Effective Writing and Figure-Making for Researchers

An event by Research Insights Club

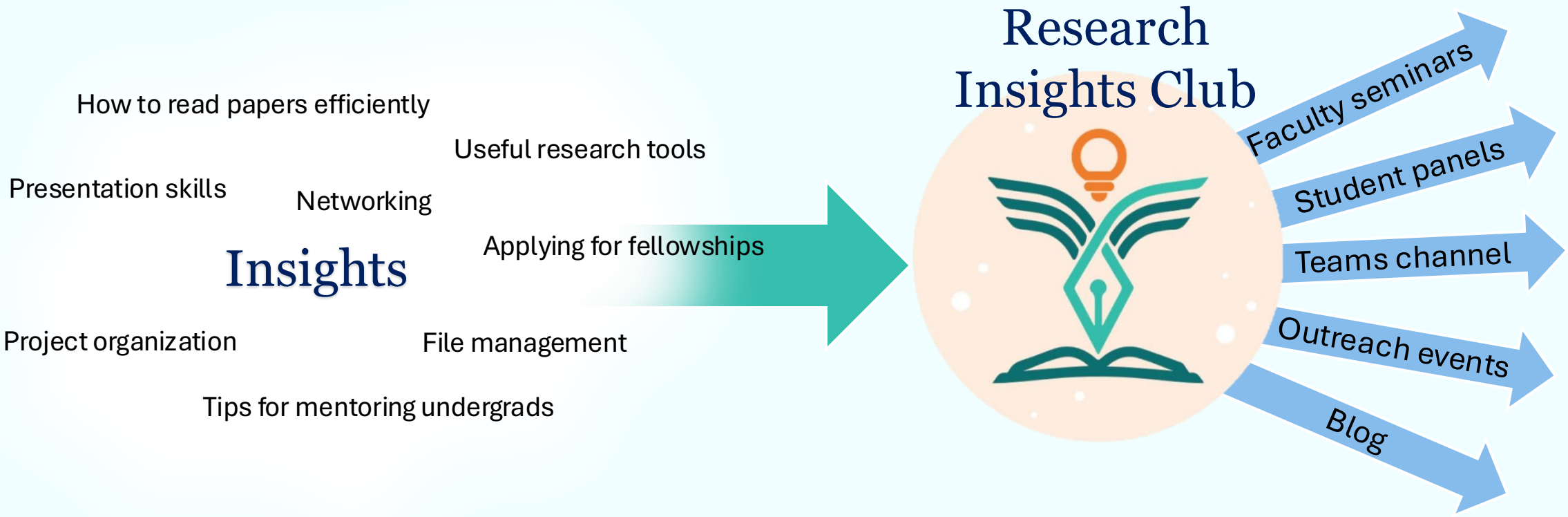
Research Insights Club

Our Purpose

(1) To disseminate detailed and hard-to-obtain knowledge to Georgia Tech students to help them navigate and thrive in the complex field of academic research.

(2) To facilitate knowledge transfer and networking between student researchers outside their usual fields.

Implementation Strategy



Join us!

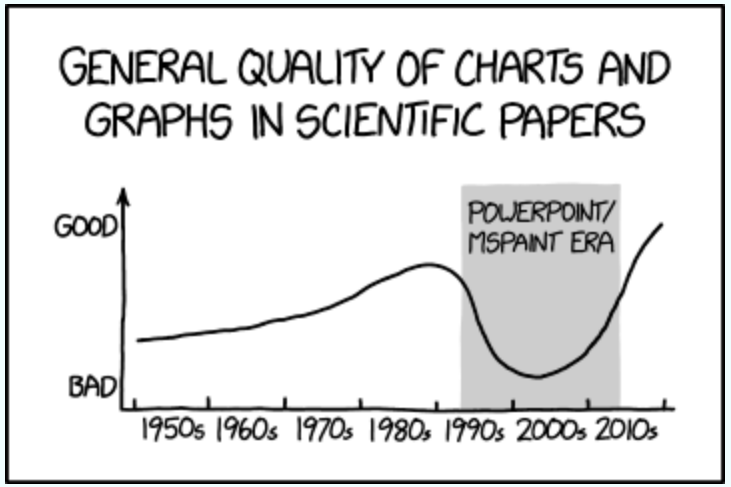
Students & researchers at all levels welcome

- If interested, reach out to Steven Swingle → steven.swingle@gatech.edu
- Find us on Engage https://gatech.campuslabs.com/engage/
- Follow us on Instagram @gatech.ric

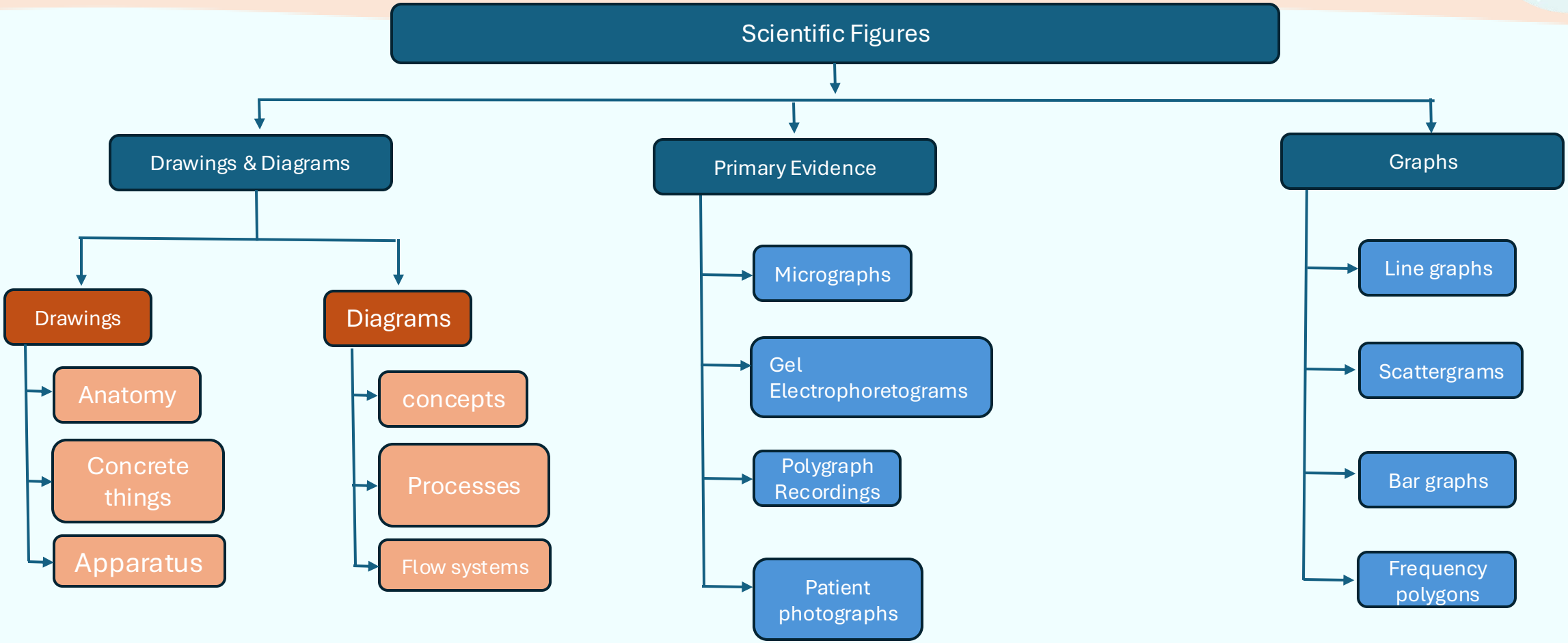
Making scientific Figures

Mehdia N. Rajab Ali

“People make snap judgements based on visuals, and if they don’t look good, they can steer someone away from a paper that otherwise they might like to read.”
- Kelly Krause, creative director for the Nature family of journals



