NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: CIT 802

COURSE TITLE:TECHNICAL REPORT WRITING

COURSE GUIDE

CIT 802
TECHNICAL REPORT WRITING

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INTRODUCTION

CIT 802, Technical Report Writing is a foundation-level course in the MSc Information Technology programme. It can be taken by students in other programmes at either the undergraduate or postgraduate level. It can also be taken as a 'one-off' course by anyone who is not registered for a programme in the National Open University of Nigeria but wants to learn the fundamentals of technical report writing and writing for publication in a scientific journal.

The two-credit unit course will consist of a Course Guide and 14 study units. The study units are packaged into three modules of four, five, and five study units respectively. The first four study units (Module 1) will define technical report writing, list and describe its components, explain its significance in science and technology, and indicate how you should plan technical report writing. The next five study units (Module 2) will indicate how to write specific aspects of a technical report - the 'Title, Introduction, Materials and Methods, Results/Findings, and Discussion. The last five study units (Module 3) will describe how to prepare and use tables, graphs, citations, and references, as well as how to write a manuscript for publication in a learned journal.

There are no prerequisites for this course, although it is assumed that you have mastery of the basic rules of grammar and syntax in the English language, and that you are familiar with the fundamentals of scientific reasoning. If you are in any doubt on either, you should seek remedial help before attempting this course.

This course requires you to practise the art and science of technical report writing as you grasp the meaning and significance of its interrelated components. You'll learn better and faster by working systematically through the course, making sure that you have fully comprehended one study unit before going to the next. Keep a standard dictionary handy each time you work through this course.

This *Course Guide* tells you briefly what the course is about. what course materials you will be using and how you can work your way through these course materials. It gives you some general guidelines for the amount of time you are likely to spend on each study unit of the course in order to complete it successfully. It also gives you some guidance on your tutor-marked assignments.

WHAT YOU WILL LEARN IN THIS COURSE

The overall aim of CIT 802, *Technical Report Writing* is to introduce you to the fundamental principles and applications of technical report writing, and the basic elements of writing for publication in a scientific journal. During this course, you will learn about the types, functions, and components of a technical report; how to write and illustrate each component; and how to convert a technical report into a journal publication, or write a scientific paper from scratch.

Technical report writing is an essential skill for many situations requiring formal and effective communication of ideas, information, and knowledge. You will learn how to *identify, compose* and *organise* relevant material for writing on a given technical subject in science and technology; *prepare* and *illustrate* written technical material for a specified audience; *cite* and *arrange* references in a technical report; and *write* a manuscript for publication in a learned journal.

Technical report writing helps to prepare you effectively for membership of the international community of scientists; writing for publication in a scientific journal registers your serious candidature for membership of that community. Consequently, this course introduces you to the 'dos' and!'donts' of writing for publication in a scientific journal. It also challenges you to take seriously your image and responsibility as a potential contributor to African content in the world of science.

COURSE AIMS

The aim of the course can be summarised as follows: This course aims to give you an understanding of the types, functions, and components of a good technical report, and how to write logically and fluently all its components for a specified audience, or rewrite it for publication in a scientific journal.

This will be achieved by aiming to:

- define technical report writing
- enumerate the types and functions of technical reports
- list and describe the components of technical report writing
- explain the significance of technical report writing in , science and technology
- indicate how to plan the writing of a technical report
- demonstrate how to write specific aspects of a technical report
- describe how to use illustrations, citations , and references in a technical report

- show how to write a good manuscript for publication in a journal.

COURSE OBJECTIVES

To achieve the aims set out above, the course sets overall objectives. In addition, each of the 14 study units of the course also has specific objectives. The unit objectives are always stated at the beginning of a unit; you should read them carefully before you start working through the unit. You are encouraged to refer to them during your study of the unit to check on your progress. You should always take a second look at the unit objectives after completing a unit. In this way, you can be sure that you have done what was required of you by the unit.

Set out below are wider objectives of the course as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole.

On successful completion of the course, you should be able to:

1. Define, in your own words, what constitutes a good technical report.
2. Describe accurately the components of a technical report.
3. Assess correctly the value of technical reports in science and technology.
4. Plan efficiently a technical report writing exercise on a given subject.
5. Select an appropriate title for a technical report.
6. Name and *write* reasonably well every facet of a technical report.
7. Indicate clearly and logically the Results/Findings of a technical report.
8. Discuss intelligently a technical report's findings for its target audience.
9. Demonstrate the judicious and economical use of illustrations, citations, and references in a technical report.
10. Write or *rewrite* a scientific manuscript for publication in a scientific journal.

WORKING THROUGH THIS COURSE

To complete this course, you are required to read all of the 14 study units, and read as many of the references as you can find. You should bear in mind, however, that your inability to locate any of the references does *not* constitute a disadvantage to your full comprehension of the course. Depending on what course materials are available in your vicinity, an appropriate package of Tutor-Marked Assignments (TMAs) will be prepared for you. Your scores in the TMAs will constitute 40 per cent of your overall course assessment. At the end of the course is a Final Examination which will constitute 60 per cent of your overall assessment-for the course.

Below you will find listed all the components of the course, what you have to do, and how you should allocate your time to each unit in order to complete the course successfully.

COURSE MATERIALS

a. Course Guide
b. Study units (there are 14 in this course)
c. References (listed at the end of each study unit)
d. Tutor-Marked Assignment Materials:

- Unpublished technical reports of public and private sector institutions
- Unpublished theses, dissertations, and master's level projects
- Published doctoral dissertations (print and electronic editions);
- Published scientific papers in primary journals
- Published and unpublished papers presented at learned conferences, seminars, symposia, etc.
- Feature articles on science topics in newspapers and magazines
- Publishers' house rules and styles; and
- Published bibliographic style manuals.

Your tutor will select appropriate materials to match the content of each study unit. An example of what a tutor-marked assignment will look like is provided for you.

STUDY UNITS

There are 14 study units in this course as follows:

Module 1

Unit 1 What is a Technical Report?
Unit 2 Components of a Technical Report
Unit 3 Report Writing in Science and Technology
Unit 4 Planning Technical Report Writing
Unit 5 Selecting and Preparing a 'Title'

Module 2

Module 3

The first four units (Module 1) concentrate on what you need to know and do before starting to write a technical report. The next five units (Module 2) address specific aspects of writing a technical report — the Title, Introduction, Materials and Methods, Results/Findings, and Discussion.

The first two units of Module 3 describe issues which help to prepare and use efficiently and effectively tables and graphs, citations and references in technical report writing. The last unit explains how you can write for publication in a scientific journal.

Each study unit consists of two to three hours' work, and includes specific objectives, directions for study, references, and a summary of key issues. Each unit contains at least one explicit or implicit self-assessment exercise. In general, these exercises question you on the material you have just covered, or require you to apply it in some way and, thereby, help you to gauge your progress and to reinforce your understanding of the material. Together with tutor-marked assignments, these exercises will assist you in achieving the stated learning objectives of the individual study units and of the course.

TUTOR-MARKED ASSIGNMENTS

Tutor-Marked Assignments are included at the end of appropriate units of the text. Answers to these questions are to be submitted at appropriate times at the study centres as directed by your tutorial facilitator. The TMAs carry 40% of the total scores in computing. Your final examination scores or end of semester examination carries 60%.

MAIN COURSE

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MODULE 1

UNIT 1 WHAT IS A TECHNICAL REPORT?

CONTENTS

1.0 INTRODUCTION

This unit answers the question: What is a technical report? It is important that you are able to answer this question clearly and confidently at the outset as all other study units of the course will be built on it. You may also need to 'unlearn' some or all of the 'wrong' notions you may have had on the topic and concentrate, in a systematic manner, on its presentation in this unit. This approach will help you to steadily build up your knowledge in technical report writing and to apply that knowledge in writing all forms of technical reports and scientific papers.

The foundations of this unit are in communication - the study of effectively sending and receiving a message in a given context, through a given medium. But since this course is not for students of communication, you will just consider a selection of conclusions which have clear implications for effective technical report writing. If you are interested in the research which lies behind these conclusions, which can be very illuminating, you can find out more from the references listed at the end of the study units for the course.

Unit 1 is divided into four topics, each of which deals with a different aspect of the 'what is ...?' question, and ends with a conclusion and a summary. There are several self-assessment questions which are very important for helping you to assimilate the new information being presented to you. Therefore, you will do well not to miss any of them.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define and recognise a technical report on any topic in science and technology
- list the types of technical reports normally encountered in science and technology
- describe the purpose and functions of technical reports
- explain the major attributes or characteristics of technical reports.

3.0 MAIN CONTENT

3.1 The Nature of Tectinical Reports in Science and Technology

A technical report in science and technology may be defined as a written document which presents the results or findings of an experiment or field observation in a coherent and logical manner.

This definition emphasises two fundamental concepts which require further explanation as follows:

"written document" implies that the -writing is done in a particular way to conform with accepted norms and standards which have evolved in science for a long time; and "coherent and logical" implies that a process is involved whose outcome may be considered 'good' or 'poor' on the basis of those norms and standards.

Thus, it is important that you should not only be able to define a technical report on any topic in science and technology, but also be able to recognise the difference between a 'good' and 'poor' one. Moreover, as stated in the Course Guide, the primary objective of this course is to help you to write 'good' technical reports on any topic in science and technology.

The outcomes of many experiments and field observations never go beyond the stage of technical reports in science and technology. In other words, they never attain the status of a valid publication (see Unit 14 of this course).

However, you must present sufficient information in a good technical report so that its readers can (i) assess observations (ii) repeat experiments and (iii) evaluate intellectual processes. (Are the author's conclusions justified by the data?) The rest of unit 1 and the course will help you to understand how to "present sufficient information" in a systematic, coherent, and logical manner when you write a technical report.

Furthermore, a technical report, by definition, is a particular kind of document containing certain specified kinds of information. A technical report, very much like a scientific paper, "demands exactly the same qualities of thought as are needed for the rest of science: logic, clarity, and precision" (Woodford, 1968). This unit and all other units in the course will help you not only to appreciate the fundamental significance of logic, clarity, and precision in technical report writing, but to apply them in your writing of the same.

3.2 The Purpose and Functions of Technical Reports

A technical report, whether commissioned, routine, or produced on the author's initiative, normally aims to achieve one or more of the following objectives:

- accurately and objectively compose and present information on an object, idea, process, or event (the "communication objective")
- promote or "sell" an idea, product or service through rational/logical presentation (the "marketing objective")
- clarify issues that may have remained obscure before the report was produced (the "educational objective")
- put forward ideas in a conventional, usable or acceptable form (the "social objective")
- recommend a specific course of action, or non-action (the "judicial objective").

Thus, a well written technical report may perform the function of informing, educating, clarifying, socialising, modifying attitudes, or directing behaviour, in an organisation. Even reports that arc produced for mere record purposes perform these functions to varying degrees. In industry, the ultimate purpose and function of all reports is to facilitate management's rational/profitable decision-making.

You should always keep in mind the purpose or function that a technical report is written to serve and ensure that no aspect of it contradicts such purpose or function. If more than one function or purpose is to be served by the report, then you should designate one as primary and the other(s) as secondary. You should never leave the reader of your report in any doubt as to its primary purpose or function.

3.3 Types of Technical Reports

It is useful for you to know\ the various types of technical reports that can be written. However, being able to classify reports is by itself not of much use simply because one classification is as good as another. For example, reports may be classified according to:

- degree of formality: formal and informal reports
- length: long and short reports
- regularity: routine, periodic, or occasional reports, annual, biannual, or quarterly reports
- phase: interim, pilot, progress, or terminal reports; and
- format: alarm form, letter form, schematic form, or mixed form.

You are more likely, however, to see and write technical reports that are classified by *content,* such as:

- *Occurrence report:* which describes an event, such as flood disaster
- *Field trip report,* such as is written by an engineer, agricultural specialist, or technologist just back from a field assignment
- *Feasibility report:* which develops and analyses an idea or concept or project to assess whether it is economically or technically feasible
- *Investigation', report :* any form of report in which you describe how to perform tests, examine data, elicit or weigh tangible evidence in order to arrive at your conclusions
- *Evaluation report:* similar to, but not exactly the same as the investigation or feasibility report. In an evaluation report you: start with the idea to be developed (evaluated)
    a. establish controlling guidelines
    b. evaluate the idea or concept in light of the parameters set and data collected
    c. conduct tests to prove or disprove your theories, and

d. draw conclusions about the soundness or otherwise of the given idea or concept.

An investigation report normally begins with known data while an evaluation report begins with the idea or concept to be evaluated. Their cousin, the feasibility report, differs from an evaluation report only insofar as it tends to concentrate on more concrete and short-term projects. An evaluation report may, however, take several years to produce.

You should also know two other types of technical reports: the *technical proposal* and the *technical brief.* You can describe each of them as follows:

- *technical proposal:* which is normally prepared by a company to convince another company or institution of its technical capability to offer a specific service or perform a specific task. It is usually expensive
- *technical brief* in which a new idea is presented in sufficient depth to enable the recipient (the contractor or consultant) to assess its practicability and cost.

It is also useful for you to know two other types or reports which, strictly speaking, are not the types of technical reports, normally written by scientists and technologists: the *staff report* and the *audit report.* The former gives a succinct account of the deployment and disposition of staff within a given period. An audit report is a short comment on the degree of efficiency with which a company has operated its financial and material accounts and kept records of such operations. It is normally based on an extensive examination of the company's books.

You will probably find the classification of technical reports by content the most productive and least confusing. In practical terms, a given technical report in science and technology is likely to combine many of the features normally used in classifying reports. You may not always need to know what type of report you are writing, but there will be times when it becomes very important to do so in order to ensure that you are doing the right thing at the right time and in the right place for the right target audience.

3.4 Characteristics of Technical Reports

Here, you should endeavour to learn thoroughly all of the seven characteristics that experts have agreed as essential for good technical report writing. You are advised not to proceed with the rest of this unit and course until you satisfy yourself that you have mastered the seven characteristics. These are:

3.4.1 Technical Accuracy

To enhance sound scientific judgment and sound business decision-making, based on data presented in the report.

Technical accuracy also preserves your own image as a careful and dependable person.

SELF-ASSESSMENT EXERCISE

List some personal examples here of the attributes you would want associated with *"your image* as a careful and - dependable person."

3.4.2 Consistency in Presenting:

- weights and measures
- decimal or imperial systems, not a mixture of both
- numbers by maintaining generally accepted conventions in using words and numerals throughout the report (e.g. there were five cars
- conveying 15 workers) and keeping to them consistently
- alphabetic style: being consistent in your use of capitals and
- small letters
- punctuation, especially in your use of the full stop and the
- semi-colon; and
- abbreviations, with or without the full stop.

The benefits of consistency in,these and other regards include pleasurable reading and avoidance of various forms of disorientation for the reader of your report.

3.4.3 Clarity

For easy comprehension by the non-technical reader in particular. Here, you should carry out audience analysis, or at least some preliminary consideration of the target reader(s) of. your report. As an authority on the subject puts it, communication is an act of the recipient. You should remember, though, that there will be some difficulty in catering to the comprehension capabilities of the varied audiences for which most technical reports, even internal ones, are written. For example, a single report may be addressed to the engineering, production, accounts, personnel, marketing, and corporate affairs departments of Nigerian Breweries Plc. But the challenge or you as the technical report writer is to constantly search for the common denominator in expressing your ideas. You should explore the richness of the English language in the use of alternatives. And you can establish rapport with your reading audience by:

- avoiding the use of jargon in a 'generalist' report, and
- organising carefully the material in your report.

3.4.4 Mechanical Accuracy

you should follow standard rules of spelling, punctuation, and grammar. Many large organisations, just like media publishing houses, have their own house-styles. In addition to making use of these, you should feel free and humble enough to consult dictionaries and standard reference works when in any doubt. Mechanical language errors (e.g. 'adopt' for 'adapt', 'twenty sits' for 'twenty seats') as well as clichés and colloquialisms, suggest laziness on your part or a lack of concern about your work.

3.4.5 Conciseness

You should say what you have to say in the shortest possible form, e.g. the police usually /often harass, not `are fond of harassing" or, worse still, "are in the habit of harassing." Brevity or conciseness makes reading your report less time-consuming for busy executives. Conciseness is also achieved through:

- presenting your report in brief sections with sub-titles, rather than in one long, unbroken piece, and
- avoiding needless repetition. Remember that:
  a. Newton's Law of Motion contains only 29 words, and
  b. Einstein's earth-shaking Law of Relativity is reducible to just five symbols.
- akin to conciseness is precision, since unmasked circumlocution is one clear evidence of an imprecise mind. Say what your mean and avoid dancing round the subject. Also,
  a. prefer the specific to the general expression (e.g. "a Peugeot 504 GR saloon car" instead of "a vehicle" is acceptable for precision instead of the longer stretch. *prefer the pointed to the vague description/expression (e.g. "a 10-acre factory" to "a large factory").

3.4.6 Persuasiveness

You may be tempted to think that this objective is secondary to the transmission of accurate information, and you will be wrong. You have a selling job to do. What you are selling is not an appeal to emotion, but the quality and objectivity of the presentation of your report.

3.4.7 Interest

You must retain the interest of your reader throughout the report without being chatty or colloquial. You can make your report lively by making it lucid, remembering that businessmen, industrial and financial executives, and other professionals who are going to read your report are human, too!

4.0 CONCLUSION

Technical report writing is both an art and a science. While most students of science and technology may be quite comfortable with learning and mastering the content of their disciplines (the science), they often exhibit obvious deficiencies in how they communicate that content to others (the art). You have been introduced in unit1 of this course to the most basic elements which constitute the foundation of technical report writing. You have the responsibility of ensuring that this foundation remains as strong as possible so that the other 13 study units of the course that will be built on it will progressively improve your knowledge of technical report writing. If at any time during the rest of the course you are in doubt about the strength of your foundation, you should always return to it.

5.0 SUMMARY

In this unit, you have learned:

- how to define a technical report and to recognise the two fundamental concepts implied in that definition
- why a good technical report must present sufficient information to enable your readers (a) assess observations (b) repeat experiments, and (c) evaluate intellectual processes
- that a- well written technical report must perform one or more of five functions: communicating, educating, marketing, socialisation, or modifying attitudes
- various types of technical reports, especially the occurrence, field trip, feasibility, investigation, and evaluation reports, as well as the technical proposal and the technical brief
- the seven characteristics of technical reports --- technical accuracy, consistency, clarity, mechanical accuracy, conciseness, persuasiveness, and interest.

6.0 TUTOR-MARKED ASSIGNMENT

i. Explain the major attributes of technical reports.
ii. List the types of technical reports normally encountered in science and technology.

7.0 REFERENCES/FURTHER READING

Folarin, Babatunde (2002). 'Report Writing and Presentation.' Unpublished manuscript. Dept. of Language & Communication Arts, University of Ibadan.

Woodford, F.P. (Ed.). (1968). *Scientific Writing for Graduate Students.* New York. The Rockefeller University Press. (A Council of Biology Editors Manual).

UNIT 2 COMPONENTS OF A TECHNICAL REPORT

CONTENTS

1.0 INTRODUCTION

This unit identifies and briefly describes each component of a technical report. It is important that you understand and learn to use all or some of the components as you write technical reports for varying categories of readers. Depending on the type of technical report you write, it is always necessary for you to understand why some components will always he included and why some may be excluded. At the outset of learning how to write technical reports, however, you arc advised to include rather than exclude, if you are in any doubt whatsoever. As you build up experience and confidence, such decision-making will become progressively easier. Unit 2 is divided into three parts - Preliminary Matter, Main Report, and

End Matter. There is no absolute agreement on this. Therefore, you may be exposed to certain situations or experiences which require that you handle the components rather differently. If you have to present a technical report using a prescribed order of components you will, of course, do so. But if you are in a position to decide for yourself or even advise on the matter, you will find it helpful to learn to justify the choice of a particular order for any technical report you write. This is what this Unit will help you to do. A number of self-assessment questions are incorporated in the text to help you assimilate the new information being presented to you. Do your best to cover all the exercises and to repeat them as many times as you consider it necessary to do so.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list the components of a technical report
- classify the components as 'preliminary matter', 'main report', or 'end matter'
- defend the use or non use of any component in a technical report.

3.0 MAIN CONTENT

3.1 Preliminary Matter

In a sense, the word "preliminary" is somewhat misleading especially as it is used in this unit to describe a number of entries in a technical report which the reader must consider before the "main report." The preliminary entries are no less important than those in the main report: they are simply different. You should, therefore, pay as much attention to identifying, listing, and describing the components of the preliminary part of your report as the main part. The same goes for the "end matter." Any demonstration of shoddiness or carelessness in the handling of either part will, undoubtedly, impact negatively on the quality of your report, no matter how well organised your "main report" might have been.

3.1.1 The Cover

You should take seriously the appearance of the cover of your technical report since it symbolises your image and/or your organisation's. The cover of a commissioned technical report should be done in colour and carry the logo of the pertinent organisation. The quality of paper varies from glossy bond paper to treated cardboard, depending on the funds available and the importance attached to the role of the report in shaping the image of the organisation. You should bear in mind, however, that a glossy, coloured cover cannot compensate for a shoddily written report.

3.1.2 The Title Page

This announces or re-announces the subject-matter, the writer(s) of the report, the occasion and, possibly, the purpose and target of the report. It should also carry the month and year of the report.

3.1.3 The Table of Contents

You should make this as detailed as possible, especially for reports that have many sub-sections and sub-subsections. The full range of fonts and symbols in a computer memory should

be deployed to make the layout of your table of contents as clear and pleasing to the eye as possible.

