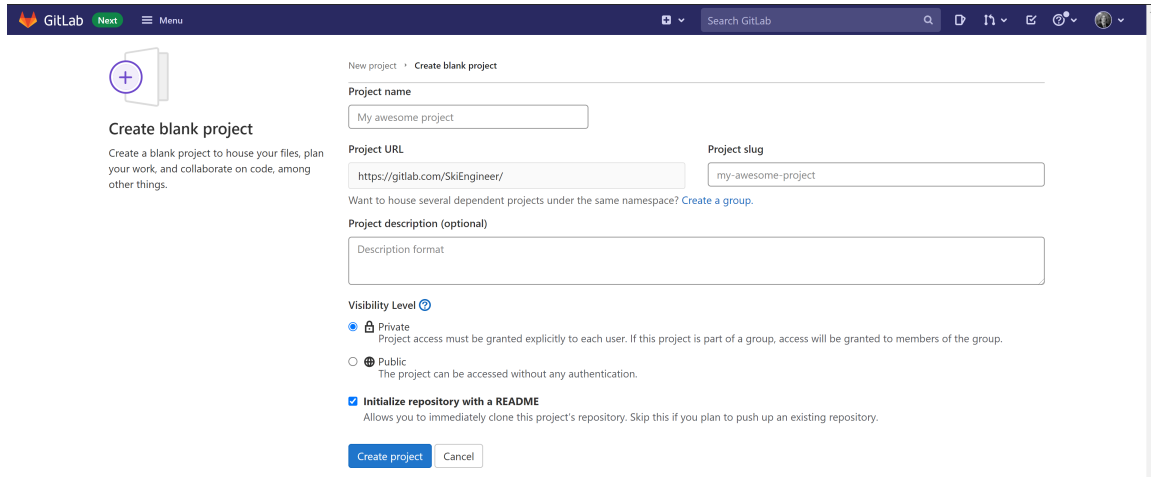


Figure D.7: Make a new project.

8. Navigate inside your newly created project “new_awesome_project” directory. Add the new folder containing the copied uofuthesistemplate thesis folder to your own repository on GitLab

```
cd ..
cd new_awesome_project
git add thesis
git commit -m "Initial commit of UofU thesis template"
git push
```

D.10.3 Required Ubuntu installations. Use a bash terminal to execute the following commands

1. Download make

```
sudo apt-get install build-essential
```

→ The Linux “make” command is used to build and maintain groups of programs and files from the source code. In Linux, it is one of the most frequently used commands by the developers. It assists developers to install and compile many utilities from the terminal.

2. Download L^AT_EX

```
sudo apt install texlive-latex-extra
```

→ L^AT_EX - is a document writing system

3. Download B_BT_EX

```
sudo apt install texlive-bibtex-extra
```

→ B_BT_EX reads the top-level auxiliary (.aux) file auxname that was output during the running of latex(1) or tex(1) and creates a bibliography (.bbl) file that will be incorporated into the document on subsequent runs of L^AT_EX or T_EX.

B_BT_EX looks up, in bibliographic database (.bib) files specified by the `\bibliography` command, the entries specified by the `\cite` and `\nocite` commands in the L^AT_EX or T_EX source file. It formats the information from those entries according to instructions in a bibliography style (.bst) file (specified by the `\bibliographystyle` command, and it outputs the results to the .bbl file.

The L^AT_EX manual explains what a L^AT_EX source file must contain to work with B_BT_EX. Appendix B of the B_BT_EX manual describes the format of the .bib files. The ‘BibTeXing’ document describes extensions and details of this format, and it gives other useful hints for using B_BT_EX.

4. Download texlive-science

```
sudo apt-get install texlive-science
```

→ `texlive-science` : Mathematics, natural sciences, computer science packages

5. Download texlive-fonts-extr

```
sudo apt-get install texlive-fonts-extra
```

—→ [texlive-fonts-extra](#) Additional L^AT_EX fonts

6. Download biber

```
sudo apt-get install -y biber
```

—→ [biber](#) Much-augmented B_BT_EX replacement for BibLaTeX users The biblatex package by Philipp Lehman is becoming the definitive citation management tool for L^AT_EX users. Biblatex has relied on the venerable B_BT_EX program only for sorting and generating a very generic .bb1 file without any formatting instruction. Everything else is taken care of by biblatex, which provides a powerful and flexible macro interface for authors of citation styles. Much-augmented B_BT_EX replacement for BibLaTeX users The biblatex package by Philipp Lehman is becoming the definitive citation management tool for L^AT_EX users. Biblatex has relied on the venerable B_BT_EX program only for sorting and generating a very generic .bb1 file without any formatting instruction. Everything else is taken care of by biblatex, which provides a powerful and flexible macro interface for authors of citation styles.