Types of Scientific Figures



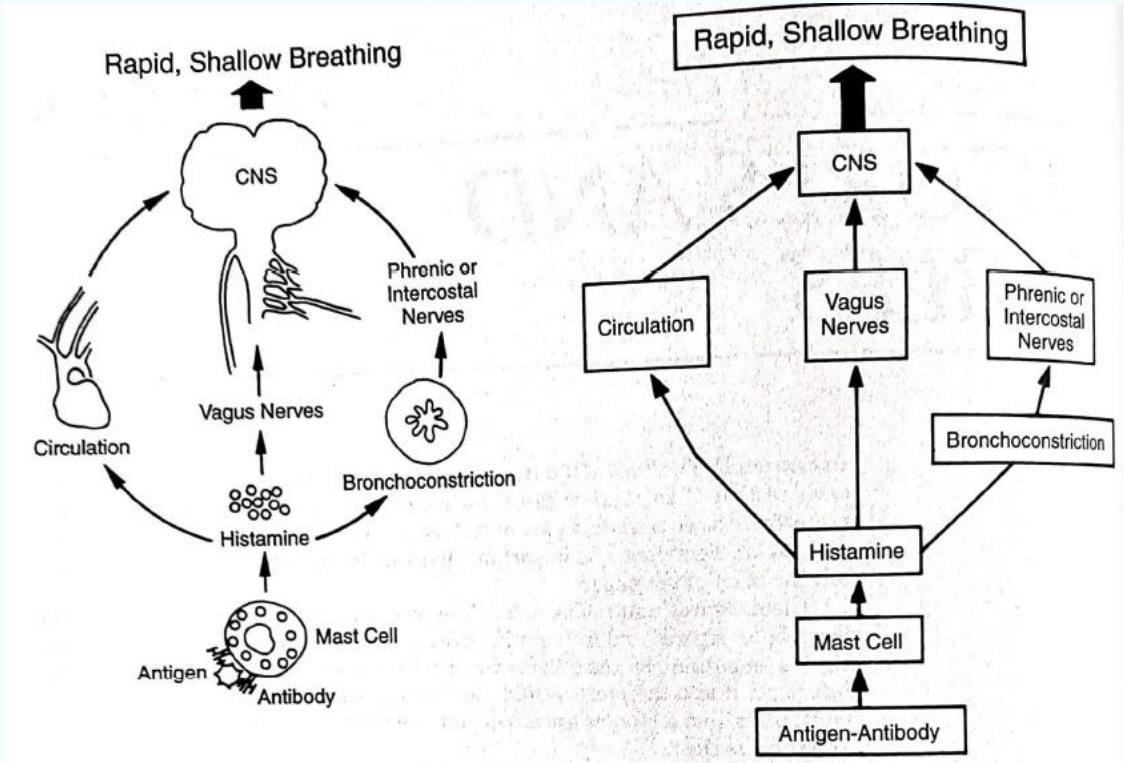
Drawings and Diagrams

Drawings:

- Illustrate anatomy, apparatus and other concrete things
- preferred for animals and apparatus

Diagrams:

- Illustrate concepts



Realistic vs Schematic Diagram

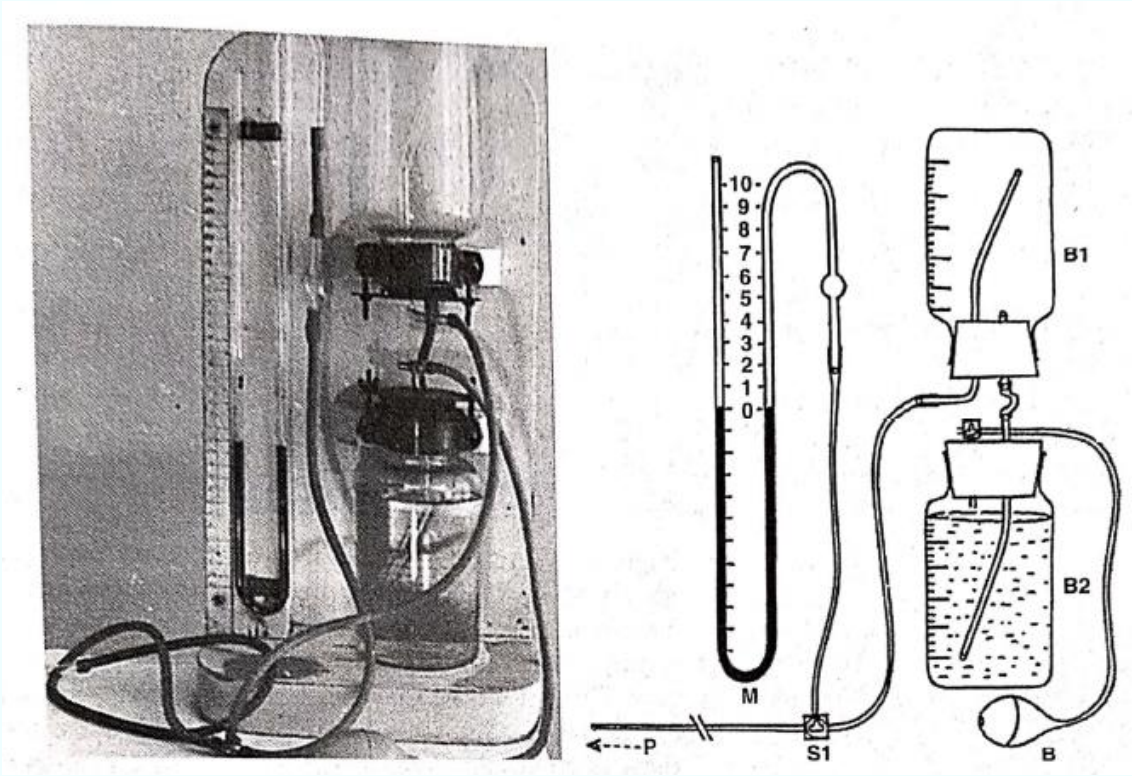
Drawings and Diagrams

Drawings:

- Illustrate anatomy, apparatus and other concrete things
- preferred for animals and apparatus

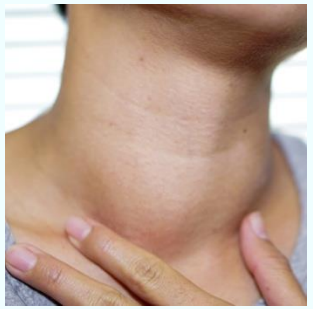
Diagrams:

- Illustrate concepts

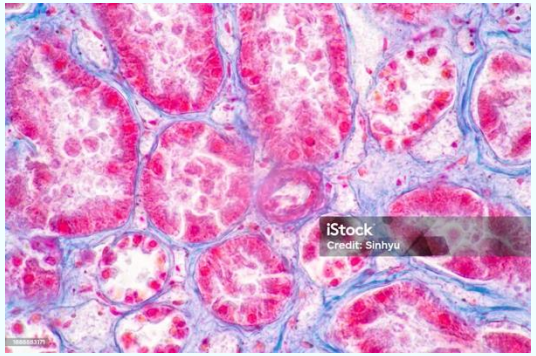


Photograph vs drawing of an apparatus

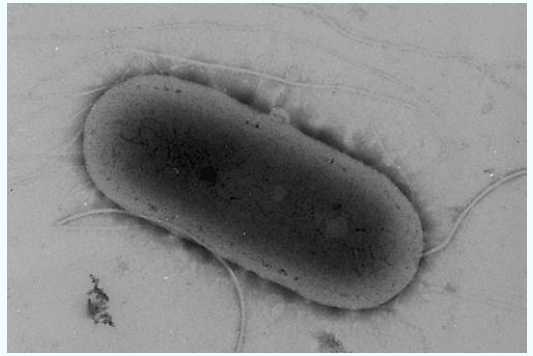
Primary Evidence



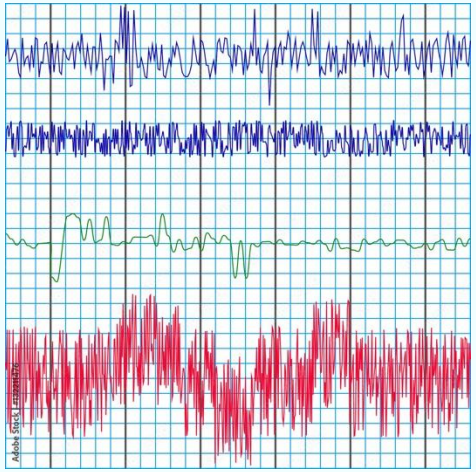
Patient pictures



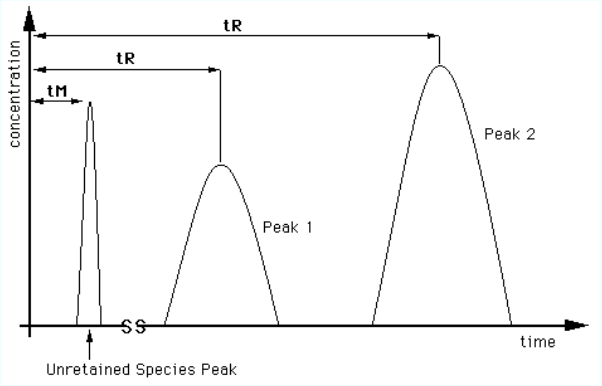
Histology Images



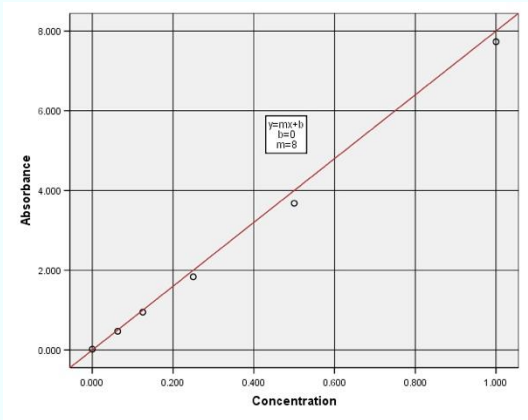
Micrographs



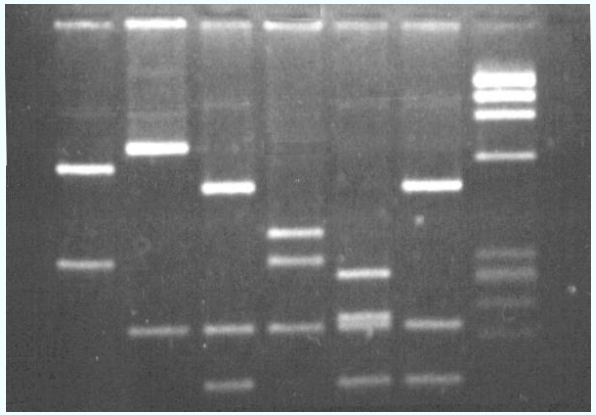
Polygraph recordings



Chromatograms



Spectrophotometer curves



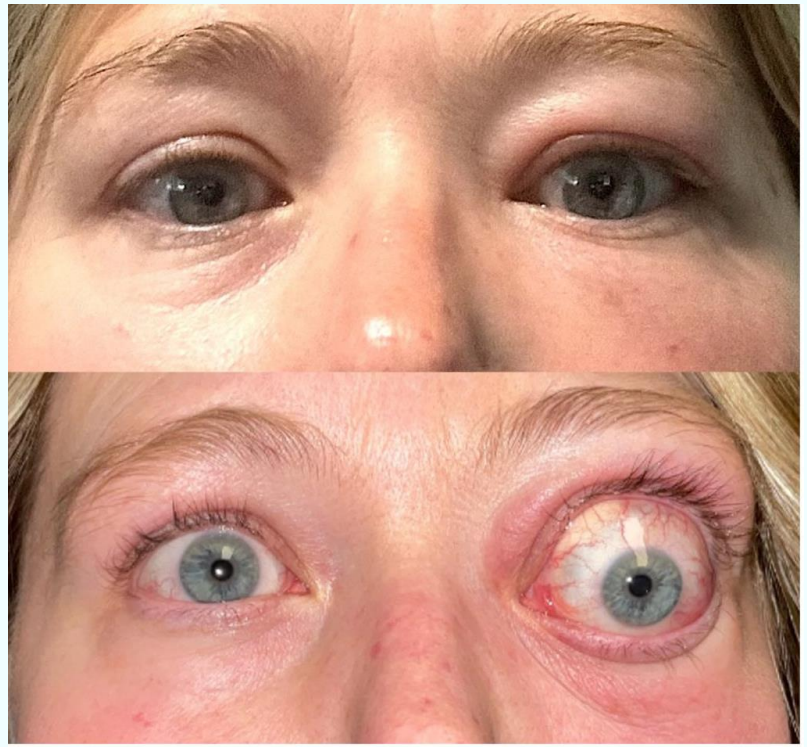
Gel electrophoretograms

Primary Evidence contd.

