Principles of Science
& Scientific Writing

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Importance of Science
& Scientific Writing

- Good science and scientific writing is not a matter of life and death…………
- It is much more important than that!

Communication in Science
Why write?

- **Official answer:** work not published = work not done
- **If nobody knows what you have done and found …**
  Energy, time and money are wasted
- So, you must write, and you must write well
- Unfortunately, you must write in **English**

Writing in English

- English is primary language of science
- 90% of papers in Index Medicus in 1999 were written in English
- English is not the first language of many in the scientific world
- Many native speakers of English are bad writers

Scientists generally recognize the need to write, but too many believe…..

that they write papers
to be published,
rather than to be read!

Why Should We Write Well?

- "Good packaging cannot make up for poor content, but poor packaging can mask the quality of content" (Nair 2005)
- So that your work is published, read and cited
- Sloppy writing = sloppy research?

Journal Selection

- Numerous options!
- Identify target audience and journals they read
- Look at recent issues
- Check Instructions to Authors

Assessing a Journal's Quality

- Huge variation!
- Impact factors, citation index, origin, circulation
- Look at recent issues
- Do a literature search to identify where the best articles are being published
- Seek advice (from experienced authors)

Journal Format and Service

- Consistent with your paper (full paper vs. short communication)
- Quality of published images
- Layout, appendices
- Interval from submission to publication

Cost of Publication

- Page charges
- Color images
- Reduced fees for membership
- Potential sources of support

Final Choice

- Among the journals that are suited for publication of your paper, choose the most prestigious one that you think is likely to accept your paper
- Be realistic!
- Don't be a 1-journal author

Marketing Your Work

- Strive to have your papers read and cited
- Readers are busy and have many options
- Clear objective, findings, presentation
- Several key locations: title, start and end of abstract, end of introduction, last paragraph of discussion
- Do not waste key opportunities!

Author's Responsibilities

- Primary responsibility is to submit a well-written paper, prepared in accordance with journal format
- Respect the editor and reviewers
- The consequences of failing to honor your responsibility are proportional to the degree of failure

Guide to Authors

- Read carefully!
- Ignore at your peril!
- Often on-line (check website)
- Usually in first or last issue of volume/year
- Use recent issues as an example

Scientific Paper

- Primary way of communicating research results (not 'real' science until published)
- Demonstrates productivity
- Maintains accountability
- First publication of original results
- Sufficient detail to repeat study
- Published in journal or other source

'Anatomy' of a Scientific Paper

- IMRAD format
- Introduction: What question/problem was studied?
- M & M: How was the problem studied?
- Results: What were the findings?
- Discussion: What do the findings mean?
- Keep everything where it belongs!

Title

- Attract attention (but not unprofessional)
- Short (<15 words) and easy to read
- Not necessarily a sentence
- Specific (include search terms)
- Minimize abbreviations, acronyms, jargon
- May need to provide 'running title'
- Check format regarding capitalization

Title: Common Errors

- Should be the fewest possible words (<15) that describe the contents of the paper
- Most common error is poor syntax
- Low-impact words (e.g. effects of…)
- Too long and too generic

Tips for Preparing a Good Title

- Choose the key words in your article
- Rank in descending order
- Use *all* key words (in rank order)
- If too long, delete lowest rank word(s)
- Edit to indicate main result/conclusion

Examples of Titles

- The effect of extracts from seaweed on the levels of lactic acid in cattle
- Extracts from seaweed prevent lactic acidosis in cattle fed high-grain diets
- Seaweed extracts have the potential to replace antibiotics in the control of lactic acidosis in cattle

Authorship

- Assessing productivity (recognition, promotions)
- Substantial/critical input
- Familiar with content, able to defend
- May need to formally list involvement
- List conflicts of interest
- Pressures and expectations

Order of Authors

- First author has primary responsibility
- Second author also important
- May have statement that first two authors contributed equally
- Last author is often senior scientist