7. Download Latexmk

```
sudo apt-get install -y latexmk
```

—→ [Latexmk](#) completely automates the process of compiling a L^AT_EX document. Essentially, it is like a specialized relative of the general make utility, but one which determines dependencies automatically and has some other very useful features. In its basic mode of operation latexmk is given the name of the primary source file for a document, and it issues the appropriate sequence of commands to generate a .dvi, .ps, .pdf and/or hardcopy version of the document.

8. Download Pygments

```
sudo apt-get install python3-pygments
```

→ *Pygments* Pygments is a syntax highlighting engine written in Python. That means, it will take source code (or other markup) in a supported language and output a processed version (in different formats) containing syntax highlighting markup.

- a wide range of over 500 languages and other text formats is supported
- special attention is paid to details that increase highlighting quality
- support for new languages and formats are added easily; most languages use a simple regex-based lexing mechanism
- a number of output formats is available, among them HTML, RTF, \LaTeX and ANSI sequences
- it is usable as a command-line tool and as a library

D.10.4 Editing Methods For Your Thesis/Dissertation

There are two ways you can edit the text of your document:

1. Use *Notepad++* (Figure D.8)

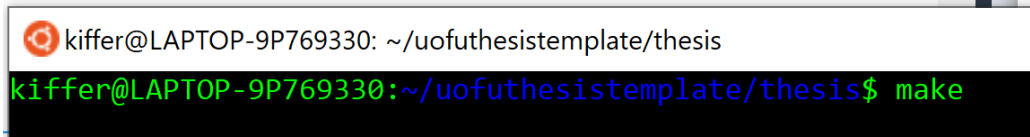
```

1  %% -*-LaTeX-*-*
2  \documentclass[../Dissertation]{subfiles}
3
4  \doublespacing
5  \graphicspath{{Chapter1/Media/}{Media/}}-% Graphics path for images
6
7  \begin{document}
8
9  \section{Overview}\label{s:chp1_overview}
10 ..... \lipsum[1]
11
12 \end{document}

```

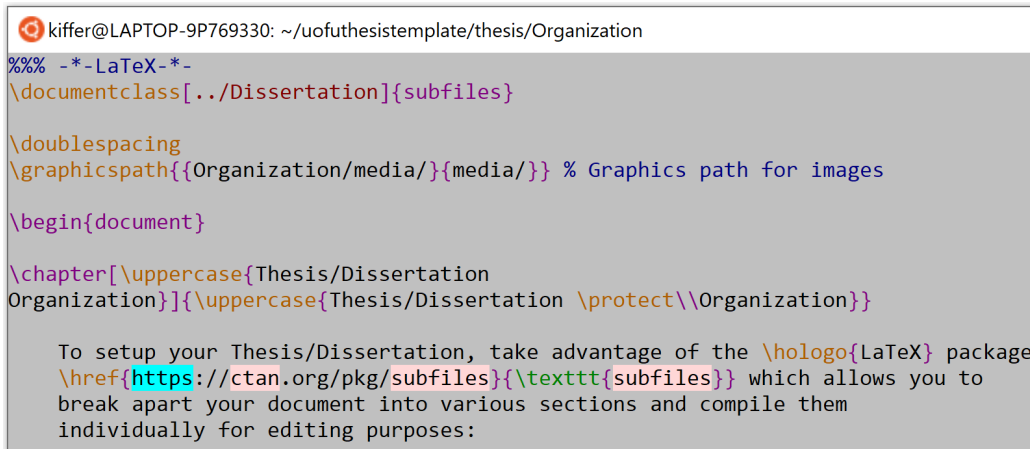
Figure D.8: Notepad++ editing tool.