- Indicate Quality of data
- Select your best quality recording for publication

Photographs of Patients

- Make sure you have informed consent
- Cover facial features to deidentify patient
- Use letters such as A,B,C to refer to patients, not their initials

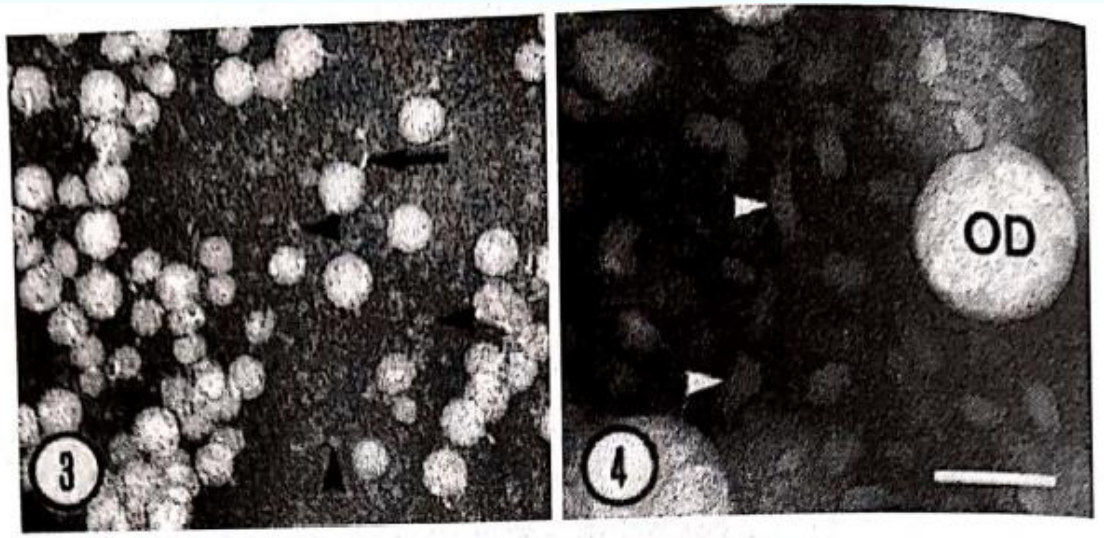


Thyroid eye disease

Primary Evidence contd.

Micrographs

- Clarity
- Size
  - Large enough to show important features
- Labelling
  - Include arrowheads, letters, numbers and symbols
  - Scale bar
- Plates
- Numbering



Figures 3 and 4. Well-prepared electron micrographs. Figure 3 shows negatively stained low-density lipoprotein treated with sodium decyl sulfate. The arrow points to one of the disc-like structures and the arrowheads point to tiny particles. Figure 4 shows the same lipoproteins after elastase digestion. The arrowheads point to irregularly shaped structures. OD identifies an oil droplet. The scale bar in the lower right corner represents 75 nm. In these micrographs, both the large, obvious structures and the small, subtle features are clearly visible.

Primary Evidence contd.

Gel Electrophoretograms

- These are halftone figures
- Identify material in each gel by adding capital letters or labels along the top or bottom of the photograph.
- Identify important fractions by adding labels along the side
- Use leader lines to join labels to their fractions
- Labels & letters should not overwhelm the data

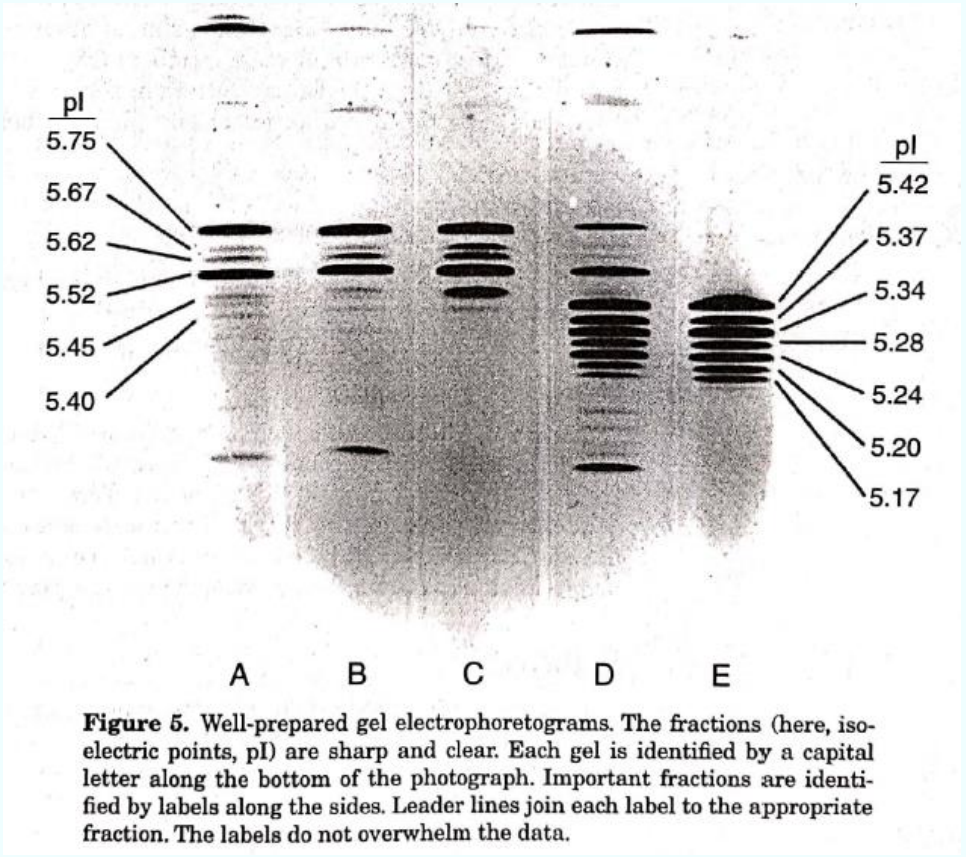


Figure 5. Well-prepared gel electrophoretograms. The fractions (here, isoelectric points, pI) are sharp and clear. Each gel is identified by a capital letter along the bottom of the photograph. Important fractions are identified by labels along the sides. Leader lines join each label to the appropriate fraction. The labels do not overwhelm the data.

Primary Evidence contd.

Polygraph Recordings

- Label axes
- Use IS abbreviations for units of measurement
- Horizontal oriented axis labels should align on the left
- Labels should not overwhelm data