Title Page

- In accordance with Instructions to Authors
- Complete affiliations and addresses
- Degrees and qualifications?
- Phone, fax and e-mail
- Present address (if have moved)
- Clearly indicate corresponding author

Abstract

- First (perhaps only) access to paper
- Should contain all elements of a paper
- Background information (0-2 sentences)
- Clear statement of objectives/hypotheses
- Combine Mat. & and Methods and Results?
- Means and P-values (no statistical methods)

Abstract (continued)

- Brief discussion, primary conclusion(s) and emphatic final sentence
- Generally a single paragraph
- 'Stand alone' from remainder of paper
- 'Rich' and descriptive (carefully choose high-impact) words
- Respect word limits (often 250 words, may be truncated)

Abstract: Common Errors

- Does not 'stand alone'
- Missing or inadequate means and P values
- Too 'generic'
- Excessive materials and methods
- Too long

Summary

- Shorter, less descriptive
- Mainly motives, results and conclusions

Key Words

- Frequently required
- Respect maximum number words/characters
- Decreasing order of importance
- Choose terms carefully; consult reference lists (e.g. MESH) or other papers

Introduction

- Describe problem, include nature and scope
- Brief review of knowledge
- Explain how your study will challenge, expand or improve existing knowledge
- Objectives/hypotheses at the end
- Summary at end (depends on journal)

Introduction Based on Objectives vs Hypothesis

- Objectives-based introduction
  - Exploration research
- Hypothesis-based introduction
  - Purpose-driven research

Objective versus Hypothesis

- Objective states intention but not motive (limited justification)
- An objective is easy to formulate; however, a hypothesis is more difficult
- A good hypothesis makes it easier to write (and read) the paper

Objectives-based Introduction

- Exploration-type research
- Brief literature review
- Starts broadly and gradually narrows
- Ends with the **objective** (but no hypothesis is tested)

Hypothesis-based Introduction

- Defines the problem studied
- Lets the reader know what to expect
- Background and previous work
- Maximum of 3 citations for each key point
- Ends with a **hypothesis**

Hypothesis

- Must fit all known information (requires knowledge of the literature)
- Must be testable
- Provides structure, reader expectation
- Regardless of acceptance/rejection, usually is the basis of a good paper

Introduction: Common Errors

- Excessive detail/length (like a thesis)
- Lacks focus
- Excessive number of references cited
- Objectives absent, inappropriate, or inconsistent (with other sections of paper)
- Including a brief summary of results (at the end of the Introduction)

Materials and Methods

- Allow replication by competent investigator
- Describe all equipment, materials, software, etc., and source (city, state, country)
- Reference common procedures (explain modifications)
- Avoid 'classic', inappropriate references
- Chronological and easy to follow
- Usually start with design/layout

## *Experimental Animals, Plants, Microorganisms*

- List genus, species, strain/breed (do not need genus or species for domestic livestock)
- Journal may require statement regarding animal care, reference to animal care guide, or indication that the study was approved by Institutional Animal Care Committee
- Increasing standards for animal care

Definitions

- Frame of reference (define start of treatment or day of ovulation as Day 0)
- Define terms used
- Give considerable thought (conventional is easiest) and minimize exceptions
- Avoid excessive abbreviations

Figures, Flow Charts and Tables

- Effectively illustrate treatments or groups
- One picture = 1000 words
- Simple and easy to interpret
- Text only highlights displayed information
- Avoid excessive detail and duplication
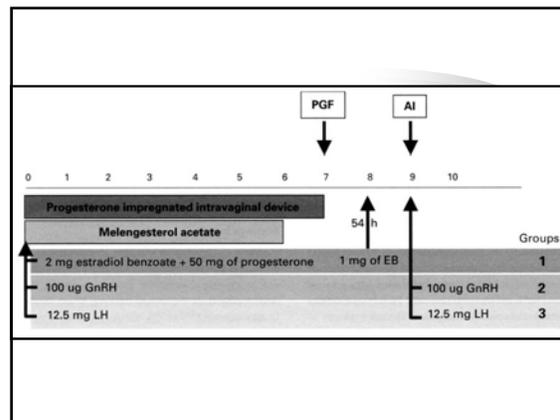
Statistical Analyses