3.1.4 The Transmittal Letter

A short, formal letter normally accompanies a commissioned report. In essence, it says, "here's the report you asked me/us to write. 1/We hope you find it useful."

3.1.5 Terms of Reference

A commissioned report should contain the agreed terms of reference for the report. While the primary value of this part of the report is to enable the clients evaluate the product they had contracted to pay for, it may also serve to adjudicate in any dispute between the clients and the writer(s) of the report.

3.1.6 Scope and Limitations

You should make your scope notes clear and precise. Any known limitations of the report should be similarly stated and hence the reservations and precautions that have to be exercised in reading and/or using it. If such limitations are due to specific problems encountered in the course of data collection or analysis, you should state them explicitly.

3.1.7 Technical Terms and Symbols

Technical report writing in science and technology will normally use a large number of technical terms and symbols. You should list and explain only those that have been used in your report, not some general list of terms and symbols in a particular branch of science. You may also wish to assemble them as a 'Glossary of Technical Terms and Symbols', either as part of 'preliminary' or as 'end matter.'

3.2 Main Report

The 'main body' of your technical report should contain all that is new in your study which you want to share with your readers as clearly and completely as you can. No extraneous material, that is, material that should properly belong to the 'preliminary' or 'end' aspects of your report, must be found here.

3.2.1 Executive Summary

This is much more than an 'abstract' or 'summary' in a scientific paper. It is a rather comprehensive overview of what the reader is going to find in the body of the report. You should write it keeping in mind the busy executive who will have neither the inclination nor the time to read the whole of your report. It is a mistake, however, to make it so snappy that the reader is forced to refer constantly to the body of your work in order to get the "Comprehensive overview" that you are trying to convey. It requires considerable practice before you get the required balance right.

SELF-ASSESSMENT EXERCISE

Collect four scientific documents of about 50, 100, 150, and 200 pages respectively. Beginning with the shortest document, prepare an executive summary (comprehensive overview) of each document until you are confident of doing the longest document with considerable ease.

3.2.2 Methods of Data Collection

You should endeavour to give as much detail here as is necessary to leave your reader in no doubt whatsoever about which methods you have used, why you have used them, and any special circumstances for using them. If you suspect that a 'general method' may not be well known to your targeted audience, provide all the necessary explanations to remove all doubt.

3.2.3 Analysis and Interpretation of Data

Remember that you are analysing and interpreting *your* data for the study, not someone else's. Occasionally, of course, you will have to compare your analysis and interpretation with those of previous or contemporary writers on the subject. But you must do so with care so that the reader's attention is not unduly diverted away from *your* analysis and interpretation.

3.2.4 Findings/Results

Some writers prefer 'results' to 'findings' as the outcome of their scientific work. Generally, 'results' are the outcome of experimental research, while 'findings' normally relate to field observations. The important point here is that you list your results/findings in a logical manner most suitable for the kind of study you are reporting.

3.2.5 Discussion and Conclusions

Here, you give discussion full reign by citing as many relevant references as possible - published and unpublished. Your discussion should lead logically to your conclusions for the study, and you will be wise to number all your conclusions for easy grasp.

3.2.6 Recommendations

Based on the conclusions, your recommendations are also best presented in a numbered list and justified with the pertinent conclusions. Since this may be the only section of your report that many important readers will have time for, you should give deep thought to writing it. In particular, always remember that your recommendations must derive scientifically from material within, not outside, the report.

3.3 End Matter

The 'end matter' comprises material which, though important, is not essential to the understanding or even appreciation of your report. In the interest of your self image as a writer, however, you should give it the same level of attention as you gave the preliminary and main components of your report.

3.3.1 Appendices

This is where to place statistics, photographs,questionnaires, interview schedules, and such other information necessary to your report but too cumbersome to include in the main body without disturbing your trend of thought.

3.3.2 Biodata of Author(s)

You should ensure that a brief biodata of each author of a technical report is given to facilitate the reader's evaluation of authors' qualifications and experience in writing the report.

3.3.3 References and Bibliography

Unless your report is essentially academic, a list of references in the report will do without a bibliography. The important point for you to note is that the references must be listed in accordance with the rules of a specified house-style or published text. A bibliography includes all documentary sources consulted but not necessarily mentioned in the main body of your report.

3.3.4 Acknowledgements

You should acknowledge any significant help that you received from any individual. Specifically, you should acknowledge the source of special equipment, cultures or other materials. Further, you should acknowledge the help of anyone who contributed significantly to your study or to the interpretation of your data. The important element in acknowledgements is simple courtesy.

3.3.5 Distribution List

Where relevant, you may include a distribution list at the end to ensure that your report reaches all those entitled to receive it**.**

4.0 CONCLUSION

You have been introduced to the components of a technical report that you are likely to encounter. Although these components have been arranged into three parts, you may find examples of good technical report writing where certain components are not always where they have been placed in this unit. For example, the 'Acknowledgements' part of a report may be placed in the 'preliminary' rather than the 'end' section. Similarly, 'References' may be spread over the relevant parts of the 'main report' rather than being collated in the 'end'. Such changes should not bother you. What is important is that you understand what the components are, no matter where they are placed. Unit 2 of this course has helped you to gain such understanding and to feel sufficiently confident to go ahead with the subsequent study units of CIT 802:Technical Report Writing.

5.0 SUMMARY

In this unit, you have learned to:

- list 18 specific components of a technical report
- describe, briefly, the function of each of the 18 components
- understand the reasoning behind their classification in a technical report; and
- justify the inclusion (or non inclusion) of each of the components in any technical report that you may choose to write.

Having been able to answer the question, *what is a technical report* in Unit 1, and learned the Components of a technical report in Unit 2, you are now in a good position to learn about the significance of Report writing in science and technology in Unit 3.

6.0 TUTOR- MARKED ASSIGNMENT

List and explain the components of a technical report.

7.0 REFERENCE/FURTHER READING

Folarin, Babatunde (2002). “Report Writing and Presentation.” Unpublished manuscript. Dept. of Language & Communication Arts. University of Ibadan.

UNIT 3 REPORT WRITING IN SCIENCE AND TECHNOLOGY

CONTENTS

1.0 INTRODUCTION

All over the world, the general impression is that those engaged in the pursuit of science or its application (technology) should not be 'distracted' by being called upon to write. Or, more correctly, when scientists and technologists do have to write, they should only be required to do so in the language most frequently used by them, mathematics or statistics, not the prose commonly used by other specialists. Consequently, the education and training of scientists are often so overwhelmingly committed to doing science that the communication arts are neglected or ignored. in short, many good scientists are poor writers. Certainly, many scientists do not like to write. As Charles Darwin once said, "a naturalist's life would be a happy one if he had only to observe and never to write" (quoted byTrelease, 1958).

Perhaps scientists in developed countries can afford the luxury of not learning to write since they have so many avenues available to them to produce well written science without doing the writing themselves. This is not the case in developing countries which have to cope with the additional handicap of learning the most commonly used medium of science communication, English, as a second language. Scientists in developing counties invariably have little choice but to learn to write the results of their experiments and field observations themselves.

This unit will attempt to argue the need for you to take seriously report writing in science and technology as a worthy contribution to the cause of science and technology. It will invite you to join a growing hand of scientists who are committed to sharing and communicating science as accurately and effectively as possible through good writing. You will be challenged to view good report writing in science and technology as a necessary stepping stone for writing for publication and career advancement in any aspect of science and technology you may choose to specialise in.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- recognise and appraise the 'importance of sharing and communicating science, initially through technical writing, as an essential part of the research process
- defend intelligently the need to place a premium on the acquisition of effective communication skills in formal education for science and technology
- explain how "doing" and "writing" science are complementary functions which need to be actively promoted at all levels of education for science
- know that writing for publication is the ultimate goal of science.

3.0 MAIN CONTENT

3.1 First Steps in Sharing and Communicating Science

As in many spheres of human endeavour, your first formal steps in learning how to communicate effectively in science could be critical. This unit assumes that you are taking your first formal steps here to recognise the significance of good technical writing as a necessary foundation to evolving effective communication in science and technology. Unless you are sure-footed in taking those first formal steps, the rest of your career in science or technology may be permanently compromised into relegating "writing science" to a secondary position to "doing science."

How should you begin? You should begin by asking yourself: What is the *ultimate* objective of science? The answer to this question is as simple as it is profound: the ultimate objective of science is to *share,* to *communicate*, to *publish* the results of experiments and findings from field observations. What is shared, communicated, or published in science may be applied to some practical objective in life to give us "technology", and a technological innovation could be the basis of flourishing industry employing thousands of workers.

It is important that you recognise and appreciate *your* role in the attainment of the ultimate objective of science. Unless you begin by learning how to write a good technical report, you are not likely to know how to share and communicate effectively your ideas, results, and findings, much less publish them. And in the context of developing countries, your role as scientists who know how to share their ideas in writing assumes a much greater significance. You might be initiating a vital development process which could transform whole communities, nations, and regions - all because you took the necessary first steps in sharing and communicating accurately in your technical reports.

You should also appreciate that sharing and communicating research results is an essential part of the research process. It is not necessary for the plumber to write about pipes, nor is it necessary for the lawyer to write about cases (except *brief* writing), but the research scientist, perhaps uniquely among the trades and professions, must provide a written document showing what he or she did, when it was done, why it was done, how it was done, and what was learned from it.

3.2 Inculcating Effective Communication Science

Given that the education or training of scientists is so overwhelmingly committed to doing science that its communication aspects are neglected or ignored, what must be done to inculcate effective communication in science? You are invited to consider the following practical steps and to discuss your views with other scientists in the context of this course.

- *Evolve a more positive attitude to communication in science by according it formal recognition as a specialization worthy of appropriate attention and resource inputs like any other specializations in science.*

Scientists pioneered "science information" and successfully demonstrated that it was worthy of equal attention and resources like other areas of science. Today, 'information science' has evolved into a discipline in its own right, but its strong roots in science remain. Similarly, "science education" has emerged as a legitimate area of postgraduate specialisation and has continued to grow in stature over the years. There is no known reason why "communication in science" should not evolve in similar fashion.

- *Design a course on 'communication in science' and make it compulsory at both undergraduate and postgraduate levels of education for science.*

Owing to the dearth of science expertise in this area, initial course designers might have to come from the ranks of specialists in communication and language arts. But as the specialisation gains greater recognition and visibility among practising scientists, it should not take too long for appreciative course designers to emerge from the ranks of scientists. As the new course becomes more and more acceptable in formal education for science, it might be necessary to envisage offering more than one course at two or more levels --- undergraduate, postgraduate, and research.

- *Initiate and appropriately endow a movement for more effective communication in science.*

Most specialists evolve naturally, but a few notable ones have been induced. In all cases, it is the enthusiasm and tenacity of one person or very few people which ensures the survival and blossoming of a new specialism. Since developing countries arguably need competence in science communication more than industrialised ones, there could be special advantages in situating such initiative in a developing society. Ultimately, however, it is the more universal appeal that will sustain it and make it prosper. What possible role might you play here?

- *In the interim, mount a sensitization drive to revive student written presentations at tutorials and seminars, and to integrate written discourse into more and more science degree programmes, especially at the postgraduate level.*

The National Open University of Nigeria is something of a pacesetter by offering a two-credit unit course on Technical Report Writing in its MSc. degree programme in Information Technology. The hope is that other Nigerian universities will emulate it. In the meantime, much can be done by Nigerian universities to promote written discourse in science degree programmes. Student written presentations at tutorials and seminars -- a regular feature of undergraduate education for science in the 1950s and 1960s — should be revived.

Finally, academic staff can demonstrate a practical commitment to inculcating effective communication in science by integrating more and more term papers into science degree programmes, especially at the postgraduate level.

3.3 Learning to Write for Publication

Inevitably, we must return to the ultimate objective of science, to publish the results of experiments and findings from field observations, as the greatest motivation for learning technical report writing as early as possible in your science career. Whether or not you wholly subscribe to the "publish or perish" adage in academia, there is no question but that the goal of scientific research is publication. Scientists, starting as graduate students, are measured primarily not by their dexterity in laboratory manipulation, not by their innate knowledge of either broad or narrow scientific subjects, and certainly not by their wit or charm; they are measured, and become known (or remain known), by their *publications.*

A scientific experiment, no matter how spectacular the results, is not completed until the results are *published.* In fact, the cornerstone of the philosophy of science is based on the fundamental assumption that original research *must* be published. Only thus can scientific knowledge be authenticated and then added to the existing pool of knowledge that we call science. This concept was given added weight when it was accepted as rational policy by the government of the United States of America. Currently U.S. government policy, first proclaimed in 1961 and restated in 1974 by the Federal Council of Science and Technology states as follows:

> *The publication of research results is an essential part of the research process. This has been recognized in part through authorization to pay publication costs from federal research grants and contract funds.*

Other national governments around the world, notably the former USSR and China, have followed the US example with similar dramatic results. Thus, the scientist must not only "do" science but must "write" science. Although good writing does not lead to the publication of bad science, bad writing can and often does prevent or delay the publication of good science. It is of vital national significance that you, as a potential contributor to the small but locally significant pool of Nigerian scientific knowledge, should imbibe the rudiments of writing good science as early as possible. This course, *CIT 802: Technical Report Writing* may not make you a great writer of science, but it will give you a firm and confident beginning in that direction. And, it is our hope that your firm and confident beginning will encourage you to become a part of the ultimate objective of science; the publication of scientific research.

4.0 CONCLUSION

Science, as we know it today, would have been impossible without a firm and entrenched tradition of simultaneously "doing" and "writing" science. Unfortunately, writing science has progressively become surbordinate to doing science, both in formal education for science and in the careers of scientists. And yet, to publish the results of experiments or field observations remains the ultimate objective of science. This implies that all scientists, including yourself, must take writing science very seriously, indeed.

This unit encourages you to recognise and appreciate that, by learning how to write a good technical report, you are taking the first vital steps in the attainment of the ultimate objective of science, that is, publishing. You are also invited to make your suggestions on how best to inculcate effective sharing and communication in science, given an educational structure that is skewed in favour of doing, rather than writing, science. The four areas suggested are designed to help you to flag off much needed debate on the subject among the rank and file of scientists. Finally, the nature and significance of publishing science are emphasised to enable you appreciate that both locally and globally, you will be making a worthy contribution to science by mastering the writing as well as the doing of science.

5.0 SUMMARY

In this unit, you have learned to:

- recognise and appraise the significance of sharing and communicating science, initially through technical writing, as an essential part of the research process
- know that writing for publication is the ultimate goal of science and that technical report writing is a vital step towards the attainment of that ultimate goal
- explain how "doing" and "writing" science are complementary functions which need to be actively promoted at all levels of education for science
- defend intelligently the need to accord high priority to the acquisition of effective communication skills in formal education for science and technology.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the statement that 'writing for publication is the ultimate goal of science.'

7.0 REFERENCES/FURTHER READING

Day, Robert A. (1983). *How to Write and Publish a Scientific Paper.* 2nd ed. Philadelphia, ISI Press.

Trelease, S.F. (1985). *How to Write Scientific and Technical Papers.* Baltimore, Md., William & Wilkins.

UNIT 4 PLANNING TECHNICAL REPORT WRITING

CONTENTS

1.0 INTRODUCTION

This unit describes for you the basic considerations in planning the writing of a technical report on a specific subject. Technical report writing can be thoroughly enjoyable and rewarding if you take sufficient time to plan it in some detail. By "planning" we mean your thinking through the entire process of writing the report and identifying all the elements, small and not so small, that have to be taken into consideration from the beginning to the end. This requirement may appear rather demanding, but it isn't really so once you come round to *think* about it. Your thinking must not be hurried; you will need to put pen to paper on a number of issues for several days, or even weeks. Then, you will have to review what you have done and each process of review should make you come up with an improved plan for the technical report you are about to write.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list the resources you will need for writing a technical report
- describe clearly the envisaged setting for your report
- organise the components of your report in a logical manner
- determine the relevant primary and secondary material you will need to write the report
- justify your careful use of language and style in technical report writing.

3.0 MAIN CONTENT

3.1 Before you Start Writing

You can avoid producing many unnecessary drafts of your report, or having to repeat procedures that could have been covered only once, if you take time to ask three fundamental questions as follows: What financial and material *resources* are available to you? How much *time* is at your disposal? What types of *help* do you need in the process of writing the report?

3.1.1 Resources

You must have a good idea of how much funds you can reasonably expect to be available. to you in writing the report. You should also know when the funds will be made available and whether or not you are entitled to supplementary funding, should you exhaust your original _cost estimate. "Material resources" will almost invariably translate to mean "computational resources." You must determine from the outset what special software packages you might need and the specifications of the computer system on which they can run.

3.1.2 Time

How much time do you have for writing the report? Can you ask for more time if you cannot deliver on the original time schedule? Are you required to produce your report in phases, progress and interim reports, then a final report? is someone expected to review your report before you submit it to a final authority? What time limitations are imposed by the reviewing and final authorities?

3.1.3 Help

You will not always be able to handle all aspects of your report by yourself. Therefore, identify from the outset your probable sources of help. For data analysis and interpretation for example, if you are not sure of the most appropriate statistical package for the analysis of your particular set of data, seek the help of statisticians rather than try it out yourself and risk invalidating a very important part of your report. Another important source of help is good proof readers. Most writers (and science writers in particular) fail to detect many errors of grammar and syntax in their writing. In addition, experienced research scientists can often easily detect illogicalities and other common faults in the writing of young scientists. The general rule in planning your report is to have a back-up for every activity, a 'contingency plan'. Being caught unawares or having to repeat an activity that you have already covered suggests that you have embarked upon your report writing too soon. You will recoup many times over the time invested in planning every aspect of your report writing.

3.2 Contextualisation

Every technical report should be written for a particular purpose and for a particular target audience. Therefore, take time to describe carefully the context of your report, and as early as possible in your writing. In doing so, you should ask a number of questions such as :

Was the report commissioned? If the answer is 'Yes', What are the agreed terms of reference? If it was not commissioned, what was your purpose in writing it?

The keyword in the second question is "agreed" which suggests that the context of writing your technical report has been duly negotiated and agreed with you, its writer. You must be completely satisfied with the terms of your contract because breaching any aspect of it may embroil you in protracted discussions or even litigation. If you suspect that there is a catch in the wording of the contract; take time to clear it with your lawyer before putting your signature to it. You should be particularly careful not to sign away your intellectual property rights which are all protected under the protocols of the World Intellectual Property Organization.

On occasions, you may be one in a team of writers of a technical report. Whether your contribution is a major or minor one in such a context, you have the responsibility of satisfying yourself that you are making the contribution in an agreeable context. Take time to resolve any lingering doubts quickly; pulling out in the middle of a report writing exercise will upset other members of your team and give you a poor image.

If the technical report you are writing was not commissioned, then its context should be your sole' responsibility. In which case, you should take time to describe carefully the purpose of the report. You need to he explicit, bearing in mind the *types* of technical reports listed for you in Unit 1 of this course. If you have any doubt at all about the type of technical report you are writing, be honest with yourself by returning to the appropriate section(s) of Unit I of this course.

What are the managerial and technical capabilities of the organisation or institution targeted by your report? Who in the organisation are likely to read your report and what do they know about the subject? What are they yet to know?

You must take time to find out all that you can about the organisation or institution that will make use of your report — its material, technical, and managerial resources and capabilities. Note in particular that an organisation/institution may have sophisticated resources, but lack the technical or managerial capabilities to exploit them fully to corporate advantage. You must turn such deficiencies to your advantage; they are *opportunities* for you to demonstrate the relevance of your expertise in the specific organisational setting you are writing for.

But you must go beyond knowing about the organisation/institution as a whole to individuals, especially those likely to read your report. What do they know about the subject of your report, and what are they yet to know'? Your knowledge of what the key members of your target organisation/institution know or don't know should, once more, be turned into an opportunity to make your report more relevant. For example, you could devote specific aspects of your report to addressing the deficiencies of the organisation's chief executive or, indeed, its entire human resource development department whose key members you have taken time to study. If you tackle this aspect of contextualisation positively and with imagination, you would have assured yourself of several influential advocates for your report from the outset.

The contexts of your report could vary enormously, depending on whether you are writing for a public or private sector organisation. It is your responsibility to understand fully the nature and structure of policy and decision-making processes in either context. General rules will help you to make a good start, but your real challenge is to find out how the exceptions operate in the particular private sector organisation targeted by your report, or in a particular ministry or parastatal. It is always a fatal mistake to extrapolate from one private sector organisation to another, from one ministry or parastatal to another. In that sense, every technical report you write is unique.

To what end are your recommendations likely to be put?

Your technical report must contain a set of recommendations which clearly set out to achieve one or more of the following:

- provide a solution to a specified problem
- offer a better (more efficient, more cost-effective, or more cost-beneficial) way of performing a particular operation
- demonstrate the need to invest additional resources in specific processes, facilities, or human resources.

The list does not exhaust the possible areas that your recommendations may cover, but they are probably the most common. You must bear in mind that your recommendations are not designed to condemn but to help. It is a common mistake for young, inexperienced technical report writers to want to give the impression of being "experts" by running down an organisation, or even individuals, in their recommendations. The outcome of such short-sightedness is predictable enough: the "experts" will not be given a second chance of returning to the organisation.

The time you spend discussing your *proposed* recommendations with those who are likely to implement them is a time well spent. Let them feel a part of your work by making them comment freely on the recommendations that *they*, not you, will have to implement. You do not always have to use such comment, of course, but the process of consultation itself will help to build up an invaluable positive image of your personality and professional competence.