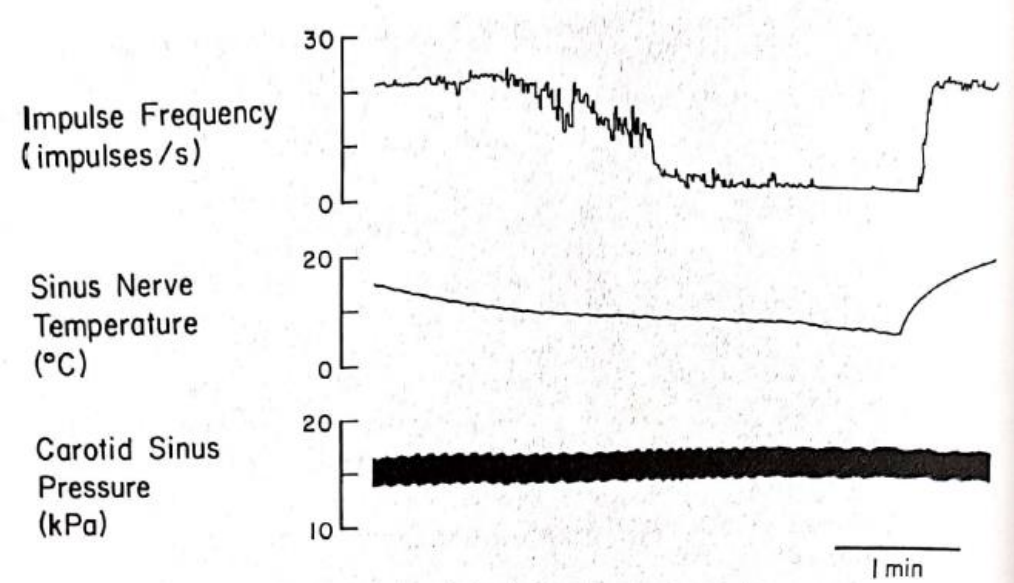


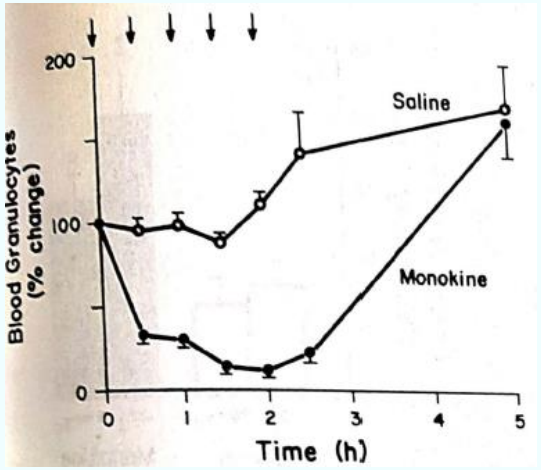
Figure 6. Well-prepared polygraph recordings. Grid lines have been eliminated, and vertical scales and a horizontal time marker have been added. Y-axis labels are aligned along the left and do not protrude into the column of scale numbers. The labels do not overwhelm the data.

Graphs

Selecting the appropriate type of graph to display the type of data you have in important

Line Graphs

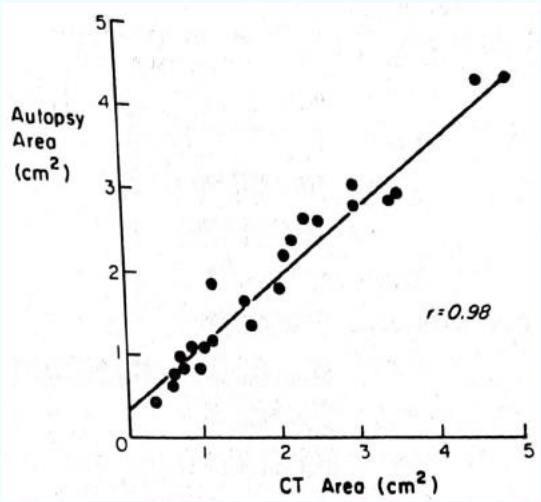
A two-axis graph on which curves, data points or both show the relation between two variables.



Line Graph

Scattergrams

A scattergram is a two-axis graph that plots individual data points and fits a mathematical function to the points to show how strongly two variables are correlated.

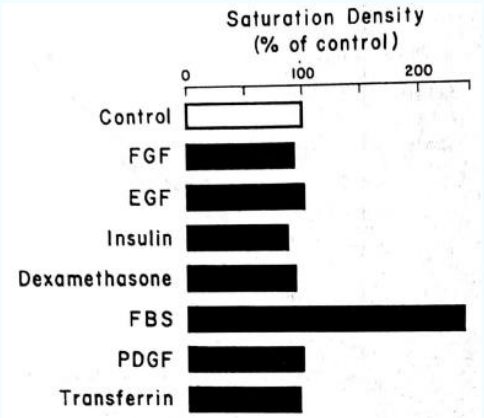


Scattergram

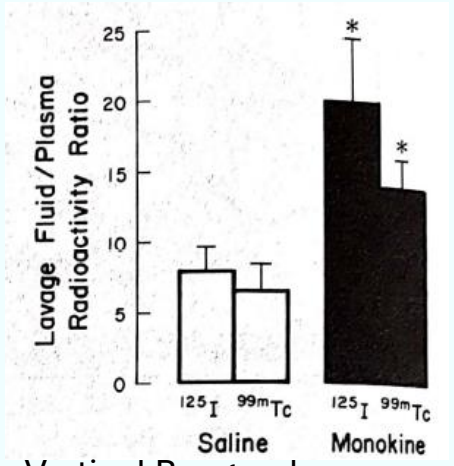
Graphs

Bar Graphs

- A bar graph is a one-axis graph that compares amounts or frequencies for classes of a discontinuous variable
- Maybe horizontal or vertical



Horizontal Bar graphs

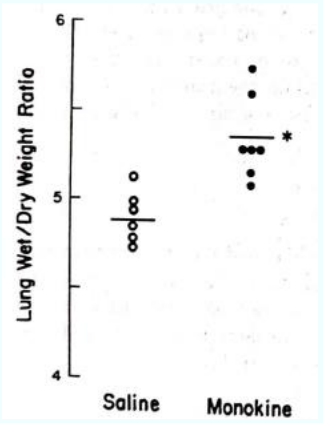


Vertical Bar graphs

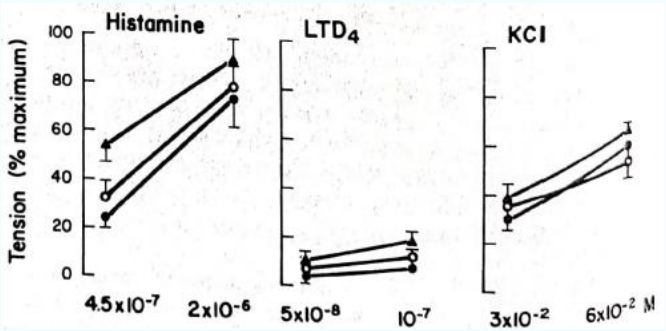
Individual-Value Bar Graph

It is a variation on vertical bar graphs in which individual data points are shown either in addition to the mean or instead of the mean.

Paired data lines can be drawn t show the direction of change



Individual-value bar graph

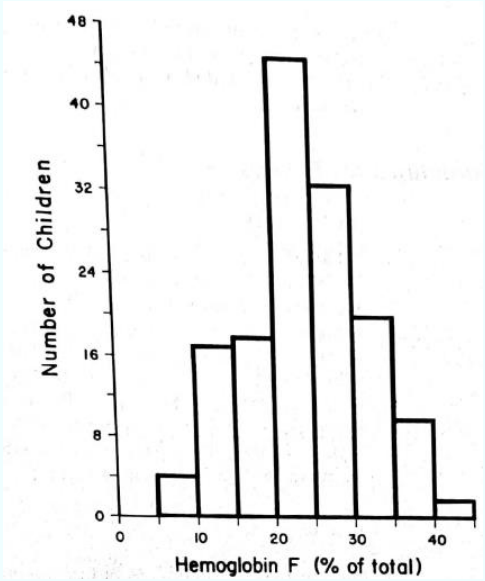


Individual-value bar graph

Graphs

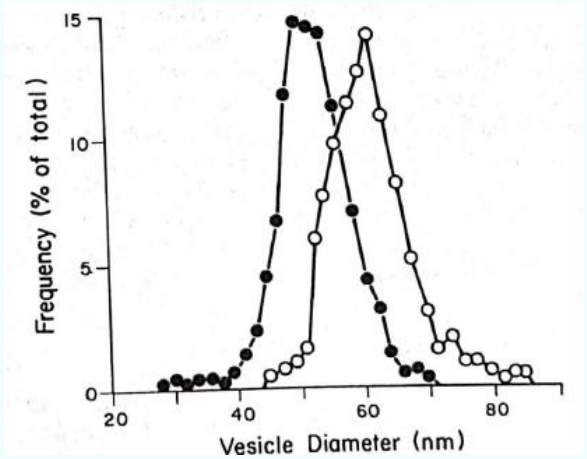
Histograms

A two-axis graph that shows a single frequency distribution by means of a series of continuous rectangles, the area of the histrogram represents the distribution.