- Appropriate
- Describe in detail, including end points analyzed, test(s) used, main effects and interactions, statistical software
- Usually do not give the model (unless complicated)
- Define significance (eg., means considered different at $P < 0.05$ and trends at $P < 0.10$)

Use of Sub-headings

- Breaks the monotony
- Need to be logical (not excessive)
- Examples
  - Experimental design
  - Treatments
  - Measurements
  - Laboratory analyses
  - Statistical analyses

Text of Results

- Refer to tables and figures
- Highlight (NOT repeat)
- More detail if sole presentation of data
- Present (NOT discuss)
- Results section must be a 'mirror image' of the Materials and methods

Reporting Data

- Use appropriate units (minimize zeros)
- Generally report to 1 decimal place
- Use '0' before decimal (e.g. 0.5)
- Remember to use a period and not a comma (1.5 vs 1,5)

Numbers

- Follow instructions for numbers < 10
- Never start a sentence with a number
- Avoid consecutive numbers (10 3 cm lids)
- Avoid use of term 'billion'
- Give original number first, eg. 209 (7.2%) of the 2901 oocytes cleaved

'Rounding' Data

- Round data to nearest 'even' number (2.55 and 2.65=2.6)
- Column of percentages does not have to sum to 100% (if 100.1, make a note regarding rounding error)

Why Use Tables or Figures?

- Data are too complex for the text
- Numbers with an interesting trend can go into a figure; otherwise, use a table
- Use a column chart for discrete data; continuous data require a line chart

Tables

- Put common elements vertically (columns); facilitates comparison among columns
- Eliminate repetition
- Must be easy to interpret
- Explore and revise; may need > 1 version
- Usually 1 or 2 main ideas; if more, need another table(s)
- Must 'stand alone' from the text

Table Format

- Minimize horizontal lines; above and below column headings and at bottom of table
- No vertical lines
- Avoid excessive width; put SD, SEM, CI, or range below means if necessary (unless doing vertical comparisons)
- Control or independent variable in first column

Table 1. Resynchronization of estrus in heifers after fixed-time insemination.

End point	Control	CIDR	MGA
No. heifers	42	121	138
Pregnant to 1st AI (%)	45.2	43.4	49.5
Estrus rate (%)	88.5[ab]	94.3[a]	81.6[b]
Conception rate (%)	62.2[ab]	65.1[a]	48.7[b]
Pregnancy rate (%)	54.9[ab]	61.4[a]	39.7[b]

[a,b]Within a row, means without a common superscript differ ($P<0.05$).

Principles of Figures

- Clear vision
- Clear understanding
- Appropriate scales

Cleveland, 1985

Clear Vision

- Prominent elements to show data
- Avoid excessive tick marks
- May use reference line (should not interfere with data)
- Minimize labels, notes, legends, etc. within data area (do not enclose within a box)

Clear Understanding

- Make legends informative
- Explain error bars
- Appropriate, clear labels
- Proofread (and fix errors)

Scales (range)

- Data should cover most of range
- Similar scales to compare ≥ 2 figures
- Zero is optional (use discretion)
- Log scales if vary by orders of magnitude
- If necessary, use scale breaks (indicate clearly)

Figure Format

- Ordinate=dependent, abcissa=independent
- Simple labels, consistent axes
- Maximum of 5 lines
- Insert a 'break' in axis if needed
- P-values on graph or in legend
- Indicate significant differences