And the final word on contextualisation: let your clients be aware that you can be contacted on any problems that may arise from implementing your recommendations, at no additional cost to the organisation. This is an important public relations undertaking which many organisations decline to take up, but which does no harm whatsoever to your professional image.

3.3 Organisation

“Good organisation is the key to good writings" (Petersen, 1961). Much of what you've already learned in Unit 2 is relevant to this part of Unit 4. If you have mastered the content of Unit 2 as you should, this part will easily fall in place in your cumulative knowledge on technical report writing.

By "organisation" here, we mean the need for you to take a decision on the most appropriate *arrangement* for the technical matter in your report. Typically, one of three approaches is adopted, depending on the nature of your report: (a) the *chronological* approach, (b) the *subject development* approach, and (c) the *concept development* approach. It is useful for you to know something of each approach so that you will be confident about using any of them in technical report writing.

3.3.1 The Chronological Approach

Certain topics are best treated and understood in an evolutionary mode. The biological and geological sciences are examples where the chronological arrangement of technical matter confers a special advantage of being easily understood by the reader. In addition, the chronological order has been agreed and standardised; you have nothing whatsoever to contribute to it. You simply organise your technical data in accordance with the agreed chronological order. But, you must cite the authority(ies) for the approach you have taken accurately and fully (See Units 12 and13 where citing and arranging references are discussed.)

3.3.2 The Subject Development Approach

Every established discipline has been broken down into its constituent parts in such a manner that one can see the organic links between the parts. The outcome of such an exercise is called *a classification scheme,* or a subject development approach of the discipline. A classification scheme could be very complex, even for a relatively "young" discipline. Many technical report writers have neither the time nor the inclination to understand such a complex document. Moreover, you will need to use only a small part of the document in any technical report. For practical purposes, therefore you should seek the help of a practising librarian, even when you feel confident about using it unaided to organise your technical data.

3.3.3 The Concept Development Approach

The organisation of material in a report using this approach is not very common in science and technology. The main reason is that it is rare to secure widespread agreement on the conceptual development of many topics in science and technology. In special cases, such as thesis writing, the approach may be used to tease out other approaches or to critique the more traditional approaches (the chronological and subject development). If you must use the concept development approach to organise your technical material, you will have to indulge in considerable explanation to enable your readers follow the message in your report.

3.4 Searching for Relevant Material

This is a critical aspect of planning your report writing. In order to maximise the resources available to you for writing the report, especially your time, you must plan this aspect very carefully. In science and technology, your most fundamental decision will be which *primary* or *secondary* material to look for.

Primary sources include the following:

- on-the-spot observation (including experiments)
- interview with people directly concerned, and
- questionnaire administered on people who are in the best position to know.

Secondary sources are of two types:

- library or documentary sources, and
- interviews with those in a position to supply secondary material, such as historians.

You should be aware that in science and technology, a much greater emphasis is placed on primary than secondary sources of material. Indeed, secondary sources are traditionally used to discuss, rather than report, the results of experiments or findings from field observations (see Unit 9). It would be an unusual technical report in science and technology which depends more on secondary than primary sources of material. Your planning must answer satisfactorily such questions as:

- *What/which* primary source material do. you need for the report? *Where? When?*
- *Who* do you need to interview? Where? When?
- *Who* will respond to your questionnaire? Where? When?
- *How* will you collect your primary or secondary source material? Effective planning means that you have answered the questions of What'? Which? Who? How? Where? When? in as much detail as possible from the beginning.

3.5 Language and Style

Many scientists and technologists seem to have the impression that they are not required to bother much about their language or style of writing, but they are wrong. In Unit 1 of this course; you were given the answer to the question, What is a technical report? Specifically, in sub-section 6 of the Unit, you were advised to be thoroughly familiar with the seven characteristics of technical reports (and scientific writing generally) - technical accuracy, consistency, clarity, mechanical accuracy, conciseness, persuasiveness, and interest. You were also advised not to proceed with the rest of the unit and the course until you satisfy yourself that you have mastered the seven characteristics. That advice is repeated for your benefit here. Furthermore, you are invited to ponder seriously on the following extensive quotation from a well known book on good writing in science and technology:

> *There are four things that make this world go round: love, energy, materials, and information. We see about us a critical shortage of the first commodity, a near-critical shortage of the second, increasing shortage of the third, but an absolute glut of the fourth.*

We in science, of necessity, must contribute to the glut [by writing technical reports and scientific papers]. But let us do it with love, especially love of the English, which is the cornerstone of our intellectual heritage; let us also do it with energy, the energy we need to put into the scientific paper [and the technical report] so that the reader will not need to use much energy to get the information out of the paper, and let us husband our materials, especially our words, so that we do not waste inordinate quantities of paper and ink in trying to tell the reader more than we know or more than the reader wants to know (Day, 1983:ix)."

Need we add anything to this in order to convince you of the importance of giving serious thought to language and style in planning your technical report writing?

4.0 CONCLUSION

Planning is of the essence in writing a good technical report. It is never a waste of time for you to spend as much time as is necessary to plan every aspect of technical report writing in as much detail as you can. In fact, much of your writing will be laboured and wasteful if you fail to devote sufficient time to planning it.

In this unit, you have been exposed to the ingredients of planning the writing of a good technical report. You are now set to start writing the technical report proper.

This unit is also the last of the first four study units comprising Module I of this course. Unit I of the module helped you to answer the question, "What is a technical report?" Unit 2 listed and described for you the components of a technical report while Unit 3 appraised the significance of technical report writing in science and technology. This final unit of Module 1 completes your necessary preparation for embarking on the writing of a good technical report on a subject of your choice.

5.0 SUMMARY

In this unit, you have learned how to:

- identify and list the resources you will need for writing a good technical report
- describe clearly and comprehensively the envisaged setting for your report
- organise the components of your report in a coherent and logical manner
- determine the relevant primary and secondary materials you will need to write the report; and
- justify your careful use of language and style in technical report writing.

6.0 TUTOR-MARKED ASSIGNMENT

1. Identify and list the resources you will need for writing a good technical report.
2. Describe clearly and comprehensively the envisaged setting for your report.
3. Organise the components of your report in a coherent and logical manner.

7.0 REFERENCES/FURTHER READING

Day, Robert A. (1983). *How to Write and Publish a Scientific Paper.* 2nd ed.Philadelphia, ISI Press.

Folarin, Babatunde (2002). “Report Writing and Presentation.” Unpublished manuscript. Dept. of Communication & Language Arts. University of lbadan.

Peterson, M.S. (1961). *Scientific Thinking and Scientific Writing.* New York: Reinhold Publishing.

UNIT 5 SELECTING AND PREPARING THE TITLE

CONTENTS

1.0 INTRODUCTION

In preparing a title for a technical report, you would do well to remember one salient fact: That title will be read by scores, possibly hundreds, of people. Perhaps few people, if any, will read the entire report, but many people will read the title for various reasons and at different points in time. Therefore, all words in the title of your report should be chosen with great care, and their association with one another must be carefully managed. The most common error in defective titles, and certainly the most damaging in terms of comprehension, is faulty syntax (word order).

What is a good title? You may define it as the fewest possible words that adequately describe the contents of a technical report, of a scientific paper, thesis, dissertation or a book. You will learn all about how to select and prepare a good title in this unit.

This unit is divided into five parts. The first part shows you how to write short, rather than long titles. The second commends specific titles and provides you with a few examples of how to attain specificity in preparing titles. Part three emphasises the importance of syntax and, again, provides you some examples of how faulty syntax can produce titles with completely unintended meanings. In part four, you are shown how to label your report properly by providing appropriate "keys" in its title that will facilitate its understanding and retrieval. Finally, in part five, you are shown why and how to avoid using abbreviations and jargon in the titles of your technical reports.

2.0 OBJECTIVES

At the end of unit, you should be able to:

- state the difference between a poor (lengthy) title and a good (short) one
- construct appropriately specific titles for technical reports and scientific papers
- recognise and apply the importance of syntax in composing the titles of technical reports and scientific papers
- prepare the title of a scientific work as a label to facilitate its understanding and retrieval
- compose the title of a scientific manuscript without using abbreviations or jargons.

3.0 MAIN CONTENT

3.1 Length of the Title

Generally, only a few titles of scientific manuscripts are too short.Consider a paper submitted to a prestigious journal in biology with the title"Studies on *Brucella."* Obviously, such a title was not very helpful to the potential reader. Was the study taxonomic, genetic, biochemical, or medical? You would certainly want to know at least that much, won't you?

However, *many* titles are too long. An overly long title is often less meaningful than a short title. In the early years of the 20th century, when science was less specialised, titles tended to be long and non-specific, such as the following published in 1896 in a prestigious journal:

"On the addition to the method of microscopic research by a new way of producing colour-contrast between an object and its background or between definite parts of the objects itself"

That certainly sounds like a poor title; perhaps it would make a good abstract. Happily, such overly long titles are now out of fashion in all forms of scientific writing. But many writers of science still yield to the temptation of constructing and publishing overly long titles. They are not good examples to emulate and by the end of this unit, you are expected to be able to do better, much better.

Without question, most overly long titles are long for only one reason, and it is a very poor one: the use of "waste" words. Often, these waste words appear right at the start of the title, words such as "Studies on"

"Investigations on," and "Observations on." You should, therefore, get into the habit of avoiding such waste words in the construction of the titles of your technical reports and scientific papers. Produce several versions of the title of a manuscript that you want to write, then sit down and slowly "cut and paste" the words in the alternative titles until you produce one with "the fewest possible words that adequately describe the contents of your manuscript." Repeat the process many times.

3.2 Need for Specific Titles

Let us examine a sample title: "Action of Antibiotics on Bacteria." Is this a good title? In *form* it is; it is short and carries no excess baggage (waste words). Certainly, it would not be improved by changing it to "Preliminary Observations on the Effect of certain Antibiotics on various Species of Bacteria." However, and this brings us to the next print, most titles that are too short are too short for only one reason: the use of general rather than specific terms.

So, take another look at the title above. Obviously, we can safely assume that the study introduced by the title did *not* test the effect of *all* antibiotics on *all* kinds of bacteria. Therefore, the title is essentially meaningless, as you will soon appreciate. If only one or a few antibiotics were studied, they should be individually listed in the title. If the number of antibiotics or organisms was awkwardly large for listing in the title, perhaps a group name could have been substituted.

Therefore, consider the following generally more acceptable titlesand select one that you judge the best replacement for the title in paragraph one above:

"Action of Streptomycin on *Mycobacterium tuberculosis"*
"Action of Streptomycin, Neomycin, and Tetracycline on Grain-Positive Bacteria"

"Action of Polyene Antibiotics on Plant-Pathogenic Bacteria"
"Action of various Antifungal Antibiotics on *Candida albicans* and *Aspergillus fumigatus"*

Whichever of the four alternative titles you selected, it would have been more acceptable than the sample. But they can still be improved upon to remove the too general impression in the mind of the reader by the use of the words "Action of." By defining those two words, the meaning of the title might be much clearer and closer to what its author intended. The first of the four titles above might then finally appear as follows:

"Inhibition of Growth of *Mycobacterium tuberculosis* by Streptomycin" --a much more specific title and one which, by all accounts, should be more helpful to the reader than either of its earlier variations.

You should consider one final example to illustrate the need to be specific in composing the titles of technical reports. In the 1930s, an important series of papers was published under the title "Studies on Bacteria." Although the title was acceptable then, it would not be acceptable today. If the study features an organism, the title would give the genus and species and possibly even the strain number. If the study featured an enzyme of an organism, a general title such as "Enzymes in Bacteria," would not be acceptable either. Perhaps something like "Dihydrofolate Reductase in *Bacillus subtilis"* would.

The examples here come from a particular branch of science. You should practise the construction of specific titles for your technical reports in particular and scientific monographs generally, using your own area(s) of specialisation. That is the only way to systematically build up your confidence until composing specific titles become routine in your writing.

3.3 Importance of Syntax

In the first paragraph of the introduction to this unit, you were given the following statement of fact: 'the most common error in defective titles, and certainly the most damaging in terms of comprehension, is faulty syntax (word order)." here, you will be invited to consider this important issue a little more closely and to make strenuous efforts to eliminate faulty syntax in the construction of the titles of your technical reports.

The use of English as the medium of scientific communication in many developing countries (including Nigeria) has had a troubled history. During the first two or three decades of university education in Nigeria, for example, *all* undergraduates were expected to demonstrate competency in written English prior to their admission into bachelor's degree programmes. A few science and technology undergraduates who fell short of this requirement were often given the opportunity of demonstrating such competency *during* their undergraduate days by sitting for and passing the examinations prescribed by appropriate external authorities. There was no question of anybody taking a first degree without satisfying this competency requirement.

Since about the mid-1970s, however, much confusion has characterised the status of competency in written English among undergraduates in Nigerian universities. At one time, the required standard was lowered considerably; at another, the requirement was abolished completely. Although much of its original status has been restored in many Nigerian universities lately, the damage had already been done. We now have a generation of students at all levels of education who have never been taught correct grammar and syntax in the English language and who, as a result, don't know the difference between correct and faulty syntax. Consequently, it would be difficult if not impossible, for such students to understand, let alone appreciate, the importance of syntax in the composition of appropriate titles for technical reports in particular and scientific papers in general.

If you are among the students who have acquired the kind of deficiency described above, this unit cannot teach you the basic rules of grammar and syntax. However, you will be given several examples of faulty syntax in the titles of published scientific writing. You should practise at correcting the faults and doing the same with additional examples in your areas of specialisation. Here, then are the examples, with one corrected for you and clues provided in the other.

(a) "Mechanism of Suppression of Non transmissible Pneumonia in Mice Induced by Newcastle Disease Virus" 'should have read:

"Mechanism of Suppression of Non transmissible Pneumonia Induced in Mice by Newcastle Disease Virus"

(b) "Preliminary Canine and Clinical Evaluation of a New Antitumor Agent, Streptovitacin" (Clue:"canine" = dog)

(c) "Isolation of Antigens from Monkeys using Complement Fixation Techniques" (clue: one simple word is missing).

(d) "Characterization of Bacteria Causing Mastitis by Gas-Liquid Chromatography" (clue: can bacteria use GI IC?)

Finally, you should be particularly careful when you use "using" in the title of a scientific manuscript. The word "using" is, arguably, the most common dangling participle in scientific writing, even by those whose mother tongue is English. It can easily be used to convey a completely unintentioned meaning, such as in the following sentence: "Using a fiberoptic bronchoscope, dogs were immunised with sheep red blood cells." Obviously, the writer had meant to say, "Dogs were immunised with sheep red blood cells by using a fiberoptic bronchoscope."

3.4 The Title as a Label

The title of your technical report is a "label"; it is not a sentence.Since it is not a sentence, with the usual subject, verb, object arrangement, it is really simpler (and shorter) than a sentence. But then, the choice and order of the words become even more important.

When you compose the title of your report, its function as a label should make you to keep two categories of potential readers in mind: (a) the potential readers who see the title in some published or unpublished table of contents reporting similar works, and (b) the potential users of the bibliographic services in which the work is cited (the indexing and abstracting services, or 'secondary sources' as opposed to 'primary sources,' such as journals and books). Most of the indexing and abstracting services are geared towards "key word" systems, that is, generating either KWIC (key word in context) or KWOC (key word out of context) entries. Therefore, it is fundamentally important that your title provide the right "keys" to your report by labeling it appropriately. This means that the terms in the title should be limited to those words that highlight the significant content of the report that are both understandable and retrievable.

Many writers provide an additional aid to readers by providing "running titles" or "running heads" at the top of each page. Such aid is particularly desirable when the report is a bulky one, has many sub-topics, or is produced in two or more volumes. Often, the title of the report is given at the top of left-facing pages and the chapter or section headings are given at the top of right-facing pages. Usually, a short version of the title is needed because of space limitations. This useful aid can easily be accommodated in most word processing software.

3.5 Abbreviation and Jargon

As a rule, your titles should almost never contain abbreviations, chemical formulas, proprietary (rather than generic) names, jargon, and the like. In composing the title of your report, you should ask: "How would 1 look for this kind of information in an index?" If the report concerns an effect of hydrochloric acid, should the title include the words "hydrochloric acid" or should it contain the much shorter and readily recognisable HO?

Your answer to the question should be quite obvious: Most users would look under "hy" in an index, not under "hc." Furthermore, if some authors used HC1 and others used hydrochloric acid, the users of the bibliographic services might locate only part of the literature relevant to their search, not noting that additional relevant references are listed under another, abbreviated entry. Fortunately, the larger secondary services now routinely use computer programs which are capable of bringing together entries such as deoxyribonucleic acid, DNA, and even ADN (acide deoxyribonucleique). However, by far the best rule for you and other authors is to avoid abbreviations in titles. And the same rule should apply to proprietary names, jargon, and unusual or outdated terminology.

4.0 CONCLUSION

This unit has attempted to impress on you that the composition of the title of your report is a vital element in either facilitating or inhibiting readers' understanding of the report. Good titles need to be short and specific, but also should adequately convey the contents of the reports they summarise. The word order (syntax) of a title is of fundamental significance because a mistake in this respect could easily produce a title with an unintended (and even embarrassing) meaning. Your title is also a label for your report. Therefore, take time to select appropriate key words that can be easily recognised and used by readers to access your report, especially in the context of bibliographic services, also called indexing and abstracting services. Finally, avoid the use of abbreviations and jargon in your title, even when such abbreviations and jargon are popular.

5.0 SUMMARY

In this unit, you have learned how to:

- tell and appreciate the difference between a poor title and a good one
- construct appropriately specific titles for technical reports and scientific papers
- recognise and apply the importance of syntax in composing the titles of technical reports and scientific papers
- prepare the title of a scientific work as a label to facilitate its understanding and retrieval; and
- compose the title of a scientific manuscript without using abbreviations or jargon.

6.0 TUTOR-MARKED ASSIGNMENT

i. Constuct five specific titles for a technical report or a scientific paper.
ii. State the importance of syntax in composing the titles of technical reports.

7.0 REFERENCE/FURTHER READING

Day, Robert A. (1983). *How to Write and Publish a Scientific Paper*. 2nd ed. Philadelphia, ISI Press.

MODULE 2

UNIT 1 WRITING THE INTRODUCTION

CONTENTS

1.0 INTRODUCTION

There is considerable debate about whether or not a technical report should have a separate section in its "Main Body" (see Unit 2) labelled 'Introduction.' The position is taken in this course that there is no need for it, hence the 'Components of a Technical Report' presented to you and described in Unit 2. However, there are two important reasons this unit is being devoted to writing the 'Introduction' part of a technical report or a scientific paper.

First, there is nothing wrong with having a separate section labelled 'Introduction' in the main body of a technical report. In other words, the 'Components of a Technical Report, as presented to you in Module 1 Unit 2, could have been modified to include a sub-section labelled 'Introduction'. The second and more compelling reason is that this course wants you to learn technical report writing as a natural stepping stone to writing for publication in scientific journals (see Module 3 Unit 4). And since the Introduction is a major component of writing for scientific publication, you are being formally exposed to how to write it here. The decision will then be yours, either to incorporate the introduction formally into your technical reporting functions or to use it only in writing for publication, or both. In this way, you could be using one stone to kill two birds.

This unit is divided into four substantive sections. In section one, you are given a list of the things you must do before you start to write an introduction to a technical report or a scientific paper. Section two is a discussion of a number of suggested rules for writing a good introduction. Section three attempts to show why it is necessary to apply the suggested rules to writing an introduction. In the fourth section, you will learn how to handle related work and specialised terms as part of the introduction you are about to write. As usual, a conclusion and a summary round off the unit. Self-administered exercises are embedded in the text.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- *list* the basic things you must do before you start writing an introduction to a technical report or a scientific paper
- *understand* and *appreciate* a number of rules for writing a good introduction to a technical report or scientific paper
- *apply* the rules in writing a good Introduction to a scientific paper/technical report
- *organise* intelligently any related work or specialised terms which you intend to use.

3.0 MAIN CONTENT

3.1 Before Writing the Introduction

You will need to ensure that a number of basic things are in place before you start writing the introduction to your technical report or scientific paper. The following list contains most of such basic things; you should add to them yourself by consulting several published papers and technical reports in your subject area.

- Some experienced writers prepare their title (see Module 1 Unit 5) and Executive Summary (see Module 1 Unit 2) or Abstract (in the case of a scientific paper (see Module 1 Unit 4) after the text is written, even though by placement they come first. Although you are not expected to be able to do this yet, you should, however, have in mind (if not on paper) a provisional title and an outline of the report or paper that you propose to "write up."
- You should also consider the level of the audience you are writing for (see Module 1 Unit 4), so that you will have a basis

for determining which terms and procedures need definition or description and which do not. If you do not have clear purposes in mind, you might go writing off in six directions at once.

- It is a wise policy to begin writing the main body of your work while the work is still in progress. This makes your writing easier because everything is fresh in your mind. Furthermore, the writing process itself is likely to point to inconsistencies in your results or findings. It might also suggest interesting sidelines that might be followed. Thus, you should start writing while the experimental apparatus and materials are still available. If you have co-authors, it is wise to write up the work while they are still available for consultation.
- The first section of the text proper should, of course, be the introduction. The purpose of the introduction should be to supply sufficient background information to allow the reader understand and evaluate the results of the present study without needing to refer to previous publications on the topic. The introduction should also provide the rationale for the present study. Above all, you should state briefly and clearly your purpose in writing the paper (or the terms of reference in a technical report - see Module 1 Unit 2).