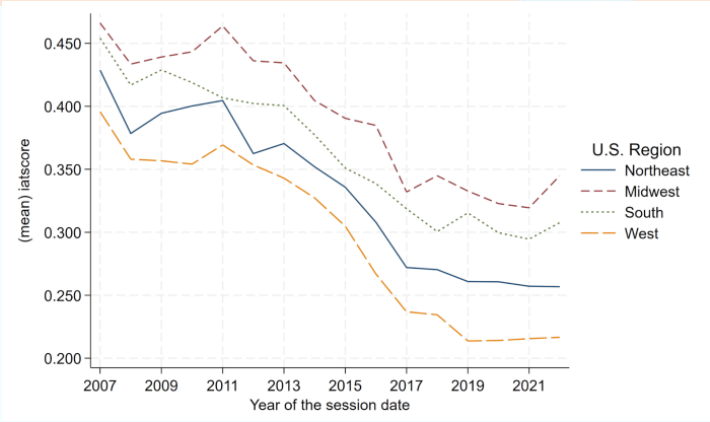
Frequency Polygons

A two-axis graph that uses data points joined by lines to show two or more overlapping frequency distributions. Data points are plotted at midpoint of each class.



General Guidelines for Figures

1. Readability
   - Lettering should be large enough
   - Symbols and shapes should be easy to differentiate
2. Emphasis
   - Use different line weights
3. Point
   - Each figure should make a clear point
4. Pick a palette
5. Do not use rainbow
6. Avoid Red



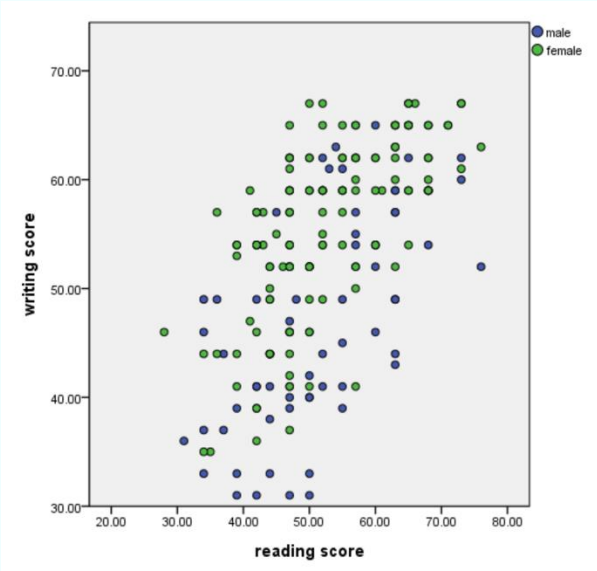
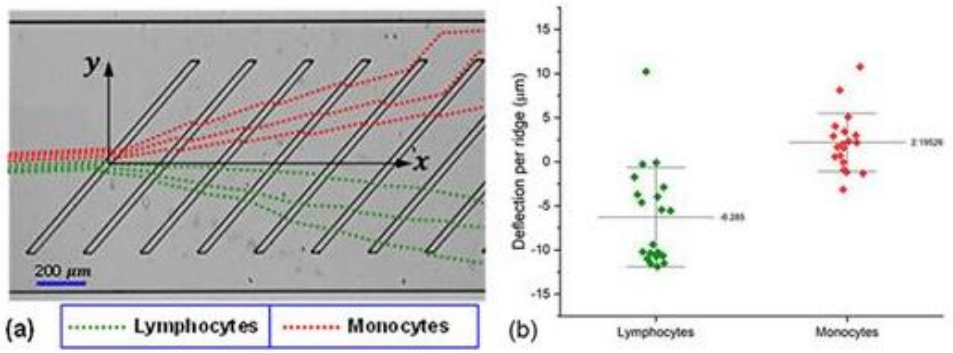


Figure Legends

Typically has 4 parts:

1. A brief title
2. Experimental details
3. Definitions of symbols, line or bar patterns
4. Statistical information (for graphs)



(a) Schematic showing the cell trajectories and coordinates of cell deflection from a previous experiment with unbiased sheath flows at 10 μl/min and the cell inlet flowing at 3 μl/min for a total flow rate of 23 μl/min. The trajectories shown with dotted lines were determined by video analysis with ImageJ. The trajectories of cells are shifted upward during biased flow. (b) Comparison of cell deflection per ridge tracked from the high-speed videos for lymphocytes and monocytes showing the separation. A total of 39 cells were tracked. The mean deflection for each cell type is displayed as well as the standard deviation bars. An unpaired, two-tailed t-test was performed to verify the difference between the mean deflection of monocytes and lymphocytes, which resulted in $p < 0.00001$.

Figure Legend title

Titles for Drawings, Diagrams, Primary Evidence

The title should identify the type of figure shown, if necessary, and the specific apparatus, concept for specimen

Example 8.1 Title for a Drawing

Fig. 1. Apparatus used for measuring intrapleural pressure.

In this title for a drawing, only the specific apparatus shown is identified.

Example 8.2 Title for a Diagram

Fig. 1. Schematic diagram of the relationship of the return cycle during resetting of ventricular tachycardia to the absence or presence of electrocardiographic fusion.

Example 8.3 Title for Primary Evidence

Fig. 1. Bright-field light micrograph of a segment of a bacterial filament showing intracellular sulfur inclusions.

Figure Legend title

Titles for Graphs

For a graph that depicts the results of an experiment in which manipulation was made and a variable measured or observed, the standard title is

Effect of X on Y in Z

X

Fig. 1. Effect of increasing concentrations of doxorubicin on release of

Y Z

histamine and lactate dehydrogenase from dog mastocytoma cells.

Alternatively, the dependent variable can come first in the standard title. In this case, the title is in a form such as

Y in response to X in Z

Y during X in Z.

Figure Legend title

Titles that state a Point

Other than the topic of the graph, the title can also state the point the graph is making. For example

Inhibition of X on Y in Z

Example 8.8 Title That States a Point

Fig. 1. Inhibition of antiviral response in MDA-MB-231 (human breast carcinoma) cells by oxyphenbutazone.

Avoid using overloaded titles and abbreviations in titles

Figure Legend title

Titles for Composites

The title should indicate the common topic illustrated in all the parts of the composite so that reader understands why is it grouped together.

Example 8.10 Parts of a Composite Figure Identified in the Title

Fig. 1. Representative Scatchard plots of the dose-response of [^{125}I] T_3-binding to lung nuclei from (A) adult and (B) 28-day-old fetal rabbits.