Figure Legends

- Four parts: brief title, description of experiment, definitions (symbols or abbreviations), and statistical information
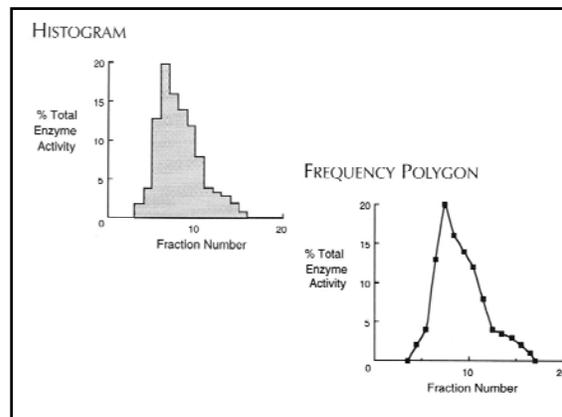- If definitions are complex, provide detailed information only once and refer back to this for subsequent figures

Figure Legends (continued)

- Sufficient for table/figure to 'stand-alone' but not long and tedious
- Explain all abbreviations
- Exclude citing statistical methods
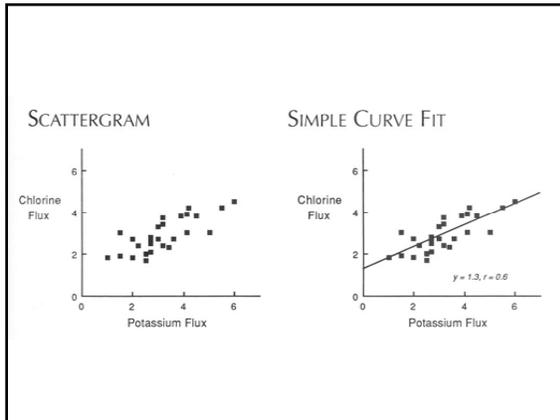- May include P-values for main effects and interactions

Labels and Lines

- Sans serif typeface, e.g. Helvetica
- Use different lines or symbols (not both)
- Lines of similar thickness, standard symbol shape and size
- Lines thicker than axes, avoid grid lines
- Columns wider than inter-column spaces
- Shades of grey are better than stripes or dots

Line Graph

- Use for continuous data
- Histogram (with connected tops of bars)
- Frequency polygon (same as histogram, connects midpoints of bars)
- Line graph connects individual or mean values of 2 or more variables
- Scattergram and curve fit show effect of one variable on another

HISTOGRAM

% Total Enzyme Activity

Fraction Number

FREQUENCY POLYGON

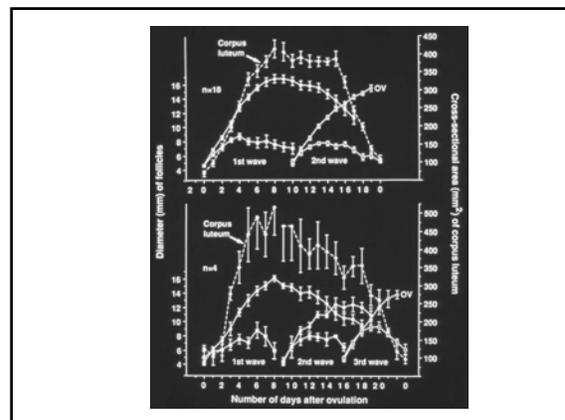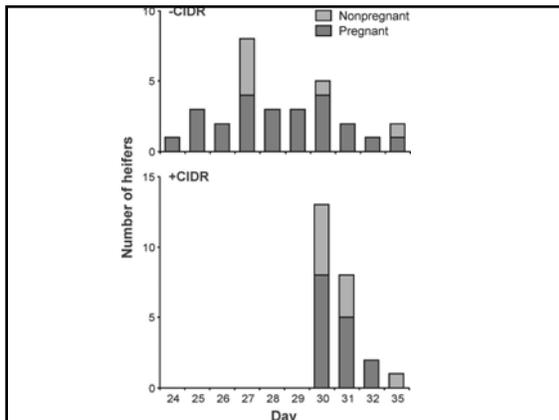% Total Enzyme Activity