3.2 Suggested Rules for a Good Introduction

- It should present first, with all possible clarity, the nature and scope of the problem investigated.
- It should review the pertinent literature to orientate the reader.
- It should state the method(s) of the investigation. If you deem it necessary, state the reasons for the choice of a particular method.
- It should state the principal results or findings of the investigation. Do not keep the reader in suspense; let the reader follow the development of the evidence. A surprise ending might make good fiction, but it does not fit the mould that we like to call the scientific method.

It is necessary for you to appreciate the last point in particular. Many authors, especially beginning authors, make the mistake (and it is a mistake) of holding up their most important findings until late in the paper. In extreme cases, authors have sometimes omitted important findings from the abstract, presumably in the hope of building suspense while proceeding to a well-concealed, dramatic climax. Such style only betrays the amateur status of the authors among knowledgeable scientists. Basically, the problem with the surprise ending is that the readers become bored and stop reading long before they get to the punch line. As Ratnoff (1981) put it, "Reading a scientific article [or report isn't the same as reading a detective story. We want to know from the start that the butler did it."

3.3 Reasons for the Rules

The first three rules of a good Introduction are self explanatory and reasonably well accepted by most science-writers, even beginning ones. It is important for you to keep in mind, however, that the purpose of the Introduction is to *introduce* (the paper). Thus, the first rule (definition of the problem) is the cardinal one. And, obviously, if the problem is not stated in a reasonable, understandable way, readers will have no interest in your solution. Even if the reader labours through your paper (which is unlikely if you haven't presented the problem in a meaningful way) the reader will be unimpressed with the brilliance of your solution.
In a sense, a scientific paper (or report) is like other types of journalism.
In the Introduction, you should have a "hook" to gain the reader's attention. Why did you choose *that* subject, and why is it *important?*

The second and third rules relate to the first. Your literature review and choice of method should be presented in such a way that the reader will understand what the problem was and how you attempted to resolve it.

These three rules, then, lead naturally to the fourth, the statement of principal results, which should be the capstone of the Introduction.

3.4 Related Work and Specialised Terms

If you have previously published a preliminary note or abstract of the Work you are reporting, you should mention this (with the citation) in the Introduction. If closely related papers have been or are about to be published elsewhere that you are aware of, you should say so in the introduction , customarily at or towards the end. Such references help to keep the literature neat and tidy for those who must search it.

You should understand fully that the "related work" is *not* the same thing as the "Citing and Arranging References" discussed towards the end of this course (see *Module 3 Unit 4).* In the Introduction to your paper, you want the reader to be aware of previous work that you or someone else has published, or are about to publish, that is related to the present one being reported. rt is *not* the place for a holistic review of all related literature, as suggested in section four above.

In addition to the above rules, you should keep in mind that your paper or report is likely to be read by people outside your narrow specialism. Therefore, the Introduction is the proper place to define any specialised terms or abbreviations which you intend to use. It is always a mistake to assume that your readers are (or should be) familiar with what appears to *you* as routine terms and abbreviations. To emphasise this point, there is the celebrated story of an advertisement (which appeared in the prestigious *Journal of Virology)* for a virologist at the National institutes of Health (NIH) of the United States, and concluded with the statement "An equal opportunity employer, M&F." A reader had written the journal's editor to complain about the advertisement and had suggested that "the designation `M&F' may mean that the NIH is muscular and fit, musical and flatulent, hermaphrodic, or wants a mature applicant in his fifties."

The interesting, but possibly embarrassing, exchanges with the reader cited above would have been totally unnecessary if the journal's editors had insisted that ‘M&F’ be replaced by 'Male and Female' in the advertisement. You can learn two simple rules from the exchanges as follows:

a) Never use an abbreviation in writing without first giving its full meaning;
b) The meaning a reader *chooses* to attach to your unexplained abbreviation would be as legitimate as any other meaning

4.0 CONCLUSION

The Introduction is an important part of a scientific paper and could also he constituted into a separate component of a technical report. Before you start writing the Introduction, however, make sure that four basic things are in place. You have also been given four rules for writing a good Introduction, the last of which is explained in some detail. Furthermore, the reasons for the four rules are explained to you to enable you to appreciate the need to apply the rules as closely as possible in writing the Introduction to your scientific paper or technical report. Finally, you have been shown the importance of pulling in related work to the one being introduced and to explain every abbreviation you use, no matter how routine or 'popular' it may seem, in the Introduction to your work.

5.0 SUMMARY

In this Unit, you have learned how to:

- enumerate four basic things you must do before you start writing an Introduction to a technical report or scientific paper;
- understand and appreciate four suggested rules for writing a good Introduction;
- apply the rules in writing a good Introduction to a scientific

report/paper;

- organise intelligently any related work or specialised terms you intend to use in writing a good technical report or scientific paper

6.0 TUTOR-MARKED ASSIGNMENT

i. List the rules for writing a good introduction to a technical report or scientific paper and

ii. the basic things to do before writing a good introduction to a technical report or scientific paper.

7.0 REFERENCES/FURTHER READING

Day, Robert A. (1981). *How to Write and Publish a Scientific Paper. 2nd* ed. Philadelphia: ISI Press.

Ratnoff, O.D. (1981). "How to read a paper." In : K.S. Warren (Ed.), *Coping with the Biomedical Literature.* New York: Praeger. pp.95-101.

UNIT 2 WRITING THE MATERIALS AND METHODS SECTION

CONTENTS

1.0 INTRODUCTION

In the first section of your technical report or paper, the Introduction, you stated (or should have) the methodology employed in the study: If necessary, you also defended the reasons for your choice of a particular method over competing methods.

Now in Materials and Methods, you must give the full details. The main purpose of the Materials and Methods section is to provide enough detail that a competent worker can repeat the experiments or field surveys. Many (probably most) readers of your paper or report will skip this section, because they already know (from the Introduction) the general methods you used and they probably have no interest in the experimental detail. However, careful writing of this section is critically important because the cornerstone of the scientific method *requires* that your results or findings, to be of scientific merit, must be reproducible. And, for the results to be adjudged reproducible, you must provide the basis for repetition of the experiments or field surveys by others. That experiments are unlikely to be reproduced is beside the point; the potential for producing the same or similar results must exist, or your paper does not represent good science.

This unit, then, is divided into six sections. The first section tells you how to handle the Materials part of your report and the second the Methods part. The remaining five sections deal with other specific aspects of Materials and Methods that scientists, especially beginning scientists, usually find troublesome: Headings and Sub-headings (section five), Measurements and Analysis (section four), the presentation of certain Tabular, Material (section five), and the use of correct Form and Grammar (section six). The usual 'Conclusion', 'Summary', and 'References' sections complete the unit. Two Self-Assessment Exercises are embedded in the text.

2.0 OBJECTIVES

At the end of this, you should be able to:

- describe accurately the technical specifications and quantities of the research materials used in your experiments or field surveys.
- explain clearly your method(s) of investigation
- show precisely how you carried out your measurements and analysis
- defend your presentation of certain tabular material in this section of your report
- use correct headings, sub-headings, form, and grammar in presenting relevant information.

3.0 MAIN CONTENT

3.1 Materials

For materials, you must include the exact technical specifications and quantities, as well as the source(s) and method(s) of preparation. Sometimes it may even be necessary for you to list pertinent chemical and physical properties of the reagents used. You should avoid the use of trade names; use of generic or chemical names is usually preferred. This avoids the advertising inherent in the trade name. Besides, the nonproprietary name is likely to be known throughout the world, whereas the proprietary name may be known only in the country of origin. However, if there are known differences among proprietary products and if these differences may be critical (as with certain microbiological media), then the use of the trade name, plus the name of the manufacturer, is essential.

Experimental animals, plants, and microorganisms should be identified accurately, usually by genus, species and strain designations. Sources should be listed and special characteristics (age, sex, genetic and physiological status) described. If human subjects are used, the criteria for selection should be described, and an "informed consent" statement should be added to the manuscript, just in case it might be required.

Because the value of your report or paper (and your reputation) can be damaged if your results are not reproducible, you must describe research materials with great care. A useful way in which you could learn to do this properly and consistently is to examine several examples of the Instructions to Authors of important journals in your subject area. Such Instructions usually give details of important specifics that are often required in technical reports, too. Below is a carefully worded statement applying to cell lines (taken from the Information for Authors of *In Vitro,* the Journal of the Tissue Culture Association):

Cell line data: The source of cells utilised, species, sex, strain, race, age of donor, whether primary or established, must be clearly indicated. The supplier's name, city, and state abbreviation should be stated within parentheses when first cited. Specific tests used for verification of purported origin, donor traits, and detection for the presence of microbial agents should be identified. Specific tests should be performed on cell culture substrates for the presence of mycoplasmal contamination by using both a direct agar culture and an indirect staining of biochemical procedure. A brief description or a proper reference citation of the procedure used must be included. If these tests were not performed, this fact should be clearly stated in the Materials and Methods section. Other data relating to unique biological, biochemical and biochemical and /or immunological markers should also be included, if available.

Evidently, describing materials in the medical sciences probably requires greater detail in certain respects than other branches of science. Whatever your area of specialisation, however, you should get into the habit of describing the materials used in any experiment or field work in as much detail as you possibly can.

**Assemble* as many 'Instructions to Authors' of journals in your field as you can. *Reproduce* the sections describing the Materials for scientific research published in the journals. *Write* the Materials sections for *two* scientific papers or technical reports of your choice. *Compare* what you have written with those in the published journals.

3.2 Methods

For methods, the usual order of presentation is chronological. However, whenever you have to make a different order of presentation, such as in geomorphology, it is suggested that you make a special case for it. Obviously, related methods should be described together and straight chronological order cannot always be followed. For example, if a

particular assay was not done until late in the investigation, you should describe the assay method along with the other assay methods, not by itself in a later part of Materials and Methods.
It is worth repeating here that in describing the methods of investigations, you should give sufficient details so that a competent worker could repeat the experiments. If your method is new (that is, unpublished), you must provide *all* of the needed detail. However, if a method has already been published in a standard journal, only the literature reference should be given (see also Module 3 Unit 4).

Scientists in developing countries face a serious ethical issue in regard to the use of the words "published in a standard journal" above. What constitutes a "standard journal"? Every answer to this question will have an element of bias as a considerable dose of opinion will be involved. Librarians, and especially information scientists, have evolved fairly objective methods for deciding "best" journals, or the "most frequently cited" journals, or journals with the "highest impact factors", etc. Unfortunately, few journals in developing countries meet the criteria of being among such "best" journals. Consequently, you may have to provide a complete description, in your present Methods section, of the same method that has been previously published in a relatively unknown scientific journal based in a developing country.

However, if the truth must be told, there have been several documented cases of scientists in developing countries publishing the same papers locally *and* in the so-called prestigious journals. Such practice is a disservice to science in general and to the course of science in developing countries in particular. You have a responsibility not to indulge in such practice, ever. (See Module 2 Unit 4).

3.3 Headings and Sub-Headings

You must learn to use headings and sub-headings to bring out clearly and logically the components of your investigation. When possible, sub-headings that "match" those to be used in presenting the Results of your investigation should be used in the Materials and Methods section. In that way, the writing of both sections will be much easier, and the reader will be able to grasp quickly the relationship of a particular methodology to the related Results.

In addition to main headings, you will find the use of a variety of levels of sub-headings helpful as signposts to direct the reader through your report. The best way to learn how to do this is to examine a variety of good journals in your subject area in order to get familiar with how main headings are effectively used with sub-headings to achieve the desired effect. You will notice differences in style as you examine them; what is important is for you to adopt a particular style and learn to stick to it in *all* your writing. Fortunately for you, the availability of word processing software introduces a large variety of alternative formats for you to choose from, in addition to the routine supply of scientific symbols with such software.

3.4 Measurements and Analysis

Your watchword here is: be precise. If a reaction mixture was heated, give the temperature. You must answer questions such as "how" and "how much" precisely; they must never be left to the reader to puzzle over.

Statistical analyses are often necessary, but you should feature and discuss the data, not the statistics. Generally, a lengthy discussion of statistical methods indicates that the writer has recently acquired this information and believes that the readers need similar enlightenment. In most cases, you should use ordinary statistical methods (the chi-squared test, regression analysis, co-variance, and the like) without comment; advanced or unusual methods may require only a literature citation.

However, in many contexts of technical report writing, your analysis of the needs of your target audience may require 'that you provide detailed explanation of even some "ordinary statistical methods." You should be particularly sensitive to such specific needs, especially when certain key individuals in your target audience may not be too numerate. In which case, your analysis takes on something of the character of marketing your product (the report) to specific clients who must appreciate the value of the product sufficiently to want to buy it.

Finally, in this section, be careful of your syntax. Errors of syntax are among the most common in scientific writing in developing countries where most writers use English as a second language. A major reason is that many writers think first in their mother tongue and then translate the thought process into written English. You can eliminate most errors of syntax in your writing through constant practice *and* reading standard published literature in your subject area. You have a responsibility of raising the level of your written communication to the level of acceptability as a member of the international community of serious writers in your field (See Module 3 Unit 4.)

3.5 Tabular Material

In Module 2 Unit 5, you will be formally shown how to prepare and use tables in presenting the *results* of scientific experiments. Here, we are concerned with letting you learn how to present tabular material during the stage of scientific writing *before* the results. Of course, it is not always as clear cut as that. If you are in any doubt, you should present your tabular material of the kind described here in the Materials and Methods section of your technical report or paper *and* cite it in the Results section.

When large numbers of microbial strains or mutants are used in a study, you should prepare tables identifying the source and properties of mutants, bacteriophages, plasmids, etc. The properties of a number of chemical compounds can also be presented in tabular form, often to the benefit of both the author and the reader. You can find help in learning how to do this properly and consistently by consulting special manuals or appendixes to standard textbooks in your subject area. Note, however, that a method, strain, etc., used in only one of several experiments reported in your technical report or paper, should be described in the Results section or, if brief enough, may be included as a footnote to a table or a figure legend.

3.6 Correct Form and Grammar

Finally, do *not* make the common error of mixing some of the Results in the Materials and Methods section of your report or paper. In summary, there is only one rule for a properly written Materials and Methods section: You must give enough information so that your experiments or field surveys could be reproduced by a competent colleague.

A good test, and a good way to avoid rejection of your report or manuscript, is to give a copy of your finished manuscript to a colleague and ask if he or she could repeat the experiments. It is quite possible that in reading your Materials and Methods, your colleague will pick up a glaring error that you missed simply because you were too close to the work. For example, you might have described your distillation apparatus, procedure, and products with infinite care, and then inadvertently neglected to define the starting material or to state the distillation temperature.

Mistakes in grammar and punctuation are not always serious; the meaning of general concepts, as expressed in the Introduction and Discussion (see Module 2 Unit 4), can often survive a bit of linguistic mayhem. In other words, nobody expects you to write a 'perfect' technical report or scientific paper. In Materials and Methods, however, exact and specific items are being dealt with and precise use of English is a must. Even a missing comma can cause havoc, as in the sentence: "Employing a straight platinum wire rabbit, sheep and human blood agar plates were inoculated." That sentence was in trouble right from the start, because the first word is a dangling participle. Comprehension didn't completely go out of the window, however, until the author neglected to put a comma after "wire".

Because the Materials and Methods section usually gives short, discrete bits of information, the writing sometimes becomes telescopic; details essential to the meaning may then be omitted. The most common error you should watch for in your writing is to state the action without stating the agent of the action. For example, in the sentence "To determine its respiratory quotient, the organism was . . ., the only stated agent of the action is "the organism," and somehow you have to doubt that the organism was capable of making such a determination. Here is a similar sentence: "Having completed the study, the bacteria were of no further interest." Again, you have to doubt that bacteria "completed the study"; if they did, their lack of “further interest” was certainly an act of ingratitude. This kind of grammar error in written scientific discourse described above is found in so-called prestigious journals as in obscure, low-rating ones. This is hardly cold comfort to many journals based in developing countries where English is, invariably, a second language. You are asked to consider the last two samples below as what might happen to your writing, once you become careless with grammar or logic.

> "Blood samples were taken from 48 informed and consenting patients . . . the subjects ranged in age from 6 months to 22 years" *(Pediatric Research*, 6:26, 1972).

There is no grammatical problem with that sentence, but the telescopic writing has compromised logic, leaving the reader wondering just how the 6-month-old infants gave their informed consent.

And, of course, you must always watch for spelling errors at every stage of your manuscript preparation. It does not require an astronomer to suspect that a word is mispelled in the following sentence:

"We rely on theatrical calculations to give the lifetime of a star on the main sequence" *(Annual Review of Astronomical Astrophysics*, 1:100, 1963).

Correct the two sentences above. *Locate* several more examples of errors of grammar or logic or both in the literature of your subject area. *Rewrite* them correctly and *apply* what you have learned to the tutor-marked assignment for this Unit.

4.0 CONCLUSION

The Materials and Methods section of a technical report or scientific paper demands that you give such detailed information in it that a competent colleague could repeat the experiments or field surveys. Therefore, you must write it carefully to include exact technical specifications and quantities, as well as the identification of experimental animals, plants and microorganisms by genus, species, and strain designations. For methods, the usual order of presentation is chronological, unless there are exceptional circumstances (which you must state) which demand a different order. You must learn to use headings and subheadings to bring out clearly and logically the components of your investigation, and you must be precise in writing your measurements and analysis. Finally, you must learn to eliminate all errors of form, grammar, syntax, logic, and spelling in the presentation of the Materials and Methods section and, indeed, all sections of your technical report or scientific paper.

5.0 SUMMARY

In this unit, you have learned to:

- describe accurately the technical specifications and quantities of the research materials used in your experiments or field surveys;
- explain clearly your method(s) of investigation
- show precisely how you carried out your measurements and analysis
- defend your presentation of certain tabular material in this section of your report; and
- use correct headings, sub-headings, form, grammar, and syntax in presenting relevant information.

6.0 TUTOR-MARKED ASSIGNMENT

i. Describe accurately the technical specifications and quantities of the research materials used in your experiments or field surveys.
ii. Explain clearly your method(s) of investigation.
iii. Show precisely how you carried out your measurements and analysis.
iv. Defend your presentation of certain tabular material in this section of your report.

7.0 REFERENCE/FURTHER READING

Day, Robert A. (1983). *How to Write and Publish a Scientific Paper.* 2nd ed. Philadelphia: ISI Press.

UNIT 3 PRESENTING THE FINDINGS/ RESULTS

CONTENTS

1.0 INTRODUCTION

For most readers of technical reports, the Findings section ranks second in importance only to the Executive Summary (see Module 1 Unit 2). For experienced readers of scientific papers, however, the Findings or Results section is considered by far the most important, even more important than the Abstract (see Module 3 Unit 4). The reason for this is quite simple: the reader learns what is *new* in the work, and how well the new material has been handled by the author, typically in the Findings section. In other words, it is the Findings section that sells your technical report to its target audience, or commends/condemns it in the eyes of the established international community of scientists.

Because English is not the mother tongue of the vast majority of scientists who do and write science in developing countries, their handling of the Findings section of scientific papers often presents them with much difficulty. And since such difficulty revolves around two words, *clarity* and *brevity,* you are being invited in this unit to ponder several aspects of the two words in a deliberately short presentation.

This unit, then, is divided into four short parts. Part one describes what the Results/Findings section should contain and how it should be described. Part two explains how a major feature of scientific writing, numbers, should be properly handled. In the third and fourth parts, the overriding significance of why you should strive to achieve both clarity and brevity is discussed. The usual 'Conclusion', `Summary', and 'References', sections complete the unit, while two 'Self-Assessment Exercises', which are embedded in the text, are designed to help you to understand better the presentation in this unit.

2.0 OBJECTIVES

At the end of unit, you should be able to:

- describe what constitutes the content of the Results/Findings section of a technical report or scientific paper
- explain how to handle numbers in writing the Findings section of a technical report or scientific paper
- distinguish between clarity and brevity in writing the Findings of technical report or scientific paper
- explain the significance of achieving both clarity and brevity in writing the Findings of technical report or scientific paper.

3.0 MAIN CONTENT

3.1 Content of the Findings

The Findings or Results component of a technical report, and especially of a scientific paper, is considered by most readers as its core. What should it contain?

Contrary to popular belief, you shouldn't start the Findings section by describing methods which you forgot to include in the Materials and Methods section. In other words, it is not the place to effect corrections to the earlier parts of your work. Indeed, there should be no need to mention this point at all since the widespread use of computers allows you to 'cut and paste' any sections of your work with ease. Unfortunately, a significant number of science manuscripts still contain a good deal of material that should not be part of the Findings/Results section.

There are usually two ingredients of the Findings section. Firstly, you should give some kind of overall description of experiments or field surveys that you carried.out for the study. This provides the "big picture", without, however, repeating the experimental or survey details previously provided in the Materials and Methods section. Second, you should present the data, the core of your report or paper.

The most important point about the content of your Findings section is that it should present representative data rather than *repetitive* data. The fact that you could perform the experiment 100 times without significant divergence in results is not of particular interest to many people. Editors of journals and, in particular, readers of your technical report, prefer a little bit of predigestion. Aaronson (1977) stated this concept pungently in the following words: "The compulsion to include everything, leaving nothing out, does not prove that one has unlimited information: it proves that one lacks discrimination." Exactly the same concept, and it is an important one, was stated almost a century earlier by John Wesley Powell, a geologist who served as President of the American Association for the Advancement of Science in 1888. In Powell's words: 'The fool collects facts: the wise' man selects them."

Therefore, select your data carefully. If you really have a lot of data that you believe should be included in a technical report, consign them to the Appendix (see Unit 2).