Figure Legend title

Experimental Details

Just enough to permit the reader to understand the figure.

Example 8.12 Experimental Details in a Sentence After the Title

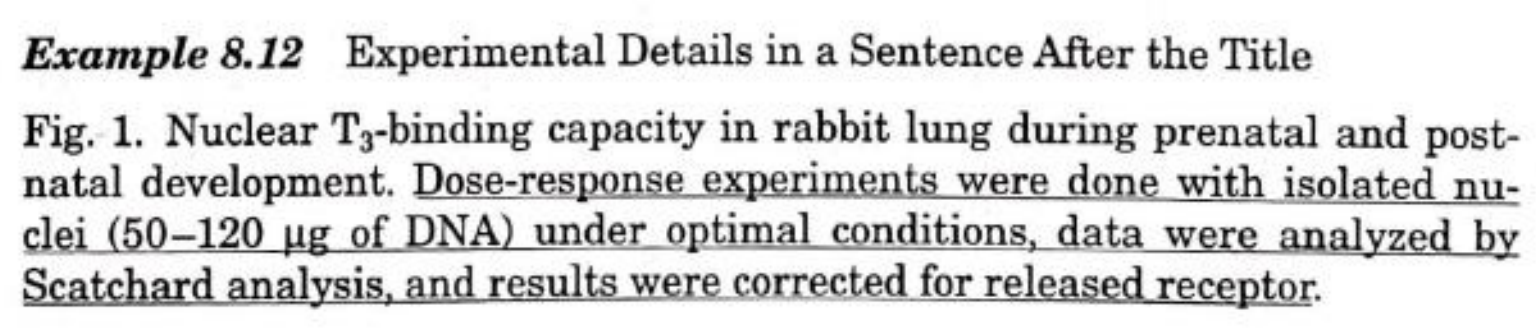


Fig. 1. Nuclear T_3-binding capacity in rabbit lung during prenatal and postnatal development. Dose-response experiments were done with isolated nuclei (50–120 μg of DNA) under optimal conditions, data were analyzed by Scatchard analysis, and results were corrected for released receptor.

Statements such as “For details, see Methods are unnecessary”

Figure Legend title

Statistical Information

Should include whether the data points or bars represent individual, mean, or median values, whether error bars represent SD or SEM, CI or ranges and the sample size (n).

Example 8.15 Statistically Significant Differences

Fig. 2. Effect of dopamine on the major determinants of left-ventricular circumferential end-systolic wall stress. *, ** significantly different from control, $*P < 0.05$, $**P < 0.01$, by ANOVA.

Example 8.16 Statistically Significant Differences, More Briefly

Fig. 2. Effect of dopamine on the major determinants of left-ventricular circumferential end-systolic wall stress. $*P < 0.05$, $**P < 0.01$ vs. control by ANOVA.

Tools & Resources

Biorender

library of around 30,000 life-science icons that can be easily turned into scientific illustrations

Free Images

Servier Medical Art

Reactome

BioIcons

Thenounproject

Scientific Writing

Anthony Compton

Introductory Question

Show of hands...

Do/Would you read the entire scientific article (start to finish w/o skipping lines)??

Why or Why not?

Introductory Question (cont.)

The truth is...

many don't read the full text.

Many people skim through to identify the major arguments/points.

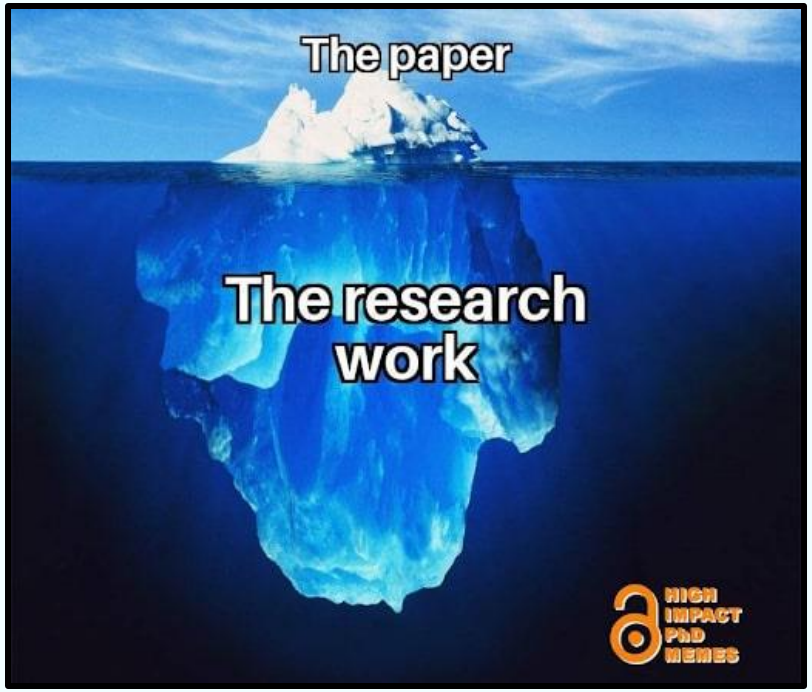
Knowing the reader's behavior is key for scientific writing.

Objectives of Scientific Writing

- Communicate the primary points
  - Scientific Question/Problem
  - Hypotheses
  - Evidence
  - Interpretations
- Make the primary points memorable for readers
- Making statements accessible across disciplines

The #1 most common rule for writing…

- Keep it concise. Short/Simple = quick and easy to read
  - Use short, simple sentences
    - Split up compound sentences
    - Avoid long dependent clauses
  - Keep terminology as basic as you can
- Try to avoid
  - Drifting to tangential topics
  - Using excess wording
    - "very", redundancies, "that…"
  - Using too many *new* acronyms
    - Common acronyms w/in a field are ok



Example/Discussion

Passage 1

This investigation proposes a novel combination of approved therapies to treat B-cell leukemia, which we are the first to compare doxorubicin and inotuzumab ozogamicin individually and in combination with other methods.

Passage 2

This investigation proposes the novel combination treatments with doxorubicin and inotuzumab ozogamicin to treat B-cell leukemia. We are the first to compare both drugs individually and in combination with other methods.

Stress the Main Points!

- Make points both clear in understanding and visuals
  - Understanding: Use signaling language to guide readers
    - Ex: Key, novel/new, innovative, significant, therefore, in conclusion
  - Visual: Make key statements *visually distinct* from your text
    - Hypothesis, statement of significance/innovation, important conclusion/interpretation
    - Italicize or underline or bold (never at the same time)
- **Main points will be memorable to readers no matter their style**

See the Difference

Age-related Macular Degeneration (AMD) is responsible for 21.6% of permanent blindness in high-income nations, and its incidence is increasing annually. Three-dimensional retinal engraftments produced from patient-derived induced pluripotent stem cells (iPSCs) have been proposed as a regenerative treatment to restore sight; however, the therapy requires functional retinal pigment epithelial (RPE) cells. There are two primary subtypes of RPE cells based on their location: macular and peripheral. Macular RPE cells are in the macula, which has a higher concentration of photoreceptors than the peripheral retina. Therefore, macular RPE cells have three times the phagocytic capacity compared to peripheral RPE cells. Retinal engraftments for AMD patients must contain macular RPE cells to ensure that the implanted photoreceptors are cared for and that the engraftment does not decrease in quality in the long term.