Fraction Number

Bar Graphs

- Column graph (vertical bar graph)
- Bar graph (horizontal)
- Multiple comparison side-by-side bar
- Multiple comparison of parts within total bar

Bar Graphs

Stacked Bar Graph
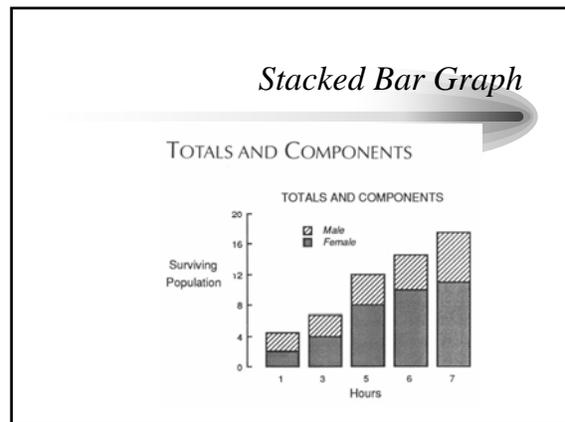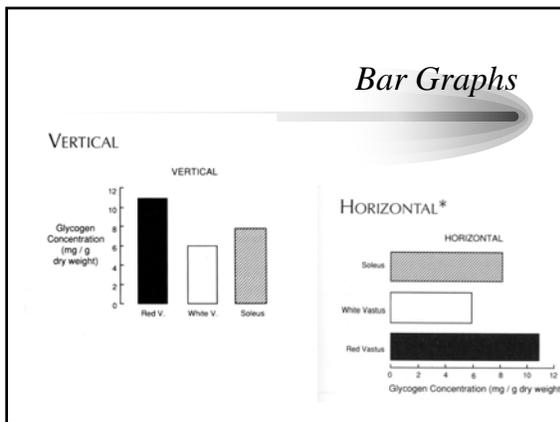
Multiple Graphs

- ≥ 2 panels facilitates comparisons
- May use 1 or 2 vertical (ordinate, y-axis) lines

Photos

- Representative (NOT 'perfect'), high quality, cropped and described, with scale
- Original (label on rear indicating author, paper and top of image), appropriate size
- Digital (high-resolution and appropriate format)
- Conversion of color photos to half-tones

Ranking Importance of Results

1. Substantial and relevant to the Hx
2. Not substantial, but relevant to the Hx
3. Substantial, but not relevant to the Hx
4. Not substantial, not relevant to the Hx

Use of Ranked Information

- Exclude 4 (may want to remove from Materials and methods)
- Suggested order: 1, 2, 3
- Provides sense of priority

Purpose of the Discussion

- Interpret current findings in the context of the literature
- Include limitations, deficiencies, and problems of current study
- Suggest further work
- Provide conclusions and implications

Mechanics of the Discussion

- Explain relationships among observed facts, DO NOT simply restate results
- Refer to own data first, then discuss with reference to the relevant literature
- Consider similarities, differences, advantages, disadvantages, may suggest future studies

Order of Presentation

- Identify key points and rank them
- Present in decreasing order of importance (start with objectives and hypotheses)
- Discuss fully and then move on
- As much as possible, avoid 'back and forth'

Paragraph Structure

- The topic sentence (what the paragraph is about)
- The logical reasoning (how results were interpreted)
- The concluding sentence (what it means)

Writing Paragraphs

- One (perhaps more) paragraph per argument
- One argument per paragraph
- Write topic sentence, then concluding sentence, then complete body of paragraph
- Edit for readability, fluency, and logic

Review of Discussion

- Objectives consistent with work
- Conclusions supported by the data
- Arguments progress logically; each paragraph leads reader step by step
- Ensure agreement with rest of paper

Significance

- $P < 0.05$ (best to cite actual P value, especially in the Results)
- Cite P value OR say 'significant'
- Include means or 'direction' of difference
- $P > 0.05$ but < 0.10 is a tendency (may be of biological relevance or inadequate power)
- Amann, R.P. Therio 63:698-715, 2005

Significant, or Not?