2. Use *vi* via the command line interface (*Increased efficiency* - Your fingers will never leave the keyboard) (Figure D.9).



```
kiffer@LAPTOP-9P769330: ~/uofuthesistemplate/thesis
kiffer@LAPTOP-9P769330:~/uofuthesistemplate/thesis$ make
```

Figure D.10: Screen snip of Makefile command to compile the Thesis/Dissertation.



```
kiffer@LAPTOP-9P769330: ~/uofuthesistemplate/thesis/Organization
%% -*-LaTeX-*-%
\documentclass[../Dissertation]{subfiles}

\doublespacing
\graphicspath{{Organization/media/}{media/}} % Graphics path for images

\begin{document}

\chapter{\uppercase{Thesis/Dissertation
Organization}}{\uppercase{Thesis/Dissertation \protect\\Organization}}

To setup your Thesis/Dissertation, take advantage of the \hologo{LaTeX} package
\href{https://ctan.org/pkg/subfiles}{\texttt{subfiles}} which allows you to
break apart your document into various sections and compile them
individually for editing purposes:
```

Figure D.9: vi editing tool.

Add all images/figures to the media folder within each chapter

D.10.5 How To Make Changes

Individual makefiles have been created to execute the necessary commands to compile your Thesis/Dissertation.

The basic commands inside of the Ubuntu terminal are:

- “`make`” → compiles the document. The associated screen snip in the Bash terminal is seen in [Figure D.10](#) to compile the Thesis/Dissertation.
- “`make release`” → cleans up the unnecessary files and moves the final PDF into the folder titled “Release”. To move the final PDF into the “Release” folder, simply type “`make release`” and the PDF will be moved and the following L^AT_EX compilation documents will be deleted from the folder. This is seen in [Figure D.11](#).
- “`make clean`”
- “`make clear`”

```
kiffer@LAPTOP-9P769330: ~/uofuthesistemplate/thesis
kiffer@LAPTOP-9P769330:~/uofuthesistemplate/thesis$ make release
```

Figure D.11: Screen snip of Makefile command to clean up the file directory and move the PDF to the “Release” folder.

D.10.5.1 Sample Makefiles

The following Makefile is used to compile the Thesis/Dissertation:

```
</> Script 25: ... $\LaTeX$  script used to compile the Thesis/Dissertation. </>
1 # Linux Makefile to create a final pdf of the project
2
3 # Variables
4 FILE = Dissertation
5
6 # PDF LaTeX specific
7 TEX = "pdflatex -interaction=nonstopmode -synctex=1 --shell-escape"
8
9 # You want latexmk to *always* run, because make does not have all the info.
10 # Also, include non-file targets in .PHONY so they are run regardless of any
11 # file of the given name existing.
12 .PHONY: ${FILE}.pdf all clean
13
14 # The first rule in a Makefile is the one executed by default ("make"). It
15 # should always be the "all" rule, so that "make" and "make all" are identical.
16 all: ${FILE}.pdf
17
18 # CUSTOM BUILD RULES
19
20 # In case you didn't know, '$@' is a variable holding the name of the target,
21 # and '$<' is a variable holding the (first) dependency of a rule.
22 # "raw2tex" and "dat2tex" are just placeholders for whatever custom steps
23 # you might have.
24
25 %.tex: %.raw
26     ./raw2tex $< > $@
27
28 %.tex: %.dat
29     ./dat2tex $< > $@
30
31 # MAIN LATEXMK RULE
32
33 # -pdf tells latexmk to generate PDF directly (instead of DVI).
34 # -pdflatex="" tells latexmk to call a specific backend with specific options.
35 # -use-make tells latexmk to call make for generating missing files.
36
37 # -interaction=nonstopmode keeps the pdflatex backend from stopping at a
38 # missing file reference and interactively asking you for an alternative.
39
40 # --shell-escape allows for *minted to run code highlighting
41
42 # -f forces latexmk to run until compiling has been complete regardless of
```

```

43 # cross referencing (i.e. it continues to run until references are in the
44 # correct location)
45
46 ${FILE}.pdf: ${FILE}.tex
47     latexmk -pdf -pdflatex=${TEX} -f -use-make ${FILE}.tex
48
49 # Clean up unnecessary files
50 clean:
51     latexmk -C
52     # specific to latexmk
53
54 clear:
55     rm -rf auto *_minted-* *.log *.aux *.synctex.gz *.out *.toc *.run *.bcf *.lof
56     ↪ *.lot *.tdo *.run.xml *.pdf *.bbl *.blg *.swp
57
58 release:
59     rm -rf Release # Once the folder is created, no need to create a new one
60     mkdir Release # Once the folder is created, no need to create a new one
61     cp *.pdf Release
62     make clear
63     make clean