See the Difference

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Structuring Content

- Making information flow and easy to follow
  - Section your writing
    - Common sections: Introduction, Methods, Results, Conclusions, Discussion
    - Add subsections with headers: Methods for which part?
      - Italics or underlined
  - Paragraph "entry points": Indications on where the reader starts
    - Starting with an important key word related to the topic
      - Typically a proper noun: capital letters stand out more
  - Place figures near the text that references them
    - Readers may want more details than the caption

Structuring Content Example

naling genes (Supplementary Fig. 1). A separate, detailed study on cell viability after rapid compressions, including expression of apoptotic genes, was consistent with this observation [21]. These results suggested that cells recovered normal volume and function after the brief volume loss.

Characterizing volume exchange through molecular delivery

The volume reduction in compressed cells indicated that a portion of cytosol was expelled from the cell interior through a mechanically compromised cell membrane. Cell volume recovery, on the other hand, requires extracellular fluid to enter the cell. Since the video analysis does not allow us to evaluate cell volume in between the ridges, we further characterized the dynamics of volume exchange and fluid transfer through the compromised cell membrane using fluorescently labeled dextran (Sigma–Aldrich) as a tracker molecule. Dextran of various sizes was added to the cell suspension immediately before compression experiments. We hypothesized that cell relaxations after each compression will cause the extracellular fluid to enter the cell interior transporting dispersed fluorescent molecules and that the molecules will partially remain in the cell interior after consecutive compressions serving as an indicator of volume exchange (Fig. 2a).

Confocal imaging determined that molecular delivery by cell VECT was dispersed throughout the cell interior, suggesting non-endocytic delivery (Fig. 2b) [22]. We experimentally observed that greater compressions from smaller ridge gaps resulted in higher delivery of fluorescent molecules (Fig. 2c, Supplementary Fig. 2). The fluorescent signal showed a positive correlation with the measured volume loss associated with the gap size (Fig. 2d). The measured delivery to cells with smaller gap dimensions (5.6 μm) was confounded at the conditions tested due to cells flowing around the ridges rather than passing through the smaller gap

faster flow rates [6,23].

Characterization of convective molecular delivery

To further confirm that intracellular delivery occurs due to cell volume change, we tested whether cell VECT is affected by the size of the molecule. Since diffusion rate is inversely proportional to molecule size, diffusive delivery typically shows lower efficiency for larger macromolecules [12–17]. In contrast, cell VECT demonstrated intracellular delivery with high efficiency (~90% of cells uptake molecules) regardless of molecule size for the range tested (Fig. 3a,b). This study used equal mass per volume of molecules ranging from 4 kDa, roughly the molecular weight (MW) of a small molecule drug, to 2000 kDa. This size-independent delivery supported our hypothesis that molecule uptake was achieved predominantly by advection of material from outside the cell due to cell volume recovery, rather than molecular diffusion through membrane pores.

The use of multiple ridges greatly increased volume exchange and molecular delivery to the cells. We observed a positive and non-linear correlation between the number of ridges and molecule delivery, which saturated at 14 ridges for these experimental conditions (Fig. 3c,d). The final molecular delivery was also found to be linearly dependent on the extracellular concentration (Fig. 3e,f), indicating that saturation of the intracellular and extracellular molecule concentration was reached.

To further explore the hypothesis that cell VECT causes the cytosol to reach equilibrium with extracellular molecule concentration, we processed previously dextran-positive cells with dextran-free buffer to remove the dextran from within the cells. We first delivered 2000-kDa FITC-dextran to K562 cells using VECT, then resuspended these delivered cells in FITC-free buffer and processed them in the device again for the Removal group. We found that the Removal group has a mean fluorescence

Except from Liu A, Islam M, Stone N, et al. Microfluidic generation of transient cell volume exchange for convectively driven intracellular delivery of large macromolecules. Mater Today (Kidlington). 2018 doi:10.1016/j.mattod.2018.03.002

Writing for and about Figures

- Writing FOR figures: Figure Caption/Text w/in a figure
  - Caption: justified/centered text
  - Bold/italicized figure name (Ex: **Figure 1**)
  - Horizontal text only (even for y-axis)
  - Table units in header for each column (not repeated in every row)
- Writing ABOUT figures: Main Text
  - **Directly mention the figure's name that is referenced**
  - Describe the figure in detail after the name is mentioned
  - Avoid repeating information given in a table/caption
    - Summarize result and state conclusions and interpretations

Specimen	Half-life in s	Volume in mm^3 ✔
Lorem ipsum	418	185.624
Dolor sit	33,518	909.114
Amet	6,672,452	223.534
Consectetuer	64,224	678.321*

Using a computational cell deformation model [19] combined with area analysis of high-speed videos of individual cells in the microfluidic channel, we evaluated the change in cell volume at several points in the channel (Fig. 1c). Measurements were

Table from Schwen LO. Ten simple rules for typographically appealing scientific texts. PLoS Comput Biol. 2020 doi:10.1371/journal.pcbi.1008458

Except from Liu A, Islam M, Stone N, et al. Microfluidic generation of transient cell volume exchange for convectively driven intracellular delivery of large macromolecules. Mater Today (Kidlington). 2018 doi:10.1016/j.mattod.2018.03.002

Active vs Passive Voice

- Active: Subject is performing an action on the direct object (DO)
  - Emphasis on the subject
  - Ex: The researcher loaded the samples into the machine.
- Passive: Restructure where the DO is the focus
  - Subject comes after the primary verb or is understood
  - Ex: The samples were loaded into the machine (by the researcher).
- How to choose?
  - Determine which is more important: Subject or DO?
  - If the question, "Who?" is important: active voice
  - Following sentences focus on DO: passive voice

Active vs Passive Voice (cont.)

- Passive Voice: Seen as more objective by making agents irrelevant
  - Disadvantages
    - Less interesting
    - Can complicate sentence structure
    - Readers may want the agent explicitly mentioned in text
- Overall Conclusion
  - Passive voice is best used when the agent has been made clear to the reader in a previous sentence.
  - Otherwise, active voice is preferable

General Scientific Writing Advice

- Be consistent in your word choice
  - Some words have synonyms w/in a field. Choose one and stick with it!
    - Ex: Reaction vs Recoil Forces
    - Different words = Different reader interpretations
      - Reader may assume something else is happening
- Be confident!
  - Be direct in what you'd like to say
  - Using discretionary language is reserved for the Discussion section
    - Ex: "May", "Perhaps", "Probably
- Don't antagonize readers
  - Avoid demeaning words: "clearly", "obviously"

Tools & Resources

- Always check relevant journal/government websites for guides
  - Nature
    - Formatting guide | Nature
    - Effective Writing | Learn Science at Scitable
  - NIH
    - Sample Applications and Documents | Grants & Funding
- Example Research Proposal by the APA
  - Research Proposal Format Example
- Purdue OWL has good advice for writing in general
  - Purdue OWL® - Purdue OWL® - Purdue University

Questions?

Scan to log attendance

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- Find us on Engage https://gatech.campuslabs.com/engage/
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