3.2 How to Handle Numbers

If you have to present only one or only a few determinations, they should be treated descriptively in the text. Repetitive determinations should be given in tables (see Module 2 Unit 5) or in graphs (see Module 3 Unit 1).

Any determinations, repetitive or otherwise, should be meaningful. Suppose that, in a particular group of experiments, a number of variables were tested (one at a time, of course). Those variables which affected the reaction become determinations or data and, if extensive, are tabulated or graphed. Those variables which do not seem to affect the reaction need not be tabulated or presented. however, it is often important to define even the *negative* aspects of your experiments. The reason you are advised to state what you did *not* find under the *conditions of your experiments* is that someone else very likely may find different results under *different conditions*. As Carl Sagan (1977) observed, ". . . absence of evidence[data] is not evidence of absence [of data]." You need to be particularly careful in using statistics to describe the results of your investigations. Yes, it is true that 'mathematics (or statistics) is the language of science,' but it must be meaningful statistics. It is not true that *any* statistics enhances the value of a scientific paper or technical report; imaginative and meaningful use of statistics does. If your mastery of statistics is not up to the level you need to use it efficiently in reporting your Findings or Results seek help (see Unit 4). In this age of customised statistical packages, there is really no excuse for the poor handling of numbers in writing the results of your investigations.

3.3 Strive for Clarity

Your results or findings should be short and sweet, without verbiage. Mitchel (1977) quoted Albert Einstein as having said, "If you are out to describe the truth, leave elegance to the tailor." Although the Results section of a scientific paper or technical report is the most important part, it is often the shortest, particularly if it is preceded by a well-written 'Materials and Methods' section (see Module 2 Unit 2) and followed by a well written 'Discussion' (see Module 2 Unit 4).

You may be wondering why all the emphasis so far has been on brevity in urging you to strive for clarity in writing the Results. The reason is simple:if you can manage to present "short and sweet" Results, you *will* be clear: clarity and brevity always go together, although more will be said on brevity a little later in this unit.

For scientists in developing countries, it is particularly important to understand and appreciate the value of the brevity/clarity relationship. You should understand that while practising on one, you are automatically improving on the other. Therefore, practise as often as you can; you will be surprised how soon you will be able to improve apparently 'good' presentations of Results in technical reports and even published scientific papers.

SELF-ASSESSMENT EXERCISE

Locate the Results/Findings section of an unpublished doctoral dissertation or master's thesis, preferably in your subject area:

i. Determine whether or not the content satisfies the criteria stipulated in this Unit.
ii. Assess clarity, sentence-by-sentence, on a three-point scale of "Clear", "Not Very Clear", and "Confusing".
iii. Isolate the "Not Very Clear" and "Confusing" sentences in (2).
iv. Rewrite the sentences isolated in (3) to attain the status of "Clear".
v. List the bonus points you have scored on *brevity* as you rewrite to attain clarity

Finally, on clarity you should remember that if any part of the scientific. paper or technical report needs to the clearly and simply stated, it is the Results. Reason? It is the results that comprise the new knowledge that you are contributing to the world, or the solution that you are offering in a specific organisational setting. The earlier parts of the paper (Introduction, Materials and Methods) are designed to tell why and how you got the Results. The later part of the paper (Discussion — see Module 2 Unit 4) is designed to tell what they mean. Obviously, therefore, the whole paper or report must stand or fall on the basis of the Results/Findings. Thus, the Results/Findings must be presented with crystal clarity.

3.4 Avoid Redundancy

Do not be guilty of redundancy in the presentation of the Results/Findings of your investigations. The most common fault is the repetition, in words, of what is already apparent to the reader from examination of the tables and figures. Even worse is the actual presentation, in the text, of all or many of the data shown in the tables or figures. Indeed, the misuse of tables and figures in scientific writing is so common that you need to be particularly careful in going through the units of this course which specifically show you how to prepare and efficiently use tables and graphs. Once you have mastered the efficient preparation and use of tables and illustrations in scientific writing, the avoidance of redundancy will be rapidly attained.

Do not be redundant, either, in citing figures and tables. 1)Do not say "It is clearly shown in Table 1 that nocillin inhibited the growth of *N. gonorrhoeae ."* Instead, say "Nocillin inhibited the growth of *N. gonorrhoeae* (Table 1)." The four unnecessary words "It is clearly shown" appear harmless here. But once you get into the habit of writing like that, it becomes much more difficult to get you to write directly and economically — the hallmarks of 'good' scientific writing.

You need to be aware, however, that some writers go too far in avoiding verbiage and, in the process, violate one important rule in good scientific writing, the rule of antecedents. Put simply, the rule specifies that when you use a noun (person, object, event), the pronoun used in place of the person, object, or event must show clear correspondence. In other words, there must be no doubt whatsoever in the minds of your readers which noun a particular pronoun used in your text is referring to. Consider the following examples from a paper submitted for publication in a medical journal:

> "The left leg became numb at times and she walked it off. .. . On her second day, the knee was better, and on the third day it completely disappeared."

The use of the first "it" clearly refers to the 'numbness in the patient's left leg. In other words, the antecedent for the "it" is the patient's left leg. However, the second "it" in the second sentence clearly does *not* refer to the patient's numbness in the left leg; it refers to the knee! Thus, the writer had managed to give the reader the (unintended) impression that the patient's knee had "completely disappeared"! You must do everything you can to avoid such errors of construction in your writing.

4.0 CONCLUSION

This deliberately short unit has described for you what should constitute the content of the Results/Findings section of a technical report or scientific paper. The most important point about the content of your 'Findings' section is that it should present representative data rather than repetitive data. This calls for your careful selection of data. You have also been shown how to handle raw numbers or statistics within the text as well as in tables, although tables, figures, and Other illustrations are presented in greater detail, You are warned to be particularly careful in using statistics to summarise the results of your investigations. The attainment of both clarity and brevity in scientific writing is explained separately although, in practice, the attainment of one automatically improves the other. In striving to attain both clarity and brevity, you should always bear in mind that it is in the Results section of your work that you present to the world the new knowledge that you are contributing, or the solution that you are offering, in a given organisational setting.

5.0 SUMMARY

In this unit, you have learned to:

- describe what constitutes the content of the Results/Findings section of a technical report or scientific paper
- explain how to handle numbers in writing the Results/Findings of technical report or scientific paper
- distinguish between clarity and brevity in writing the Findings of a technical report or scientific paper
- explain the significance of achieving clarity and brevity in writing the Findings of a technical report or scientific paper.

6.0 TUTOR-MARKED ASSIGNMENT

i. Describe what constitutes the content of the Results/Findings section of a technical report or scientific paper.
ii. Explain how to handle numbers in writing the Results/Findings of technical report or scientific paper.
iii. Distinguish between clarity and brevity in writing the Findings of a technical report or scientific paper.
iv. Explain the significance of achieving clarity and brevity in writing the Findings of a technical report or scientific paper.

7.0 REFERENCES/FURTHER READING

Aaronson, S. (1977). "Style in scientific writing." *Current Contents.* No.2, 10 January, pp.6-15.

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UNIT 4 WRITING THE DISCUSSION

CONTENTS

1.0 INTRODUCTION

The 'Discussion' is harder to define than the other sections of a technical report or scientific paper. As a result, it is usually the hardest section to write. And, whether you are aware of it or not, many technical reports and many scientific papers fail to register the authors' desired impact on readers because of a faulty discussion. Indeed, it is quite common to have valid and interesting data in a scientific paper that is rejected by a good journal, solely on account of its poor discussion. Even more likely, the true meaning of the data may be completely obscured by the interpretation presented in the discussion, again resulting in rejection. When this happens in respect of a technical report, the author may not be given a second chance, as several journals often do.

Many, perhaps most, discussions are too long and verbose. The most common explanation for such faulty writing is that the author is doubtful about his facts (Results or Findings', or his reasoning, and retreats behind a protective cloud of ink). In developing countries, however, the reason is frequently traceable to ignorance or absence of proper quality control. In any event, poor discussions in technical reports or scientific papers always impact negatively on the author; the objective of this unit is to provide help in eliminating most of the weaknesses found in the discussions of scientific reports or papers.

This unit, then, comprises four parts. In part one, the essential features of a good Discussion are listed and briefly described. In part two, the need to establish appropriate relationships between observed facts is demonstrated. In part three, you are urged to take pains to let your readers appreciate the significance of the results you are discussing. And, finally, in part four, you are guided in trying to lay claim to "truth in science" with great caution. The usual "Conclusion", "Summary", and "Reference" sections complete the unit; a self-assessment exercise is incorporated in the text.

2.0 OBJECTIVES

At the end of this unit, you should he able to:

- identify and describe the essential features of a good Discussion in a technical report or scientific paper
- show clearly the relationships among established facts, as presented in your Results/Findings section
- demonstrate convincingly the significance of the results you have already presented and discussed
- define accurately and modestly what your conclusions may have contributed to the corpus of knowledge in the area investigated.

3.0 MAIN CONTENT

3.1 Components of the Discussion

The basic question to ask here is, 'What are the essential features of a good Discussion? In answering the question, you will do well to heed the following injunctions:

Try to present the principles, relationships, and generalisations shown by the Results.

And bear in mind, in a good Discussion, you discuss—you do not recapitulate the Results.

A common justification for recapitulating the Results is the author's (gratuitous) assumption that the reader may have somehow forgotten the Results already presented. In reality, readers rarely display such short memory and can always take a second look at your Results section if they have to. And, remember, you are discussing the principles, relationships, and generalisations thrown up by *your* data, not someone else's.

Point out any exceptions or any lack of correlation, and define unsettled points.

Progress is made in science on the basis of being aware of both established and unestablished knowledge. In other words, by reporting the negative aspects of your experiments (Module 1 Unit 3, section 3.2) and discussing them in terms of "exceptions or lack of correlations" and thereby defining “unsettled points,” you are laying a solid foundation for subsequent investigations to build on your work.

Show how your results and interpretations agree (or contrast) with previously published work.

This injunction implies that you must be current with the literature in your area of investigation — a major obstacle for most scientists working in developing countries. Being "current with the literature" also implies access to both print and electronic literature. Increasingly, it is being demonstrated that access to the Internet is a fundamental requirement for research in science, anywhere.

Don't be shy; discuss the theoretical implications of your work, as well as any practical implications.

As a general rule, technical reports tend to be heavy on "practical implications" in a specific organisational setting and almost silent on theoretical implications. Indeed, theoretical considerations are often consigned to Appendixes. In writing scientific papers for presentation at learned conferences or publication in learned journals, however, the reverse is the case: theoretical implications are given more emphasis.

State your conclusions, as clearly as possible.

In earlier units you were enjoined to strive for clarity and brevity respectively in presenting your Results. The same attributes should also be evident in the presentation of the conclusions of your Discussion. Your conclusion should, as often as possible, be in the form of "Therefore …" in one sentence or, at most, two short sentences.

Summarise your evidence for each *conclusion, and never assume anything as you do so.*

It is a mistake to neglect giving the summary of what your discussion has led you logically to conclude. In other words, neither the facts nor the discussion can be assumed to be 'self-evident': you will have to summarise each conclusion, on the basis of the objectives set out in your investigation. And, for emphasis, remember that the conclusion alone is not enough: present the reader with its summary, too.

3.2 Factual Relationships

The primary purpose of the Discussion can be described in simple terms as follows: to show the relationships among observed facts. But, this apparent simplicity doesn't always translate into simple practical realities when the facts of an investigation have to he discussed. To illustrate the point, we shall consider a classic story and then invite you to answer several questions, based on the story. The questions are, of course, a series of self-assessment exercises on 'drawing valid conclusions from the discussion of your scientific work.'

The Story about the Biologist who Trained a Flea

After training the flea for many months, the biologist was able to get a response to certain commands. The most gratifying of the experiments was the one in which the professor would shout the command **"jump",** and the flea would leap into the air each time the command was given. The professor was about to submit this remarkable feat to posterity via a scientific journal, but he — in the manner of the true scientist — decided to take his experiments one step further. He sought to determine the location of the receptor organ involved. In one experiment, he removed the legs of the flea, one at a time. The flea obligingly continued to jump upon command, but as each successive leg was removed, its jumps became less spectacular. Finally, with the removal of its last leg, the flea remained motionless. Time after time the command failed to get the usual response.

The professor decided that at last he could publish his findings. He set pen to paper and described in meticulous detail the experiments executed over the preceding months. His conclusion was one intended to startle the scientific world: *When the legs of a flea are removed, the flea can no longer hear*.

SELF-ASSESSMENT EXERCISE

Attempt the following questions, on the basis of the story related above:

i. State, in your own words, the objective of the professor's study in terms of the *relationship(s)* being sought.
ii. Was the professor's decision to "determine the location of the receptor organ involved" a logical step, in light of the objective stated in (1)?
iii. How would you *summarise* the conclusion reached' by the professor? Was the professor's conclusion valid? Give reasons for your answer.

3.3 Significance of the Report/Paper

When you write a technical report, it is to attain a specified objective as defined by the authorities that have commissioned you to do it, or according to the specific priorities set by yourself, the writer (see

Module 1 Unit 2). Similarly, how to state the objective(s) of writing a scientific 'paper will have been clearly set out in several of the preceding units already covered in this course.

Too often, however, the *significance* of the results of the technical report or paper is not discussed at all or not discussed adequately. This is a serious error of omission which you must work hard to avoid in your writing technical reports or papers. If the reader of your techni.cal report/paper finds himself or herself asking "So what?" after reading the Discussion, the chances are that you have become so engrossed with the data that you failed to notice the principles and the generalisations (or the pattern) shown by the data (See section 3.1 of this unit again).

Your Discussion should end with a short summary or conclusion regarding the significance of your work. If several discernible objectives were set at the beginning, it should be possible to summarise your Discussion by listing how well your study has met each of the set objectives. This is, in itself, a self-assessment exercise: if your set objectives have not been adequately met (that is, you are unable to summarise them by producing a list), it may mean that something has seriously gone missing in your work. Or, it could mean that the original objectives were unrealistic and may have to be reset.

Finally, try to end your Discussion with a memorable climax that links your work to what has been done in your area of investigation and to what subsequent investigators might wish to work on. It should be done in a sentence or two, stressing the significance of continuing the effort you have either initiated or contributed to.

3.4 Defining Scientific Truth

Most investigators, at the beginning of their careers, like to believe that they are involved in some earth-shaking work. And, it does not matter at what level: the small project written by a master's level student is perceived by the writer as just as 'earth-shaking' as the doctoral student's dissertation. The reality is quite different, however.

In showing the relationships among observed facts, you do not need to reach cosmic conclusions. Seldom will you be able to illuminate the whole truth; more often, the best you can do is shine a spotlight on one area of truth. Your one area of truth can be buttressed by your data; if you extrapolate to a bigger picture than that shown by your data you may appear foolish to the point that even your data-supported conclusions are cast into doubt.

The point being made is just as poignant when you are writing a technical report aimed at providing one or more solutions to specified organisational problems. In drawing your conclusions; always bear in mind that you may not have all the facts. Therefore, make your Recommendations very carefully, and take time to discuss at least one draft of your Recommendations with those who are likely to implement them within the organisation.

Whether you are writing a scientific paper or a technical report, you will do well to reflect carefully on the following words of poetry, so thoughtfully expressed by Sir Richard Burton in the poem, *The Kasidah:*

1. All Faith is false, all Faith is
2. true:
3. Truth is the shattered mirror strown
4. In myriad bits; while each believes
5. His little bit the whole to own.

So, exhibit your little piece of the mirror, or shine a spotlight on one area of the truth. The "whole truth" is a subject best left to the ignoramuses, who loudly proclaim its discovery every day. And when you describe the meaning (significance) of your little bit of truth, do it simply. The simplest statements evoke the most wisdom; verbose language and fancy technical words are used to convey shallow thought.

4.0 CONCLUSION

Six essential features of a good Discussion in a technical report or scientific paper have been listed and briefly described for you. The features are mutually reinforcing, that is, no Discussion should neglect any of them. Your discussion must be written to explore only factual relationships; nothing should be included which your data have not clearly established. It is a gross mistake to jump a logical step in order to establish factual relationships; your work immediately exhibits an obvious flaw in scientific writing, as the self-assessment exercise tries to show you. Your Discussion should also let the reader know how significant your work is, without being pedantic. If possible, list the specific areas of significance highlighted by your work. Finally, remember that you can only "shine a spotlight on one area of the truth" in your work, no matter how big or long it takes to complete it. Be modest, even conservative, in your claims, always bearing in mind that it is only a matter of time before other workers improve on it.

5.0 SUMMARY

In this unit, you have learned how to:

- list and describe six components of the Discussion of a technical report or scientific paper
- show clearly the relationships among the established facts presented in the Results/Findings section of your report or paper
- demonstrate convincingly the significance of the results you have already presented and discussed; and
- define accurately and modestly what your conclusions may have contributed to the corpus of knowledge in the area investigated.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the essential features of a good Discussion?

7.0 REFERENCE/FURTHER READING

Day, Roberts A. (1983). *How to Write and Publish a Scientific Paper. 2nd* ed. Philadelphia: ISI Press.

UNIT 5 PREPARING AND USING TABLES

CONTENTS

1.0 INTRODUCTION

Tabular presentations are more commonly used by writers in science and technology than writers in other disciplines. The reason is quite simple: experiments and field surveys tend to produce a large body of readings and observations which investigators may be tempted to simply turn over to readers of technical reports and scientific papers in an unending catalogue of tables. Thus, tables are often abused, rather than being used to illustrate text material for the benefit of readers. It is, therefore, important that you know when *not* to use tables in your writing as well as when to use them.

This unit, then, is divided into three parts. In the first part, you are shown when *not* to use tables in your writing. Several examples are provided of tables that appear alright, but are in fact not necessary. You are encouraged to look for similar examples in your subject areas. Part two shows you how to arrange tabular material, again with several examples that have been selected to cover as wide a range of possibilities as possible. You can easily widen the range by consulting the best journals and books in your subject areas. The third part describes other aspects of tabular presentations which can make your tables more effective, but which are sometimes overlooked by many writers. The usual Conclusion; Summary , and References complete the unit; self-assessment exercises are in the text.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- recognise when not to use tables in scientific writing
- organise efficiently and effectively the tabular material in a technical report or scientific paper
- list and describe the characteristics of a good table
- describe clearly all the components of a table so that readers will understand fully their significance, both in the table and the text.

3.0 MAIN CONTENT

3.1 When not to use Tables

As a general rule, do not construct a table unless repetitive data *must* be presented. There are two reasons for this general rule. First, it is simply not good science to regurgitate reams of data just because you have them in your laboratory or field notebooks; only samples and breakpoints need be given. Second, the effort and time required to construct tables should be viewed as an investment in facilitating readers' better understanding of subject matter, not an obstacle to be overcome. If you made (or need to present) only a few determinations , give the data in the text. Tables 1 and 2 are useless, yet they are typical of many tables that are found in the technical reports or manuscripts submitted to journals.

Tale 1: Effect of Aeration on Growth of Streptomyces coelicolor

Tem(uC)	No. of expt	Aeration of growth medium	Growth [a]
24	5 →	+[b] →	78
24	5 →	- →	0

[a] As determined by optical density (Klett units)
[b] Symbols:+, 500-ml Erlenmeyer flasks were aerated by having a graduate student blow into the bottles for 15min out of each hour; --, identical test conditions, except that the aeration was provided by an elderly professor.

Table 1 is faulty because two of the columns give standard conditions, not variables and not data. If temperature is a variable in the experiments, it can have its column. If all experiments were done at the same temperature, however, this single bit of information should be noted in Materials and Methods and perhaps as a footnote to the table, but not in the table. Table 1 is not a proper table. These data can be presented in the text itself in a form that is readily comprehensible to the reader, while at the same time avoiding the substantial additional typesetting cost of tabulation. Very simply, these results would read: "Aeration of the growth medium was essential for the growth of *Streptomyces coelicolor*. At room temperature (24°C), no growth was evident in stationary (unaerated) cultures, whereas substantial growth (OD, 78 Klett units) occurred in shaken cultures."

Table 2: Effect of Temperature on Growth of Oak (Quercus) Seedlings [a]

Temp (°C)	**Growth in 48h (mm)**
-50	0
-40	0
-30	0
-20	0
-10	0
0	0
10	0
20	7
30	8
40	1
50	0
60	0
70	0
80	0
90	0
100	0

[a] Each individual seedling was maintained in an individual round pot, 10cm in diameter and 100m high, in a rich growth medium containing 50% Michigan peat and 50% dried horse manure. Actually, it wasn't "50% Michigan"; the peat was 100% "Michigan," all of it coming from the state. And the manure wasn't half-dried (50%); it was all dried. And, come to think about it, I should have said "50% dried manure (horse)": I didn't dry the horse at all.

Table 2 has no columns of identical readings, and it looks like a good table. But is it? Let's look at it more closely.

The independent variable column (temperature) looks reasonable enough, but the dependent variable column (growth) has a suspicious number of zeros. You should question any table with a large number of zeros (whatever the unit of measurement) or a large number of 100s when percentages are used. Table 2 is certainly a useless table, because all that it tells us is that "The oak seedlings grew at temperatures between 20 and 40°C; no measurable growth occurred at temperatures below 20°C or above 40°C."

Table 3 : Oxygen Requirement of various Species of Streptomyces

Organism	Growth under Aerobic conditions [a]	Growth under anaerobic conditions [b]
Streptomyces griseus	+	-
S.coelicolor	+	-
S.nocolor	-	+
S.everycolor	+	-
S.gnenicus	-	+
S,rainbowenski	+	-

[a] See Table 1 for explanation of symbols. In this experiment, the cultures were aerated by a shaking machine (New Brunswick Shaking Co., Scientific, NJ).