- If something is significant, then say that it was different (otherwise it appears that you do not believe your own data)
- Do not 'pretend' something is significant when it is not significant
- Minimize statements regarding 'numerical' differences

Comparisons

- Direct (planned)
- Indirect (unplanned, combinations or non-contemporaneous); comparison by inference
- Seemed or appeared

Statistical Terms

- Parameter, significant, tendency, corrrelated
- Use ONLY in strict statistical sense

Unexpected and Unexplainable

- Speculate if possible, but be brief
- Some things are simply unexplainable

Tense

- Present study is described in past tense
- Well-accepted literature in present tense
- Recent literature (not well accepted) may be in past tense
- Conclusion in present tense? (may be a cultural difference)

Conclusion

- Final paragraph of discussion
- Summarize major findings (that are supported by the data)
- Avoid citing references and new speculation
- Strong concluding sentence; do not 'waste' this opportunity

Acknowledgements

- Short and focused (avoid 'wish')
- Institutional reference number (if applicable)
- Money, in-kind, people (with permission)
- Previous publication (abstract or proceedings, not peer-reviewed, limited data or limited distribution)

Citations and Bibliography

- In text, at logical location (not necessarily at end of sentence)
- Verify original source
- If not original, state 'cited by'
- Bibliography should follow format and be carefully checked for errors
- Appropriate number of references

Foreign Language Citations

- Cite original title
- [English translation in square brackets]
- Do not abbreviate foreign-language journal titles

Submitting Your Paper

- Follow Instructions for Authors
- Ensure correct format (line and page numbers, line spacing, number of copies)
- For paper copy, package well, label properly, separate envelope for figures, disk(s) in correct format
- For on-line, follow instructions
- Suggest reviewers, indicate conflicts

Cover Letter

Please find enclosed three copies of an original paper (cite title) for your consideration for publication in (cite journal). All co-authors are familiar with the contents of this paper and are in agreement that it be submitted. We look forward to your decision.

Confirmation of Receipt of Paper

- May be automatic if on-line
- Within 2-4 weeks of paper's arrival
- Polite inquiry if delayed

Reviews

- 4-8 wk after receipt (inquire after 8-10 wk)
- Several possible outcomes
- Accept with no revisions (rare)
- With minor revisions
- Revise and re-review
- Reject

Revisions

- Reply promptly (enforced time limit)
- If an improvement or equivocal, make the change
- Firm stand and rebuttal on points of strong disagreement or principle
- Indicate changes on point-by-point basis
- You have the right to withdraw the paper

Language revisions

- Enlist assistance of a colleague
- Commercial assistance available

Reject

- MAY be able to appeal to editor, especially if you feel that they have a fundamental misinterpretation of the paper
- Generally simply have to accept the decision
- Once the paper is formally rejected, you are free to submit it to another journal

Preparation for Writing

- Objectives and hypotheses
- Analyze data and summarize
- Prepare draft versions of figures and tables
- Literature search, summary of major points
- Prepare outline (brief or detailed, in accordance with skill)

Practical Steps for Writing

- Write it down; …..and then write it up!
- Let ideas flow; do not be constrained
- Consult other papers for key sentences
- Materials & Methods/Results; mirror image
- Discussion (descending order)
- Abstract
- Bibliography (cross-reference and format)

Practical Considerations

- Small, descriptive words (eliminate extra words) and short sentences
- Be as specific as possible (heifer, cow, cattle, animals)
- Consistency in terminology and order
- Use abbreviations sparingly
- If you cannot force yourself to read it….

Final Thoughts

- Imagination, effort and attention to detail
- Focus on science, not methodology
- Respect resources and other people
- Develop a network of contacts
- Read many papers and practice your writing
- Publish good papers (in quality journals) to bring honor and positive recognition

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