```

The following Makefile is used to compile Chapter 1 of the Thesis/Dissertation:

```

</> Script 26: ... $\LaTeX$  script used to compile Chapter1. </>
1 # Linux Makefile to create a final pdf of the project
2
3 # Variables
4 CHAPTER = Chapter1
5 OVERVIEW = 0_Overview
6 BACKGROUND = 1_Background
7 AIMS = 2_Aims
8 IMPACT = 3_Impact
9
10 # PDF LaTeX specific
11 TEX = "pdflatex -interaction=nonstopmode -synctex=1 --shell-escape"
12
13 # You want latexmk to *always* run, because make does not have all the info.
14 # Also, include non-file targets in .PHONY so they are run regardless of any
15 # file of the given name existing.
16 .PHONY: ${CHAPTER}.pdf all clean
17
18 # The first rule in a Makefile is the one executed by default ("make"). It
19 # should always be the "all" rule, so that "make" and "make all" are identical.
20 all: ${CHAPTER}.pdf
21
22 # CUSTOM BUILD RULES
23
24 # In case you didn't know, '$@' is a variable holding the name of the target,
25 # and '$<' is a variable holding the (first) dependency of a rule.
26 # "raw2tex" and "dat2tex" are just placeholders for whatever custom steps
27 # you might have.
28
29 %.tex: %.raw
30     ./raw2tex $< > $@
31

```

```

32 %.tex: %.dat
33     ./dat2tex $< > $@
34
35 chapter: ${CHAPTER}.pdf
36 overview: ${OVERVIEW}.pdf
37 background: ${BACKGROUND}.pdf
38 aims: ${AIMS}.pdf
39 impact: ${IMPACT}.pdf
40
41 # MAIN LATEXMK RULE
42
43 # -pdf tells latexmk to generate PDF directly (instead of DVI).
44 # -pdflatex="" tells latexmk to call a specific backend with specific options.
45 # -use-make tells latexmk to call make for generating missing files.
46
47 # -interaction=nonstopmode keeps the pdflatex backend from stopping at a
48 # missing file reference and interactively asking you for an alternative.
49
50 # --shell-escape allows for *minted to run code highlighting
51
52 # -f forces latexmk to run until compiling has been complete regardless of
53 # cross referencing (i.e. it continues to run until references are in the
54 # correct location)
55
56 ${CHAPTER}.pdf: ${CHAPTER}.tex
57     latexmk -pdf -pdflatex=${TEX} -f -use-make ${CHAPTER}.tex
58
59 ${OVERVIEW}.pdf: ${OVERVIEW}.tex
60     latexmk -pdf -pdflatex=${TEX} -f -use-make ${OVERVIEW}.tex
61
62 ${BACKGROUND}.pdf: ${BACKGROUND}.tex
63     latexmk -pdf -pdflatex=${TEX} -f -use-make ${BACKGROUND}.tex
64
65 ${AIMS}.pdf: ${AIMS}.tex
66     latexmk -pdf -pdflatex=${TEX} -f -use-make ${AIMS}.tex
67
68 ${IMPACT}.pdf: ${IMPACT}.tex
69     latexmk -pdf -pdflatex=${TEX} -f -use-make ${IMPACT}.tex
70
71
72 # Clean up unnecessary files
73 clean:
74     latexmk -C
75
76 clear:
77     rm -rf auto *_minted-* *.log *.aux *.synctex.gz *.out *.toc *.run *.bcf *.lof
78     ↪ *.lot *.tdo *.run.xml *.pdf *.bbl *.blg *.swp
79
80 release:
81     # rm -rf Release # Once the folder is created, no need to create a new one
82     # mkdir Release # Once the folder is created, no need to create a new one
83     cp *.pdf Release
84     make clear
85     make clean

```

The following Makefile is used to compile Chapter 2 of the Thesis/Dissertation:

</> **Script 27: ... \LaTeX script used to compile Chapter2.** </>

```

1 # Linux Makefile to create a final pdf of the project
2
3 # Variables
4 CHAPTER =      Chapter2
5 ABSTRACT =     0_Abstract
6 INTRODUCTION = 1_Introduction
7 METHODS =      2_Methods
8 RESULTS =      3_Results
9 DISCUSSION =   4_Discussion
10 CONCLUSION =   5_Conclusion
11 ACKNOWLEDGE = 6_Acknowledgment
12
13 # PDF LaTeX specific
14 TEX = "pdflatex -interaction=nonstopmode -synctex=1 --shell-escape"
15
16 # You want latexmk to *always* run, because make does not have all the info.
17 # Also, include non-file targets in .PHONY so they are run regardless of any
18 # file of the given name existing.
19 .PHONY: ${CHAPTER}.pdf all clean
20
21 # The first rule in a Makefile is the one executed by default ("make"). It
22 # should always be the "all" rule, so that "make" and "make all" are identical.
23 all: ${CHAPTER}.pdf
24
25 # CUSTOM BUILD RULES
26
27 # In case you didn't know, '$@' is a variable holding the name of the target,
28 # and '$<' is a variable holding the (first) dependency of a rule.
29 # "raw2tex" and "dat2tex" are just placeholders for whatever custom steps
30 # you might have.
31
32 %.tex: %.raw
33     ./raw2tex $< > $@
34
35 %.tex: %.dat
36     ./dat2tex $< > $@
37
38 chapter: ${CHAPTER}.pdf
39 abstract: ${ABSTRACT}.pdf
40 introduction: ${INTRODUCTION}.pdf
41 methods: ${METHODS}.pdf
42 results: ${RESULTS}.pdf
43 discussion: ${DISCUSSION}.pdf
44 conclusion: ${CONCLUSION}.pdf
45 acknowledge: ${ACKNOWLEDGE}.pdf
46
47 # MAIN LATEXMK RULE
48
49 # -pdf tells latexmk to generate PDF directly (instead of DVI).
50 # -pdflatex="" tells latexmk to call a specific backend with specific options.
51 # -use-make tells latexmk to call make for generating missing files.
52
53 # -interaction=nonstopmode keeps the pdflatex backend from stopping at a
54 # missing file reference and interactively asking you for an alternative.
55
56 # --shell-escape allows for *minted to run code highlighting

```

```

57
58 # -f forces latexmk to run until compiling has been complete regardless of
59 # cross referencing (i.e. it continues to run until references are in the
60 # correct location)
61
62 ${CHAPTER}.pdf: ${CHAPTER}.tex
63     latexmk -pdf -pdflatex=${TEX} -f -use-make ${CHAPTER}.tex
64
65 ${ABSTRACT}.pdf: ${ABSTRACT}.tex
66     latexmk -pdf -pdflatex=${TEX} -f -use-make ${ABSTRACT}.tex
67
68 ${INTRODUCTION}.pdf: ${INTRODUCTION}.tex
69     latexmk -pdf -pdflatex=${TEX} -f -use-make ${INTRODUCTION}.tex
70
71 ${METHODS}.pdf: ${METHODS}.tex
72     latexmk -pdf -pdflatex=${TEX} -f -use-make ${METHODS}.tex
73
74 ${RESULTS}.pdf: ${RESULTS}.tex
75     latexmk -pdf -pdflatex=${TEX} -f -use-make ${RESULTS}.tex
76
77 ${DISCUSSION}.pdf: ${DISCUSSION}.tex
78     latexmk -pdf -pdflatex=${TEX} -f -use-make ${DISCUSSION}.tex
79
80 ${CONCLUSION}.pdf: ${CONCLUSION}.tex
81     latexmk -pdf -pdflatex=${TEX} -f -use-make ${CONCLUSION}.tex
82
83 ${ACKNOWLEDGE}.pdf: ${ACKNOWLEDGE}.tex
84     latexmk -pdf -pdflatex=${TEX} -f -use-make ${ACKNOWLEDGE}.tex
85
86 # Clean up unnecessary files
87 clean:
88     latexmk -C
89
90 clear:
91     rm -rf auto *_minted-* *.log *.aux *.synctex.gz *.out *.toc *.run *.bcf *.lof
92     ↪ *.lot *.tdo *.run.xml *.pdf *.bbl *.blg *.swp
93
94 release:
95     # rm -rf Release # Once the folder is created, no need to create a new one
96     # mkdir Release # Once the folder is created, no need to create a new one
97     cp *.pdf Release
98     make clear
99     make clean

```

The variables in each Makefile are the L^AT_EX file names and you can simply type “`make methods`” to compile the methods section of a particular chapter. The same is true for “`make abstract`”, “`make results`”, and “`make discussion`” which will compile the abstract, results, and discussion section, respectively. This is useful for editing sections of the document where you do not necessarily need to compile the entire document.