In addition to zeros and 100s, be suspicious of plus and minus signs. Table 3 is of a type that often appears in print, although it is obviously not very informative. All this table tells us is that *"S.griseus S.coelicolor, S.everycolor,and S.rainbowenski* grew under aerobic conditions, whereas *S.nocolor* and *S.greenicus* required anaerobic conditions." The lesson'? Whenever a table, or column within a table, can be readily put into words, do it.

Some writers believe that all numbers must be put in a table. They are wrong, and Table 4 is a sad example of such misguided belief. It gets even sadder when we learn, at the end of the footnote, that the results were not significant anyway (P=0.21). If these data were worth publishing at all, one sentence would have done the job as follows: 'Me difference between the failure rates — 14% (5 out of 35) for nocillin and 26% (9 out of 34) for potassium pencillin V — was not significant (P=0.21)." Thus, you learn another lesson here: In presenting numbers, give only significant figures. Non-significant figures may mislead the reader by creating a false sense of precision. In addition, comparison of the data becomes more difficult. Similarly, unessential data, such as laboratory numbers or markers for field notebooks, results of simple calculations, and columns that show no significant variations, should be omitted in tables.

Table 4: Bacteriological Failure Rate

Nocillin	Kpenicillin
5/35(14)[a]	9/341761

[a] Results expressed as a number of failures/total, which is then converted to a percentage (within parenthesis). P =0.21.

Another very common, but useless, table is the word list. Table 5 is a typical example. The information contained in Table 5 could, and quite obviously should, be presented in the text. A good copy editor will kill this kind of table and incorporate the data into the text. In doing so, the editor will often discover that much or all of the information was already in the text, anyway. Thus, the rule for you is as follows: present the

Table 5: Adverse Effects of Nicklecillin in 24 Adult Patients

No. of patients	Side effect
14	Diarrhea
5	Easinophilia
2	Metallic taste[a]
1	Yeast vaginitis
1	Mild rise in urea nitrogen
1	lIematuria (8-10rbc/hpl)

[a] Both of the patients who tasted metallic worked in a zinc mine.

[b]The infecting organism was a rare strain of *Canclida albicans* which causes viginitis in yeasts but not in humans.

data in the text, *or* in a table, *or* in a figure. *Never* present the same data in more than one way.

Tables 1 to 5 provide you with typical examples of the kinds ol material that should not be tabulated. Look for additional material yourself, preferably in your subject area(s). Once you are convinced that the examples you have found are 'useless tables,' put them in words and incorporate them into the appropriate sections of the text.

You are now in a good position to look at material that should be tabulated.

3.2 How to Arrange Tabular Material

Once you have taken the decision to tabulate, you must ask yourself exactly what should go into the table and in what form. Your first question is: "how do I arrange the data?" Since the table has both left-right (horizontal) and up-down (vertical) dimensions, you have two choices. In other words, your data can be presented either horizontally or vertically. But *can,* does not mean *should;* your data should be organised so that the like elements read *down,* not across. Your understanding of this point is crucial to the effective organisation of every table in your scientific writing. Therefore, we shall illustrate it in some detail to ensure that you grasp the essential points.

Table 6: Characteristics of Antibiotic-producing Streptomyces

Determination	S.fluoricoloi	S.griseus	S.coelicolor	S.nocolor
Optimal growth Temp.(0c)	-10	24	28	92
Color of mycelium	Tan	Gray	Red	Purple
Antibiotic produced	Fluoricil-linmycin	Strepto-mycin	Rhdmon--delay	Nomycin
Yield of antibiotic (mg/ml)	4,108	78	2	0

[a] Pronounced "Rumley" by the British.

Table 7: Characteristics of Antibiotic-producing Streptomyces

Organism	Optimal Growth temn(0c)	Color of mycelium	Antibiotic produced	Yield of antibiotic
S.fluoricolor	-10	Tan	Fluoricillin -Mycin	4,108
S.griseus	24	Gray	Streptomycin	78
S.coelicolor	28	Red	Rholmondelay	?
S.nocolor	92	Purple	Nomycin	0

Examine Tables 6 and 7. They are equivalent, except that Table 6 reads across and Table 7 reads down. Clearly, Table 7 is the preferred format because:

- it allows the reader to grasp the information quickly, and
- it is more compact and neater. It appears smaller than Table 6, although it contains exactly the same information.

The point about ease for the reader should be paramount in your mind as you write a technical report or scientific paper. (Did you ever try to add numbers that were presented horizontally rather than vertically?).

Table 8: Distribution of Protein and ATPase in Fractions of Dialyzed Membranes[a]

		ATPase	
Membranes from	**Fraction**	**U/mg of protein**	**Total U**
Control	Depleted membrane	0.036	2.3
	Concentrated supernatant	0.134	4.82
El treated	Depleted membrane	0.034	1.98
	Concentrated supernatant	0.11	4.6

[a]Specific activities of ATPase of non depleted membranes from control and treated bacteria were 0.21 and 0.20, respectively. Membranes were prepared from cells treated with colicin El as described in the legend to Fig. 4.

Table 8 is an example of a well-constructed table (copied from the "Instruction to Authors" of the *Journal of Bacteriology).* You should note the reasons Table 8 is described as "well-constructed" as follows:

- It reads down, not across
- It has headings that are clear enough to make the meaning of the data understandable without reference to the text — a rule for a good table; and
- It has explanatory footnotes, but it does not repeat excessive experimental detail.

The last point needs further explanation to enable you appreciate its significance. It is proper to provide enough information to ensure that the meaning of the data is apparent without reference to the text. But it is improper to provide *in the table* the experimental detail that would be required to repeat the experiment. The detailed materials and methods used to derive the data should remain in the section of that name (see Unit 7).

3.3 Additional Issues in Organisiing Tabular Material

There are other issues that you need to be aware of in organising tabular material — issues that may appear trivial individually, but cumulatively help or hinder readers' comprehension of your tabular and/or text material. Three such issues are briefly described: (a) exponents in table headings, (b) marginal, indicators, and (c) the use of captions, footnotes, and abbreviations.

3.3.1 Exponents in Table Headings

If possible, avoid using exponents in table headings. Confusion is often the result because some authors use positive exponents and others use negative exponents to mean, the same thing. For example, "cpm x 10^3" is used to refer to thousands of counts per minute by an author, while another uses "cpm x10 for the same thousands of counts. If it is not possible to avoid such labels in the table heading (or in figures), it may be worthwhile to state in a footnote (or the figure legend) what convention is being used, in words that eliminate the ambiguity.

3.3.2 Margin Indicators

It is a good idea to identify in the margin of your technical report or scientific paper the location of the first reference to each table. Simply write "Table 3" (for example) in the margin and circle it. This procedure is a good check to make sure that you have indeed cited each table in the text, in numerical order. Moreover, you might want to make passing reference to a table early in your report/paper but would prefer to have the table appear later on in the text. Only by your marginal notes to tables will you be able to integrate all parts of your text accurately and consistently.

3.3.3 Captions, Footnotes and Abbreviations

The caption of a table (and the legend of a figure)is like the title of the report/paper itself. That is, the caption or legend should be concise and not divided into two or more clauses or sentences. Unnecessary words should be omitted.

Give careful thought to the footnotes to your tables. If abbreviations must be defined, you can give all or most of the definitions in Table 1. Then later tables can carry the simple footnote: "Abbreviations as in Table 1."

You may have noticed in Tables 1,2,6 and 7 that "temp" is used as an abbreviation for "temperature." It is fairly common practice to use *standard* abbreviations in the tables of journal articles and technical reports. Such abbreviations would, however, not be allowed in the text. if you are in doubt about the standard abbreviations in your subject area(s) you should consult the appropriate reference source(s). Get into the habit of using these abbreviations so that your word processed manuscript will have camera-ready tables.

4.0 CONCLUSION

Writers of technical reports and scientific papers often need to use a lot of tables in order to summarise their experiments or field observations as efficiently, and effectively as possible. In the process, they may construct tables that are neither helpful nor necessary. Consequently, you have been shown how to recognise when *not* to use tables. To illustrate the point, five unnecessary tables were constructed for you and the reasons they are not the types of tables you should aim to construct were carefully explained to you.

The salient points of how to arrange tabular material were then presented to you, again by giving you specific tables (three in all) to illustrate the major points of the presentation. The attributes of a "well-constructed" table were then listed for you and briefly described. Finally, you are invited to consider additional issues in organising tabular material 'issues which individually may appear trivial but which, cumulatively, facilitate or hinder readers' comprehension of your tables and/or text. You are also asked to examine several more examples of "good" and "bad" tables, preferably in your subject area(s).

5.0 SUMMARY

In this unit, you have learned to:

- recognise the circumstances when it would be inappropriate to use tables in your technical report or scientific paper
- organise efficiently and effectively the tabular material in a technical report/scientific paper
- list and describe the characteristics of a good table; and
- describe clearly all the components of a table so that readers will understand fully their significance, both in the table and the text.

6.0 TUTOR-MARKED ASSIGNMENT

i. Discuss the merits of a well organised table with reference to Tables 1 to 8 given in the text.
ii. Show with reference to Tables 1 to 8 given in the text why disorganised tables hinder comprehension of Technical Reports.

7.0 REFERENCE/FURTHER READING

Day, Roberts A. (1983). *How to Write and Publish a Scientific Paper*. 2nd ed. Philadelphia: ISI Press.

MODULE 3

UNIT 1 PREPARING EFFECTIVE GRAPHS

CONTENTS

1.0 INTRODUCTION

In Unit 10, you have learned the circumstances which must be considered in deciding whether or not tables would be appropriate in scientific writing. Next to tables, graphs constitute the second most frequently used illustrations in writing technical reports and scientific papers. It is important, therefore, that you learn how to construct and use graphs as well as you have done with tables. These two types of illustration - tables and graphs - are the only ones you will be expected to handle all on your own, or with minimal assistance. And even with the increasingly widespread use of computer graphics to replace hand-drawn graphs, the science writer is still expected to be able to choose the appropriate computer graphics *and* to supervise their drawing.

Graphs are basically pictorial tables. Therefore, all the precautions you have learned in handling tables apply in equal force to graphs. In other words, if your decision is that some data that you have collected should not be tabulated, they should *not* be turned into figures either. For this reason, you will need to learn when it is necessary to use graphs before you learn how to draw them.

This unit, then, comprises four parts. In part one, you are reminded, once again, that the most fundamental lesson is being able to decide accurately and consistently when to illustrate in scientific writing. Part two shows you when to use graphs, and part three shows you how to draw them. Part four draws your attention to important aspects which, when used sensibly and consistently, combine to make your graphs legible and pleasant to the reader. The usual Conclusion, Summary, and References complete the unit. Self-assessment exercises are incorporated in the text.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- decide accurately and consistently when to use graphs in scientific writing
- draw line graphs from data generated by your experiments or field observations, essentially by using the services of computer graphists
- use appropriate scales, symbols, and legends in graphs
- arrange graphs in the text to achieve the desired effect.

3.0 MAIN CONTENT

3.1 When to Illustrate

Certain types of data, particularly of the sparse type or of the type that is monotonously repetitive, do not need to be brought together in either a table or a graph. The facts are still the same: The cost of preparing and printing an illustration is high, and you should consider illustrating your data only if the result is a real service to the reader.

This point bears repeating, because many writers, especially those who are still beginners, think that a table, graph, or chart somehow adds importance to the data and their writing. Thus, in the search for credibility, there is a tendency to convert a few data elemens into an impressive-looking graph or table. You are advised not to indulge in such practice. Your more experienced peers and most journal editors will not be fooled; they will soon deduce that (for example) three of four curves in your graph are simply the standard conditions and that the meaning of the fourth curve could have been stated in just a few words. Attempts to dress scientific data are usually doomed to failure.

If there is only one curve on a graph, can you describe it in words? Possibly only one value is really significant, either a maximum or a minimum; the rest is window dressing. If you determined, for example, that the optimum pII value for a particular reaction was pH 8.1, it would probably be sufficient to state something like "Maximum yield was obtained at pH 8.1." Similarly, if you determined that maximum growth of an organism occurred at 37°C, a simple statement to that effect is better economics and better science than a graph showing the same thing.

If the choice you have to make is not graph versus text but graph versus table, your choice might relate to whether you want to impart to readets exact numerical values or simply a picture of the trend or shape of the data. Rarely, there might be a reason to present the same data in both a table and a graph, the first presenting the exact values and the second showing a trend not otherwise apparent. This procedure seems to be rather common in physics.

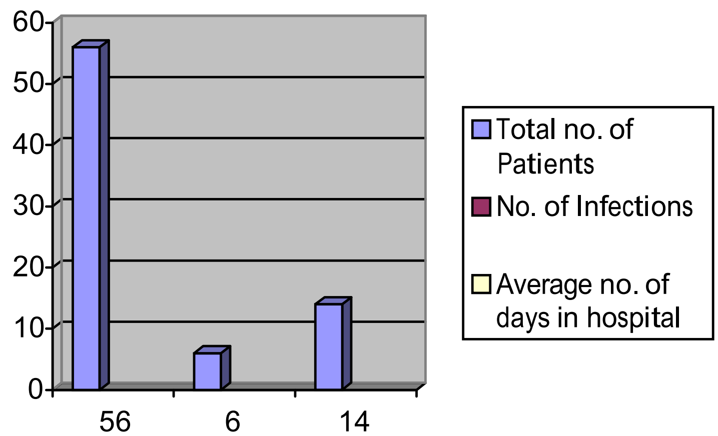

Fig. 1: Incidence of Hospital-acquired Infections
(Courtesy of Erwin F. Tassel)

An example of a nice, but unneeded, bar graph is shown in Figure 1. This figure should be replaced by one sentence in the text: "Among the test group of 56 patients who were hospitalised for an average of 14 days, 6 acquired infections."

So, how can you decide in every case when an illustration is justified? There are no clear rules, but you can learn how to use graphs and photographs — the types of illustration most commonly used in scientific writing — and thereby acquire the necessary confidence in illustrating your writing appropriately. Only graphs are covered in this unit.

3.2 When to Use Graphs

Graphs are called line drawings in printing terminology because they are very similar to tables as a means of presenting data in an organised manner. In fact, the results of many experiments or the findings of many field observations can be presented either as tables or as graphs. How do you decide which is preferable? This is often a difficult decision. You should, however, try to apply the following basic rule to such a decision situation:

- If the data show pronounced trends, making an interesting picture, use a graph. If the numbers just sit there, with no exciting trend in evidence, a table should be satisfactory (and actually easier and cheaper for you to prepare).

Generally, it is not difficult to grasp this rule. In practice, however, you will have to try very hard to apply it accurately and consistently. In particular, you must learn to resist the temptation of presenting the same set of data twice, that is in tabular *and* graphical formats. Indeed, some manuscripts have been known to present both tabular and graphical formats *and* then to describe the illustrations in the text. It bears repeating to remind you that such writing is not scientific at all. You will appreciate better the point being made by considering a practical example.

Examine Table 9 and Figure 2, both of which record exactly the same data. Then, try to answer the following questions:

a. Which format is more acceptable? Why?
b. In which of the two presentations is the synergistic action of the two-drug combination more immediately apparent?
c. Which presentation enables the reader to more quickly grasp the significance of the data?
d. Would you use one or both presentations?

TABLE 9: Effect of streptomycin, isoniazid, and streptomycin plus isoniazid on Mycobacterium tuberculosis'

	Percentage of negative cultures at:			
Treatment[b]	2 wk	4wk	6wk	8wk
Streptomycin	5	10	15	20
Isoniazid	8	12	15	15
Streptomycin + isoniazid	30	60	80	100

The patient population was described in a preceding paper . . .
Highest quality available from our supplier (Town Pharmacy, Podunk, IA).

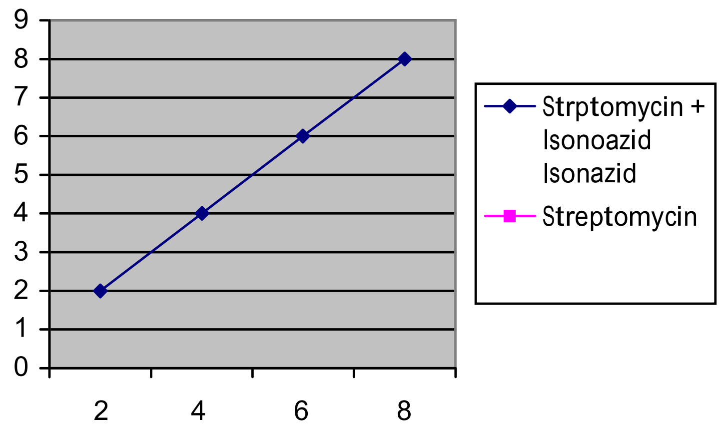

Fig. 2: Graph of the effect of streptomycin, isoniazid and streptomycin isoniazid on mycobacterium tuberculosis

3.3 How to Draw Graphs

Until quite recently, the drawing of line graphs constituted a formidable task for most writers of technical and scientific papers. Consequently,standard textbooks on "How to write and publish scientific papers" devote much energy and space to detailed instructions on how to convert data into line graphs. In reality, most writers in science and technology would prefer to be spared the effort and time required to produce even the simplest of line graphs; they generally prefer to turn over the task to specialists who are called cartographers.

Cartographers can be described as those who have been specially trained to convert data into maps (two-dimensional, line drawings). They use special equipment to do their job and can produce line drawings (maps, graphs, charts, etc) from any number of data rather easily and efficiently at affordable costs. Consequently, most writers in science and technology have tended to turn to cartographers to satisfy their need for graphs, until recently.

Over the last decade or so, the: use of computer graphics has become widespread among all specialists and professionals, including writers. Computer graphics are specially designed software programmes to convert data of any kind into different types of graphic illustrations - line graphs, bar and pie charts, etc. Most of them come in beautiful colours as well. Thus, there is really no longer *a* need to use cartographers to produce most of the graphs required in scientific writing; they can be effectively produced on the writer's personal computer, so long as the appropriate software is loaded into it.

If you don't have the facilities or the time to produce your computer graphics yourself, they can be efficiently and inexpensively produced for you by any of the ubiquitous computing shops found all over Nigerian cities and towns today. In patronising a computer outfit, you should ensure that it:

a. has the appropriate software to handle your type of data. Preferably, you should inspect similar work that it had previously handled
b. has an effective virus detection software which is updated regularly (preferably every week) and
c. has a colour printer.

Because graphs constitute such an important part of scientific writing, you may have to go some distance away from where you live or work in order to secure satisfactory computing service to handle your need for graphics. Such extra effort and expense would be more than compensated for by the high quality of graphs that would adorn your writing.

One final point on how to draw graphs needs to be made: You must always keep in mind *why* the graphs are being used. In particular, the size of the lettering must be based on the anticipated photographic reduction that will occur in the printing process. This factor becomes especially important if you are combining two or more graphs into a single illustration.

3.4 Scale, Arrangement, Symbols, and Legends

The inherent advantages in the use of graphs can be easily lost if you don't pay enough attention to such apparently small matters as scale, arrangement, symbols and legends. You must provide appropriate guidelines to the computer graphist, otherwise you will get beautiful graphs that are not, at all helpful in your writing. In order to facilitate your handling of such "small matters," a number of ground rules are provided here:

- The lettering of your graphs must be of sufficient size to withstand reduction to column or page width. And if you have to combine figures; you should do so "over and under" rather than "side by side."
- Whenever figures are related and can be combined into a composite, they should be combined. The composite arrangement saves space and thus reduces printing expense. More importantly, the reader gets a much better picture by seeing the related elements in juxtaposition.
- Do not extend the ordinate or the abscissa (or the explanatory lettering) beyond what the graph demands. For example, if your data

points range between 0 and 78, your topmost index number should

- be 80. You might feel a tendency to extend the graph to 100, a nice round number. This urge is especially difficult to resist if the data points are percentages, for which the natural range is 0 to 100. You must resist this urge, however. If you don't, parts of your graph will be empty; worse, the live part of your graph will then be restricted in dimension, because you have wasted perhaps 20% of the width (or length) with empty white space.
- In the example above (data points ranging from 0 to 78), your lettered reference numbers should be 0, 20, 40, 60, and 80. You should use short index lines at each of these numbers and also at the intermediate l0s (10, 30, 50, 70). Obviously, a reference stub line between 0 and 20 could only be 10. Thus, you need not letter the 10s, and you can then use larger lettering for the 20s, without squeezing. By using such techniques, you can make graphs simple and effective instead of cluttered and confusing.
- If there is space in the graph itself, use it to present the key to the symbols you have used. In the bar graph (Fig. 1), the shadings of the bars would have been a bit difficult to define in the legend; given as a key, they need no further definition.
- If you must define the symbols in the figure legend, you should use only those symbols that are considered standard, for which the printer will have type. (The rule applies to computer typesetting as well). Perhaps the most standard symbols are open and closed circles, triangles, and squares (OADOA•). If you have just one curve, use open circles for the reference points; use open triangles for the second, open squares for the third, closed circles for the fourth, and so on. If you need more symbols, you probably have too many curves for one graph and you should consider dividing it into two. If you must use a few more symbols, consider the multiplication sign (x) or different types of connecting lines (solid, dashed).
- Finally, remember that you are in control of what comes out of the cartographer's drawing board, or the graphist's computer. In other words, you *must* proofread carefully to ensure that all the guidelines you have learned in this unit on the production of good graphs are adhered to.

4.0 CONCLUSION

The preparation and use of graphs constitute an important aspect of scientific writing. The need to use them must be the result of serious thought and deliberate action; it is never automatic. Having decided to use them, every care must be taken to prepare them efficiently and to use them effectively to illustrate text material. You have been shown how to prepare and use good graphs; even when you have to use cartographers or computer graphics, you are always in control. Therefore, knowing what to do and how, as well as seeking help from whatever source(s), remain your responsibility from the beginning to the end of producing .You use graphs to enhance the quality of your scientific writing.

5.0 SUMMARY

In this unit, you have learned to:

- decide accurately and consistently when to use graphs in scientific writing
- draw line graphs by using the services of cartographers or computer graphists
- use appropriate scales, symbols, and legends in graphs and
- arrange graphs in the text to achieve the desired effect.

6.0 TUTOR-MARKED ASSIGNMENT

1.How do you arrange graphs in the text to achieve the desired effect.

2. Of what importance is graphs in scientific writing?

7.0 REFERENCES/FURTHER READING

Aiyepeku, W.O. (2000). "Using computer graphics in scientific communication and research." Unpublished lecture notes, University of Ibadan.

Day, Roberts A. (1983). *How to Write and Publish a Scientific Paper*. (2nd ed.). Philadelphia: ISI Press.

UNIT 2 CITING AND ARRANGING REFERENCES 1

CONTENTS

1.0 INTRODUCTION

Few writers in science and technology pay sufficient attention to the citations and references in their works. The impression is too often given that citations and references are of secondary significance to the subject matter treated in the text. This attitude is not only wrong but a disservice to the cause of science, as you will soon appreciate in this unit.

You have a responsibility to learn, as early as possible in your career, why it is important to take citations and references as seriously as the text material in all types of writing that you undertake. The application of that learning will bear much dividends in a better organisation of your work, in a greater appreciation of your worth as a scientist, and in a better understanding and appreciation of all aspects of human knowledge. The last point is particularly important because science and technology must always be perceived as only a slice—albeit an important slice - of the corpus of human knowledge.

This unit, then, is presented in five parts. Part one describes the antecedents of the reference tradition in science, a tradition that is heavily indebted to the humanities. Part two gives you some basic rules to follow in citing the literature handled in your writing. Part three describes the major features of bibliographic and reference styles that you need to know, and the last part describes the name and date citation system that is commonly used in scientific writing. The usual Conclusion, Summary, References, and a self-assessment assignment complete the unit.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- recognise and appreciate the main attributes of the citation and reference tradition in science
- name and describe the three basic rules of citing the literature of science
- describe the major characteristics of bibliographic and reference styles
- recall and correctly use the name and year system in making citations and listing references.

3.0 MAIN CONTENT

3.1 The Citation and Reference Tradition in Science

The reference tradition in science derives from the principle of citation indexing which is based on the simple concept that an author's references to previously recorded information should identify much of the earlier work that is pertinent to the subject of his present document. These references are commonly called citations, and a citation index is a structured list of all the citations in a given collection of documents. Such lists are usually arranged so that the cited document is followed by the citing documents.

The first practical application of this concept was *Shepard 's Citations,* a legal reference tool that has been in use since 1873. *Shepard's Citations* owes its existence to the fact that American law, like English law, operates under the doctrine of *Stare Decisis. Stare Decisis* means that all courts must follow their own precedents as well as those established by higher courts. The precedents are the decisions handed down in previous cases.

To try a case under *Stare Decisis,* a lawyer must base his argument on previous decisions regarding a similar point of law. Before presenting the previous decision as a precedent, however, the lawyer must make sure that the decision has not been overruled, reversed, or limited in some way. *Shepard's Citations* enables the lawyer to do this with a minimum of trouble.

As the doctrine of *Stare Decisis* provided the logic for *Shepard's Citations,* so did the "reference tradition"' provide the rationale for citation indexes in science. The scientific tradition requires that when a scientist or technologist writes or publishes a paper, he should refer to earlier articles which relate to his theme. These references are supposed to identify those earlier researchers whose concepts, methods, apparatus, etc., inspired or were used by the author in ¯developing his own paper. Some specific reasons for using citations are as follows:

1. Paying homage to pioneers
2. Giving credit for related work
3. Identifying methodology, equipment, etc
4. Providing background reading
5. Correcting one's own work
6. Correcting the work of others
7. Criticising previous work
8. Substantiating claims
9. Alerting researchers to forthcoming work
10. Providing leads to poorly disseminated, poorly indexed, or uncited work
11. Authenticating data and classes of fact- physical constants, etc
12. Identifying original publications in which an idea or concept was discussed
13. Identifying the original publication describing an eponymic concept or terms like Hodgkin's disease, Pareto's Law, Friedel-Crafts Reaction
14. Disclaiming work or ideas of others
15. Disputing priority claims of others. Etc., etc.

In the early 1950s, the availability of this built-in system for linking scientific papers began to receive attention as the possible foundation of an indexing system for the scientific literature. Today, citation indexing has become a significant part of the literature of science, thanks largely to the pioneering efforts of Eugene Garfield and the Institute for Scientific Information in the USA.

It is very important that you both understand and appreciate the significance of this tradition in enhancing the quality of science. Your technical report or scientific paper is *not* an isolated work; it is part of a long established and continuing tradition of science. You must, therefore, do everything within your powers to maintain and even strengthen the tradition. The guidelines provided in this unit and in Unit 3 are designed to help you maintain and strengthen this cherished tradition.

3.2 Basic Rules to Follow

There are three basic rules to follow in handling the citations and references of your technical reports and scientific papers. The first is by far the most important, and you should always recall it in your citations and references, as well as in the citations and references of others. Here, then are the three rules:

a. *Rule I:* A fundamental objective for citing another work, or for referring to it in your own work, is to *identify* it with a sufficient number of unique features that it cannot possibly be confused with another work, no matter how similar.

This 'verification objective' needs to be fully understood and appreciated by all scientists. Because so much scientific work is published or unpublished every day, keeping track of what has been done in science is a daunting task. Therefore, everything possible must be done to identify each piece and the citing and referencing procedure is a necessary aspect of attaining that identification objective. You must identify each piece in your work by listing all its _unique features such that it cannot possibly be confused with another work, no matter how similar.

b. *Rule 2:* You should list only significant, published and unpublished references, but you must not allow references to unpublished data, papers in press, abstracts, and other secondary materials to clutter your References.

A long list of References does not necessarily confer authority respectability on your work. On the contrary, it may expose you as being unable to select what is really necessary from a large pool of available works.

c. *Rule 3:* Take time to check all parts of every reference against the original publication, before the report or manuscript is submitted, and perhaps again at a later stage, say, the page-proof stage.

References obtained from electronic media, such as the Internet, may not be available for physical inspection. In which case, your report or paper should say so, unequivocally. You should never leave the reader in any doubt about whether or not you, as author, can vouch for the accuracy of all the parts of a citation in your work. And you should also remember this:

- there are far more mistakes in the Literature Cited (References) section of a paper than anywhere else.

3.3 Bibliographic and Reference Styles

There are many good bibliographic and reference manuals that have been published and regularly updated by major organisations and institutions. These manuals are designed to remove completely the burdensome issue of deciding how you should cite a book, chapter in a book, journal article, conference paper, etc., in your work *and* then arrange them at the end to satisfy *Rule 1* given to you above. The United Nations Organisation's Dag liarmmarksjold library, for example, has such a manual which many writers have used for decades. The British Museum and the Library of Congress have published similar manuals for use by authors.

All that you are required to do is *adopt* one of such manuals as your working tool for citing any type of published or unpublished work within your text, and for arranging all the references at an appropriate place(s) in the work. In other words, your adopted manual will show you *how* to cite as well as *what* to include (and exclude) in order to make your citations and references both complete and consistent. You obviously have to learn to be familiar with your adopted manual, so that citing and referencing will become virtually automatic throughout your career.

But you sometimes have to conform with other styles preferred by other authorities with which you have to do business. Journals are the most obvious example of such authorities because 'publishing in scientific journals' is such an important activity in science and technology.

Journals vary considerably in their style of handling citations and references. One person looked at 52 scientific journal and found 33 different styles for listing references. Some journals print the titles of articles and some don't. Some insist on inclusive pagination, whereas others print first pages only. What do you do when faced with such a situation?

The wise thing to do is to write out all your references in full at all times,irrespective of the journals or authorities to which you intend to submit your manuscript. There are several advantages in cultivating this habit including the following:

a. Your manuscript has all the needed information. It is easy to edit out information; it is much more difficult (and less certain) to add bits of bibliographic information, such as article titles or ending pages, to a reference list that is deficient in such areas.
b. The journal you selected may reject your manuscript, resulting in your decision to submit the manuscript to another journal, perhaps one with more demanding requirements.
c. It is more than likely that you will use some of the same references again, in later research papers, review articles (and most review journals demand *full* references), technical reports, and books.

In view of the above, you should adopt the, fullest, possible bibliographic and reference style in all your writing. Since your knowledge of what you learn in this unit will be most readily applied in dealing with scientific journals, it would be useful for you to know the three general ways in which journals cite references). The three ways are usually referred to as "name and year", "by number from alphabetical list," and "by number in order of citation." Only the "name and year", approach will be covered in this unit. In Module 3 Unit 3, the two other approaches will be described for you, as well as other considerations in citing and arranging references.

3.4 The Name and Year System

The name and year system (often referred to as the 'Harvard system) was very popular for many years and is still used in many journals, although that system is not as widely used as it once was. Its big advantage is convenience to the writer. Because the references are unnumbered, references can lie added or deleted easily. No matter how many times the reference list is modified, "Onwumechili and Ette (1964)" remains exactly that. If there are two or more "Onwumechili and Ette (1964)" references, the problem is easily handled by listing the first as "Onwumechili and Ette (1964a)," and the second as "Onwumechili and Ette (1964b)," etc.

The disadvantages of the name and year system relate to readers and publishers. The disadvantage to the reader occurs when (often in the Introduction) a large number of references must be cited within one sentence or paragraph. Sometimes readers must jump over several lines of parenthetical references before they can again pick up the text. Even two or three references, cited together, can be distracting to the reader. The disadvantage to the publisher is less serious but not insignificant: increased cost. When "Owumechili, Ette, and Awe (1962)" can be converted to "(8)", considerable typesetting and printing cost savings can be realised.

Because it is the norm, rather than the exemption, for scientific papers to have multiple authors, most journals that use the name and year approach to referencing have an "et al" rule. Most typically, the rule works as follows: Names are always used in citing papers with either one or two authors, e.g., "Onwumechili (1962)," "Onwumechili and Ette (1964)," If the paper has three authors, list all three the first time the paper is cited, e.g., "Onwumechili, Ette, and Awe (1962)." If the same paper is cited again, it can be shortened to "Onwumechili et al. (1962)." When a cited paper has four or more authors, it should be cited as "Onwumechili et al.(1962a)" even in the first citation. When it comes to the 'Literature Cited' or 'References' section, however, some journals prefer that all authors be listed (no mater how many); other journals cite only the first three authors and follow with "et al." You should have no problem adapting to the requirements of any journal if, as you were advised above, you always write every entry in your 'Literature Cited' or 'References' in full.

Locate a standard textbook in your subject area(s). Examine the approach adopted by its author(s) in making citations within the text and in listing the citations at the end of the chapters of the books. If there is a ‘Bibliography’ at the end of the book, look it over as well.

On the basis of what you have learned in this unit, try to answer the following questions:

i. Is every entry full and complete?
ii. Does the approach to citing references in the text help or hinder readers’ fluent reading of the text?
iii. Are there obvious flaws in the citations or references that you can correct?
iv. To what extent have the “three basic rules of citing the literature of science” been adhered to?

4.0 CONCLUSION

It is important that every scientist knows and appreciates why and how citations are made in scientific texts. It is equally iinportant that the citations be properly and accurately arranged at the end of the text where the citations occur. Every written work must endeavour to perpetuate this noble tradition of science.

In order to help you understand and appreciate this tradition, the doctrine of *Stare Decisis* is explained to you, as well as how the principle has been applied to establish a pattern of citations and references in science and other areas of human knowledge. You are then given three basic rules for handling the citations and references in your technical reports and scientific papers. Then, the characteristics of bibliographic and reference styles are explained to you and you are advised to adopt a standard style in your scientific writing. Finally, the 'name and number' system, used by many journals in organising citations and references, is described for you with several examples.

5.0 SUMMARY

At the end of unit, you have learned to:

- recognise and appreciate the major attributes of the *citation* and reference tradition in science
- name and describe the three basic rules of citing the literature of science
- describe the major characteristics of bibliographic and reference styles; and
- recall and correctly use the 'name and year' system in making citations and listing references.

6.0 TUTOR-MARKED ASSIGNMENT

i. Name and describe the three basic rules of citing the literature of science.

ii. Describe the major characteristics of bibliographic and reference styles.

iii. What are the main attributes of the citation and reference tradition in science ?

7.0 REFERENCES/FURTHER READING

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UNIT 3 CITING AND ARRANGING REFERENCES II

CONTENTS

1.0 INTRODUCTION

The importance of the citation and reference tradition in science is underlined by devoting two study units to 'Citing and Arranging References.' In order to ensure that you have learned the fundamental issues as thoroughly as possible, the salient points of the first two parts of Module 3 Unit 2 are summarised as the first component of this unit. Thus, you are expected to regard Module 3 Unit 3 as essentially a continuation of Module 3 Unit 2, the one helping to reinforce the other in your learning process.

Two important 'systems' of citing works and arranging them logically and consistently are described for you in parts two and three of this unit. They are described essentially as *alternatives* to the 'name and year system' described in Module 3 Unit 2. In other words, only one of the three alternative systems may be used in citing and arranging references in any type of scientific writing. It is always wrong to switch from one system to another in the same work.

Three other aspects of how to cite and arrange the literature of science are then briefly described for you. They may appear less important than the three systems of citing and referencing described in the later part of Module 3 Unit 2 and the earlier part of this unit. In practice, however, they are just as important; any negligence on your part in handling these 'relatively minor' considerations will impact negatively on the quality of your work. You should, therefore, pay as much attention to them as you would to the 'major' parts. The usual Conclusion, Summary, and References conclude the formal presentation.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list the major attributes of the citation and reference tradition in science
- recall and use the alphabet-number system in citations and references
- recall and use the citation order system in citations and references
- name and describe three other aspects of citing and referencing to enhance the quality of scientific writing.

3.0 MAIN CONTENT

3.1 The Citation and Reference Tradition in Science: A Recapitulation

The following is a list of the major attributes of the citation and reference tradition in science, as described for you ,in Module 3 Unit 2. It is being repeated here for two reasons: (i) to underline its significance and (ii) to reinforce your knowledge of this fundamental aspect of technical report writing. Here, then, is the list:

1. Citations and references are as important as the text material in all types of writing that you undertake.
2. The product of your technical report writing — a term paper, a project, thesis, or dissertation, or a scientific paper, etc. - - is an important part of the corpus of human knowledge.
3. The citation tradition derives from the doctrine of *Stare Decisis.* You have a responsibility to ensure the integrity of that tradition.
4. The scientific tradition requires that when a scientist or technologist writes or publishes a paper, he should refer to earlier works which relate to his theme.
5. You should endeavour to recall at least some of the 15 reasons authors refer to earlier works which relate to the theme of their current work.
6. There are three basic rules to follow in handling the citations and references of your technical reports and scientific papers. The first is by far the most important and you should always recall it in all your writing. The three basic rules are listed as (a), (b) and (c) as follows:

a. A fundamental objective for citing another work, or for referring to it in your own work, is to identify it with a sufficient number of unique features that it cannot possibly be confused with another work, no matter how similar.

b. You should list only significant, published and unpublished references, but you must not allow references to unpublished data, papers in press, abstracts, and other secondary materials to clutter your References.
c. Take time to check all parts of every reference against the original publication, before the report or manuscript is submitted, and perhaps again at a later stage, say, the page-proof stage.

3.2 The Alphabet Number System

This system, citation by number from an alphabetised list of references, is a modern modification of the name and year system. The system has two major advantages: (i) citation by number keeps printing expenses within reasonable control, and (ii) the alphabetised list, particularly if it is a long list, is relatively easy for authors to prepare and readers (especially librarians) to use.

Writers at the beginning of their careers in science and technology tend to favour the name and year approach and generally dislike the alphabet-number system. Their chief claim is that the citation of numbers cheats the reader on the following grounds:

a. The reader deserves to be told the name of the person associated with the cited phenomenon and
b. Sometimes the reader should also be told the date. For instance, it is argued, an 1876 reference might be viewed differently from a 1976 reference, especially in a work of science.

The arguments are sound, but can be easily overcome. As you cite references in the text, decide whether names or dates or both are important. If dates and names are not important (and this is usually the case), use only the reference number: "Pretyrosine is quantitatively converted to phenylalanine under these conditions (13)." If you want to feature the name of the author, do it within the context of the sentence: "The role of the carotid sinus in the regulation of respiration was discovered by Heymans (13)". lf, however, you want to feature the date, you can also do that within the sentence: "Streptomycin was first used in the treatment of tuberculosis in 1945(13):" Rarely will it be necessary to feature both name and date in the text, except in the infrequent cases when it is important to identify the original publication describing an eponymic concept or term as Hodgkin's disease (See section 3.1 of Module 3 Unit 2).

3.3 The Citation Order System

The citation order system is simply a system of citing the references (by number) in the order that they appear, in your report or paper. This system avoids the substantial printing expense of the name and year system. Readers often like it because they can quickly refer to the references, if they so desire, in one-two-three order as they come to them in the text. It is a useful system for a journal or a house magazine in which each article contains only a few references. For long papers or technical reports with many references, the citation order system is neither good for the author nor the reader. It is not good for the author because of the substantial renumbering chore that results from addition or deletion of references. It is not ideal for the reader because the non-alphabetical presentation of the reference list may result in separation of various references to works by the same author.

You may come across much persuasive argument to use the name and year system, or the alphabet-number system, or the citation order system in citing and arranging your references. Reputable publishing houses and influential journal publishers are usually the agencies for promoting the use of one system in preference to any others. For example, the International Committee of Medical Journal Editors published, in 1982, the first version of the "Uniform Requirements for Manuscripts Submitted to Biochemical Journals," sponsoring the citation order system for the cooperating journals.

As result, the "Uniform Requirements" have since been adopted by several hundred journals all over the world. In the same year, 1982, a new edition of the Chicago Manual of Style, the authoritative reference source for most of the publishing community, appeared with its usual strong endorsement of alphabetically arranged references. In the Manual's more than 100 pages of detailed instructions for handling references, it several times makes such comments as: "The most practical and useful way to arrange entries in a reference list or a bibliography is in alphabetical order, by authors, either running through the whole list or in each section of it."

What practical sense should you make out of all this? Quite simple: don't get involved in such arguments, sound and persuasive as they may seem. The advice given to you in section 3.3 of unit 2 remains valid still. As a reminder, the advice is repeated here as follows: "…adopt one of such manuals as your working tool for citing any type of published or unpublished work within your text, and for arranging all the references at the appropriate place(s) in the work." When you have to conform to the requirements of a specific journal to which you have submitted a manuscript for publication you will, of course, comply strictly with the journal's Instruction to Authors.

3.4 Titles and Inclusive Pages

Should article titles be given in references? The question is not as odd as it may see at first sight. Not a few authors of scientific works avoid the titles of articles in their references on the grounds of cost or time savings. You are advised not to give such reasons for a practice which is essentially borne out of laziness.

If your work is being submitted for publication in a journal, normally, you will have to follow the style of the journal. Some journals, however, leave the choice of including or not including article titles to authors. Whatever the situation, you are advised to give complete references at all times, that is, always include titles in your references. This practice has the big advantage of enabling interested readers (and librarians) to decide whether they need to consult none, some, or all of the cited references. With the increasing use of alerting services in science and technology, many researchers learn of recently published or forthcoming articles and conference presentations solely through their titles. Obviously, it would be impossible to benefit fully from alerting services in any subject area if the inclusion of titles in references were made voluntary.

The use of inclusive pagination (first and last page numbers) make it easy for potential users to distinguish one-page notes and 50-page review papers. Technical reports, in fact, are usually considerably longer that 50 pages. Obviously, the cost to you (or your library) of obtaining the references, particularly if acquired as photocopies, can vary considerably depending on the number of pages involved. Therefore, cultivate the habit of giving inclusive pages in all your references.

3.5 Journal Abbreviations

Although journal titles vary widely, one aspect of reference citation has been standardised for quite some time, that is, journal abbreviations. As the result of widespread adoption of the "American National Standard for the Abbreviation of Titles of Periodicals" (ANSI Z39.5-1969), almost all of the major primary journals and secondary services now use the same system of abbreviation. Previously, most journals abbreviated journal names, primarily to help reduce printing cost, but there was no uniformity. For example, the *Journal of the American Chemical Society* was - variously abbreviated to "J. Amer. Chem. Soc.," "j.A.C.S.," etc. These differing systems posed problems for everybody authors, publishers, and, especially, readers.

Now there is essentially only one system, and it is uniform. The word "Journal" is now always abbreviated as "J." (with or without the full stop after the letter J). By noting a few of the titles in your subject area(s), you can abbreviate many journal titles, even unfamiliar ones, without reference to a source list. It is helpful to know, for example, that all "ology" words are abbreviated at the "1" (e.g., "Bacteriology" is abbreviated "Bacterial."; "Physiology" is abbreviated "Physiol.," etc.). Thus, if you memorise the abbreviation of words commonly used in titles, most journal titles in your subject area(s) can be abbreviated with ease. An exception to be remembered is that one-word titles *(Nature, Science, Biochemistry)* are never abbreviated.

Despite the rather straightforward guidelines provided in this unit, you should never hesitate to make appropriate consultations in order: (i) to confirm what you may have done on your own, or (ii) to clear any lingering doubts. Librarians have been trained to provide the help you need. Therefore, consult them as often as the need arises, until you have acquired the necessary experience and confidence to handle journal abbreviations all on your own.

3.6 Citation in the Text

Many authors use slipshod methods in citing the literature of their text material. A common offender is the "handwriting reference," in which the reader is glibly referred to "Awojobi's elegant contribution" without any hint of what Awojobi reported or how Awojobi's results relate to the present author's results. If a reference is worth citing, the reader should be told why and in full, that is, within the text *and* in the list of references at the end.

Some authors get into the habit of putting all citations at the end of sentences. This is wrong. The reference should be placed at that point in the sentence to which it applies. Let's examine two different ways of citing two references in a single sentence as follows:

- We have examined a digital method of spread-spectrum modulation for multiple-access satellite communication and for digital mobile radio telephony. [1,2]

Note how much clearer the citations become when the sentence is recast as follows:

- We have examined a digital method of spread-spectrum modulation for use with Awojobi's development of multiple-acces communication' and with Brown's technique of digital mobile radio-telephony.[2]

4.0 CONCLUSION

This unit concludes the theme which was begun in Module 3 Unit 2. In order to underline the significance of using appropriate citations and references in scientific writing, you are provided, at the beginning of this unit a list of the major attributes of the citation and reference tradition in science. The list is a summary of the first part of Module 3 Unit 2. The merits and disadvantages of two additional systems — the 'alphabet-number' and 'citation order' for handling citations and references are discussed for you. You are now in a good position to decide for yourself which of the three systems discussed in Module 3 Unit 2 and in Unit 13 that would be most appropriate for handling citations and references in our subject area(s).

Three other aspects of citations and references, that is, Titles and Inclusive Pages, Journal Abbreviations, and Citation in the Text are described and illustrated for you. It is emphasised that while these aspects may appear minor, compared to the three 'system'. they often contribute significantly to the poor quality of scientific writing, if sufficient attention is not paid to them. You are, therefore, advised not to consider any aspect as minor.

5.0 SUMMARY

At the end of unit, you have learned to:

- list six major attributes of the citation and reference tradition in science
- recall and use the alphabet-number system in citations and references
- recall and use the citation order system in citations and references; and
- name and describe three other aspects of citing and referencing to enhance the quality of scientific writing.

6.0 TUTOR-MARKED ASSIGNMENT

i. What are the major attributes of the citation and reference tradition in science.
ii. Name and describe three major systems of citing and referencing to enhance the quality of scientific writing.

7.0 REFERENCES/FURTHER READING

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UNIT 4 WRITING FOR PUBLICATION IN A SCIENTIFIC JOURNAL

CONTENTS

1.0 INTRODUCTION

The contents of Module 1 Unit 1 to Module 3 Unit 3 emphasise the characteristics of 'technical report writing and then, gradually, almost imperceptably, incorporate major elements of writing for publication in a scientific journal. This approach enables you to learn all that you need to know about technical report writing, as well as prepare you for writing a scientific paper, the ultimate goal of scientific research. It is now time for you to learn, formally, what it takes to write for publication in a scientific journal. You should also find this unit helpful in rewriting a technical report, or parts thereof, for publication in a scientific journal.

The unit is presented in five parts. Part one describes how a comprehensive definition of a scientific paper has evolved, and explains why it is important for you to get familiar with all aspects of the definition in order to appreciate the definitive transition from writing a technical report to writing a scientific paper. Part two shows you why good organisation is the key to writing a good scientific paper, while part three underlines the proper use of English at all stages of writing for publication. In part four, the significance of using abbreviations in scientific writing is explained, with particular emphasis on the demands of journals. Finally, in part five, aspects of the challenge facing African writers of science are discussed, in the hope that you will face up to them positively and rewardingly throughout your career. The usual Conclusion, Summary, References and TMAs complete the unit.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define clearly and comprehensively what constitutes a scientific paper
- distinguish writing a scientific paper from technical report writing
- explain the significance of good organisation in writing a scientific paper
- underline the proper use of English and abbreviations at all stages of writing
- demonstrate a clear understanding of the challenge facing the African scientist who aspires to publish in a scientific journal.

3.0 MAIN CONTENT

3.1 Definition of a Scientific Paper

A scientific paper is a written and published report describing original research results. The short definition must be qualified, however, by noting that a scientific paper must be written in accordance with over three centuries of a solid tradition of editorial practice, scientific ethics, and the interplay of printing and publishing procedures. Much of that tradition has already been explained to you in Module 1 Unit 1 to Module 3 Unit 3 of this course.

To properly define "scientific paper", it is necessary to define the mechanism that creates a scientific paper, namely, valid publication. Abstracts, theses, dissertations, conference and technical reports, and many other types of scientific literature are published, but such publications do not normally meet the test of valid publication; they do not qualify as primary literature. Furthermore, and this is particularly significant from the African perspective, even if a scientific paper meets all of the other tests, it is not validly published if it is published in the wrong place. That is, a relatively poor research report, but one that meets the tests, is validly published if accepted and published in the right place (a primary journal, usually). On the contrary, a superbly prepared research report is not validly published if published in the wrong place. For example, most of the government report literature and conference literature, as well as house organs and other ephemeral publications, do not qualify as primary literature.

Many people have struggled with the definition of "valid publication", from which is derived the definition of "scientific paper." You will gain much insight, however, from the position taken by the Council of Biology Editors

(CBE), an authoritative professional organisation in biology, in dealing with the issue. The CBE arrived at the following definition, after long and careful deliberation:

- An acceptable primary scientific publication must be the first disclosure containing sufficient information to enable peers (1) to assess observations, (2) to repeat experiments, and (3) to evaluate intellectual process; moreover, it must be susceptible to sensory perception, essentially permanent, available to the scientific community without restriction, and available for regular screening by one or more of the major recognised secondary services (e.g., *Biological Abstracts, Chemical Abstracts, Index Medicus, Excerpta Medica, Bibliography of Agriculture*, etc., in the United States and similar facilities in other countries).

At first reading, this definition may seem excessively complex, or at least verbose. It is doubtful, however, that an acceptable definition could be provided in appreciably fewer words. Because it is important that you understand what a scientific paper is and what it is not, you should exercise considerable patience as we walk our way through this definition to understand what it really means.

"An acceptable primary scientific publication" starts out as the defined substantive, but gives way to "the first disclosure", which the rest of the paragraph defines. Certainly, first disclosure of new research data often takes place via oral presentation at a scientific meeting. But the thrust of the CBE statement is that disclosure is more than disgorgement by the author; effective first disclosure is accomplished *only* when the disclosure takes the form that allows the peers of the author (either now or in the future) to comprehend that which is disclosed.

Thus, sufficient information must be presented so that potential users of the data can (i) assess observations, (ii) repeat experiments, and (iii) evaluate intellectual processes (For example, are the author's conclusions justified by the data?). Then the disclosure must be "susceptible to sensory perception." This may seem an awkward phrase, because in normal practice it simply means publication. However, this definition provides for disclosure not just in terms of visual materials (printed journals, microfilm, microfiche) but also in nonprint, nonvisual forms. For example, "publication" in the form of audio cassettes, if that publication met the other tests provided in the definition, would constitute effective publication. Similarly, first disclosure by way of entry into a computer database or an electronic facility, such as a website would qualify, so long as all other criteria for a publication are met.

Regardless of the form 44 publication, that form must be essentially permanent, must be made available to the scientific community without restriction, and must be made available to the information retrieval services *(Biological Abstracts, Chemical Abstracts, Index Medicus, Science Citation Index*, etc.). Thus, publications such as newsletters and house organs, many of which are of value for their news and other featines, cannot be considered part of the primary literature of science.

You can restate the CBE definition in simpler but not more accurate terms as follows:

- A scientific paper is (i) the first publication of original research results, (ii) in a form whereby peers of the author can repeat the experiments and test the conclusions, and (iii) in a journal or other source document readily available within the scientific community.
- To understand this definition as comprehensively as possible, however, it is necessary to add an important caveat. In modern science (since about the 1930s), the part of the definition that refers to "peers of the author" is accepted as meaning prepublication peer review. Thus, by definition, scientific papers are published in peer-reviewed media. That is why most of the scientific community has been reluctant to accept much of the material published on the Internet as publications in the manner defined in this unit.

There are two important reasons why you must be able to define a scientific paper as clearly and comprehensively as the presentation above has attempted to do. First, the transition from writing a technical report to writing a scientific paper for publication in a journal is a real one. You must make the transition, conscious of the new and demanding changes required of you in the process although, of course, much of what you have learned in technical report writing will be helpful. Second, a scientific paper is, by definition, a particular kind of document containing certain specified kinds of information. As Woodford (1968) put it, a scientific paper "demands exactly the same qualities of thought as are needed for the rest of science: logic, clarity, and precision." If you, a budding scientist, and even many of those scientists who have already published several papers, can fully grasp the significance of this definition, the writing task should be a good deal easier. Confusion results from an amorphous task. The easy task is the one in which you know exactly what must he done and in exactly in what order it must be done.

3.2 Organisation of a Scientific Paper

A scientific paper is a paper organised to meet the needs of valid publication. A scientific paper is, or should be, highly stylized, with distinctive and clearly evident component parts. Each scientific paper should have, in proper order, its Introduction, Materials and Methods, Results, and Discussion. In other words, the components you have already learned in respect of technical report writing (Module 2 Units 1 to 4) apply also to writing a scientific paper. Any other order will pose obstacles for the reader and yourself as the writer. Put in Peterson's (1961) words, "Good organisation is the key to good writing."

This order is so eminently logical that, increasingly, it is being used for many other types of expository writing as well. Whether you are writing an article about chemistry, archaeology, economics, or crime in urban areas. An effective way to proceed is to answer four questions in the following order: (i) What was the problem? Your answer is the *Introduction.* (ii) How did you study the problem? Your answer is the *Materials and Methods.* (iii) What did you find? Your answer is the *:Results.* (iv) What do these findings mean? Your answer is the *Discussion.* In addition, you have learned to cite and arrange *References* (Units 2 and 3) as a vital component of writing science.

What has been said above is generally true for papers reporting laboratory studies. There are, of course, exceptions that you need to be aware of. As examples, reports of field studies in the earth sciences (e.g., geology and geography) and clinical case reports in the medical sciences do not readily lend themselves to this kind of organisation. However, even in such "descriptive" papers, the same logical progression from problem to solution is often appropriate.

Occasionally, you must organise even "laboratory" papers differently. If you used a number of methods to achieve directly related results, it might be desirable to combine the Materials and Methods with the Results into an integrated "Experimental" section of your paper. Rarely, the Results might be so complex or provide such contrasts that immediate discussion seems necessary. In which case, a combined Results and Discussion section might be desirable.

In descriptive areas of science, there is a wide variety of types of organisation. To determine how to organise such papers, and which general headings to use, you will need to refer to the Instructions to Authors of your target journal. If you are in doubt as to the journal, or if the journal publishes widely different kinds of papers, you can obtain general information from appropriate source books. For example, the several major types of medical papers are described in detail by Huth (1982), and the many types of engineering papers and reports are outlined by Michaelson (1982).

The central point needs to be restated for emphasis: the well-written scientific paper should report its original data in an organised fashion and in an appropriate language, without undue emphasis on literary skill. A scientific paper is not "literature"; it is primarily a question of *organisation.* The writer of a scientific paper is not really an "author" in the literary sense. If the ingredients are properly organised, the paper will virtually write itself.

Finally, in this section, you need to bear in mind that today, the average scientist must examine the data reported in a very large number of papers in order to keep up with a field. Therefore, scientists and, of course, editors must demand a system of reporting data that is uniform, concise, and readily understandable. That is precisely why it was said: "A scientific paper is not designed to be read. It is designed to be published." Although this was said in jest, there is much truth in it. And, actually, if the paper is designed to be published, it will also be in a prescribed form that can be read and its contents grasped quickly and easily by the reader. That is your responsibility to your colleagues in the scientific community every time you write a scientific paper.

3.3 Language of a Scientific Paper

Next to organisation, the second principal ingredient of a scientific paper should be appropriate language. If scientific knowledge is at least as important as any other knowledge, then it must be communicated effectively, clearly, in words of certain meaning. You, the budding scientist who wishes to succeed in this endeavour, must therefore be literate. David H. Truman, when he was Dean of Columbia College in the USA., put it well: “In the complexities of contemporary existence the specialist who is trained but uneducated, technically skilled but culturally incompetent, is a menace." Don't be a menace.

Although the ultimate goal of scientific research is publication, it has always been amazing to observe how many scientists neglect the responsibilities involved. A scientist will spend years of hard work to secure data, and then unconcernedly let much of their value be lost because of lack of interest in the communication process. The same scientist who will overcome tremendous obstacles to carry out a measurement to the fourth decimal place will literally go to sleep while a careless word processing hand changes micrograms per milliliter to milligrams per milliliter. There is no reason you should allow your work to suffer such embarrassment, if only you will pay due attention to the important details of your manuscript.

English need not be difficult. In scientific writing, a popular dictum is: "The best English is that which gives the sense in the fewest short words." Literary tricks, metaphors and the like, divert attention from the message to the style. They should be used rarely, if at all, in scientific writing. You should always aim to communicate the message of your scientific research in plain, unardoned English.

3.4 Using Abbreviations in Scientific Writing

Many experienced journal editors loathe abbreviations. Some editors would prefer that they not be used at all, except for standard units of measurement and their Si (Systeme International) prefixes, abbreviations for which are allowed in all journals. In your own writing, you would be wise to keep abbreviations to a minimum. The editor will look more kindly to your paper, and the readers of your paper will bless you forever. It is always irritating when the reader comes across undefined and incomprehensible abbreviations in the literature. Just recall how annoyed you felt when you were faced with these conundrums, and it will not be too difficult for you to vow never again to pollute the scientific literature with an undefined abbreviation.

The "how to" of using abbreviation is easy, because most journals use the same convention. When you plan to use an abbreviation, you introduce it by spelling out the word or term first, followed by the abbreviation within parentheses. The first sentence in the Introduction of a paper might read: "Bacterial plasmids, as autonomously replicating deoxyribonucleic acid (DNA) molecules of modest size, are promising models for studying DNA replication and its control."

The "when to" of using abbreviations is much more difficult. You should find the following guidelines helpful:

1. Never use an abbreviation in the title of an article. Very few journals allow abbreviations in titles, and their use is strongly discouraged by the indexing and abstracting services. The major reason is that even the so-called "standard" abbreviations change over time.
2. Abbreviations should almost never be used in the Abstract. Only if you use the same, a long one, and quite a number of times should you consider an abbreviation. If you use an abbreviation, you must define it at the first use in the Abstract. Remember that the Abstract will stand alone in whichever abstracting publications cover the

journal in your paper appears.

3. In the text itself abbreviations may be used, always bearing in mind the reader's primary interests. In doing so, you are advised to consider the following procedures as "good practice" to further the interests of your readers and for your self-assessment in learning aspects of this unit:

a. When writing the first draft of the manuscript, spell out all the terms. Then examine the manuscript for repetition of long words or phrases that might be candidates for abbreviation. Do not abbreviate a term that is used only a few times in the paper. If the term is used with modest frequency, say, between three and six times, and a standard abbreviation for that term exists, introduce and use the abbreviation. If no standard abbreviation exists, do not manufacture one unless the term is used frequently or is a very long and cumbersome term that really cries out for abbreviation.

b. Often, you can avoid abbreviations by using the appropriate pronoun (it, they, them) if the antecedent is clear, or by using a substitute expression, such as "the inhibitor", "the substrate", "the drug", "the enzyme", or "the acid".

c. Usually, you should introduce your abbreviations one by one as they first occur in the text. Alternatively, you might consider a separate paragraph (headed "Abbreviations Used") in the Introduction or in Materials and Methods. The latter system is especially useful if related reagents, such as a group of organic chemicals, are to be used in abbreviated form later in the paper.

d. Units of measurement are abbreviated when used with numerical values. You would say "4mg was added". (The same abbreviation is used for the singular and the plural.) When used without numerals, however, units of measurement are not abbreviated. You would say ¯Specific activity is expressed as micrograms of adenosine triphosphate incorporated per milligram of protein per hour."

e. Because in science we should use only common abbreviations (those not needing to be spelled out in the reader's mind) the proper choice of article should relate to the *sound* of the first letter of the abbreviation, not the sound of the first letter of the spelled out term. Thus, although it is correct to say, "a Master of Science degree," it is incorrect to say, "a M.S. degree." Because the reader reads "M.S." as "em ess,¯ the proper construction is "an M.S. degree."

f. In biology, it is customary to abbreviate generic names of organisms after first use. At first use, you would spell out

Streptomyces griseus. In later usage, you can abbreviate the genus name but not the specific epithet: *S.griseus.* Suppose, however, that you are writing a paper that concerns species of both *Streptomyces* and *Straphylococcus.* You would then spell out the genus names repeatedly. Otherwise readers might be confused as to whether a particular "S." abbreviation referred to one genus or the other.

g. The SI (Systeme International) units and symbols, and certain derived SI units, have become part of the language of science. This modern metric system should be mastered by all students of the sciences.

Briefly, SI units include three classes of units: base units, supplementary units, and derived units. The seven base units that form the foundation of SI are the metre, kilogram, second, ampere, Kelvin, mole, and candela, in addition to these seven base units, there are two supplementary units for plane and solid angles: the radian and steradian, respectively. Derived units are expressed algebraically in terms of base units or supplementary units.

3.5 The Challenge facing African Writers of Science

Science is universal. Therefore, its content and development must be the collective concern of scientists world-wide and be guided by universally agreed norms and standards. With the significant exception of Egypt, Africa has, hitherto, made almost negligible contributions to the corpus of scientific knowledge. The 'African Renaissance Movement' and similar initiatives seem designed to change this situation in the shortest possible time. Rapid human resource development in science and technology is a key element of such initiatives; enhancing your potential contributions to the world of science is an important objective for meeting the targets being set for the initiatives. What, then, is the nature of the challenge facing you as a budding African scientist?

Only three aspects of the challenge are outlined here for your consideration. They derive specially from the course, *Technical Report Writing* as presented in Units 1 to 4 above and are as follows: (i) Enhancing African Content in World Science, (ii) Halting the Dearth of African Journals, and (iii) Helping to Strengthen Science Ethics.

a. *Enhancing African Content in World Science*: Africa contributes less than 2 per cent of the world's scientific literature in all formats; slightly less than this proportion represents the Region's contribution to the Internet (Aiyepeku, 1997; 1998). Indeed, if the proportion contributed by South Africa were subtracted, the figure would he less than 1 per cent. Thus, African science is being practically marginalised, and the trend is to perpetuate rather than improve the situation. Your commitment to writing quality papers that would be acceptable for publication in the best journals in your subject area(s) would go some way in increasing the quantum of African content in world science.

b. *Halting the Dearth of African Journals*: Far too many African journals are launched with little thought about how they will be sustained. As a result, the mortality rate of African journals, especially the science titles, is among the highest in the world. The net effect is that serious African scientists have little or no incentive to submit their manuscripts to African journals, thereby perpetrating a vicious circle. You can begin to apply what you have learned in this course to help bring about greater stability among African science journals.

c. *Helping to Strengthen Science Ethics:* Science is indivisible and its ethics should not be the object of regional differentiation either. African scientists must learn to submit their manuscripts to one journal at a time; it is simply not ethical to. Submit simultaneously, a manuscript to two or more journals in the hope of getting it published in one of them. The image of African science is being compromised as a result, and you can decide now never to have anything to do with such practice.

4.0 CONCLUSION

Writing for publication in a scientific journal is a distinctly different activity from writing a technical report although both activities have many features in common. The transition is a deliberate one; that is why so much attention has been devoted to providing you a comprehensive definition of the scientific paper, the ultimate objective of scientific writing. The definition also enables you to appreciate what it takes to convert a technical report, or parts thereof, into a manuscript for publication in a scientific journal.

A scientific paper is a paper organised to meet the needs of valid publication. If you take time to organise a good manuscript properly, it will virtually write itself and, therefore, virtually guarantee its acceptance for publication in a good journal. You must also pay due attention to the use of simple, correct English and ensure that you are fully in charge at every stage of manuscript preparation. In particular, do not allow careless compugraphic errors to compromise the quality of your paper. Because science uses a large number of technical and special terms, most of them have to be abbreviated in formal writing. It is your responsibility to know when and when not to use abbreviations, as well as how to use them.

Finally, you are invited to ponder three specific aspects of the special challenge facing every African scientist who aspires to contribute to the corpus scientific knowledge, via publication in a journal. Your attitude to the challenge should be a positive commitment to doing all you can to make the Africa Region a force to reckon with in the fast growing and fast changing world of science.

5.0 SUMMARY

At the end of unit, you have learned to:

- define clearly and comprehensively what constitutes a scientific paper, the ultimate goal of scientific writing
- distinguish between writing a scientific paper and writing a technical report
- explain the significance of good organisation in writing a scientific paper
- underline the proper use of English and abbreviations at all stages of writing a scientific paper and
- demonstrate a clear understanding of the challenge facing the African scientist who aspires to publish in a scientific journal.

6.0 TUTOR-MARKED ASSIGNMENT

i. Comprehensively describe the constituents of a scientific paper.
ii. Briefly discuss the challenges facing African scientists willing to publish in scientific journals.

7.0 REFERENCES/FURTHER READING

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