THE TED MATRICULATION, HIGHER GRADE, BIOLOGY EXAMINATION AS AN EVALUATOR OF EDUCATIONAL OBJECTIVES FOR EFFECTIVE BIOLOGY TEACHING

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DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University, nor has it been prepared under the aegis or with the assistance of any other body or organisation outside the University of the Witwatersrand, Johannesburg. All help received from individuals with the preparation and/or presentation of this thesis has been clearly acknowledged on the next page.

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ABSTRACT

This study aims at providing some evaluation of the impact of the Transvaal Senior Certificate, Higher Grade, Biology Examination on Biology teaching in the Transvaal. It also looks at the effectiveness of this examination as an assessment/evaluation instrument.

A questionnaire is used to secure the views of practising Biology teachers, and teacher trainers, about the stated objectives of Biology teaching at senior high school level, in terms of:-

- their relative merit and importance.
- their attainment through current teaching practices.
- their evaluation by the examination Board.

The views of 63 teachers and 9 teacher trainers are analysed and the views of Transvaal and Natal teachers are compared to those of Teacher Trainers.

Much consensus is found in the responses of all three groups of educators. They are well aware of modern trends and methodologies in the field of Biology Education but are pessimistic about the current achievement of many of the objectives they identify as being important for effective Biology Teaching. They see the examination as one which focuses mainly on the assessment of Recall of Knowledge.

The implications of these findings are discussed and several recommendations are made.

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The use of external matriculation examinations has continually been one of the most debated and highly controversial issues in the fields of assessment and selection. Many researchers support the matriculation examinations as the single most efficient predictor of success at tertiary institutions (Behr, 1985; Biggs, 1978; and Wilson, 1982). Others (Choppin, 1972; Jackson, 1986; Powell, 1973 and Sanders, 1986) question this claim and consider other criteria such as psychological and social factors, cognitive skills and attitudes learnt at school as being of greater importance. It appears, however, that many countries continue to use matriculation examinations as their major selection criterion - even those who rejected them (e.g. some states in America), are now reinstituting them as a means of upgrading and maintaining standards (Tamir, 1988).

Tamir (1988:43) lists seventeen potential drawbacks of such examinations, but goes on to show how the Israeli 'Bagrut' has overcome most of these problems in Biology. Whereas that country has made the best of its matriculation examination, here in South Africa, the situation is far from being ideal. The Biology Higher Grade examinations, used currently by most examination boards, are known to act as the driving force behind the curriculum (Mooney, 1985; Rossow, 1985), but unfortunately they seem to be driving Biology Education in the wrong direction.

The tremendous pressures of having to produce good matric results - to meet expectations of pupils, parents and, more recently, the management of the so-called 'Model C' Schools - are forcing teachers to ignore those objectives which are not evaluated in the examination. In most schools, and in most subjects, the Standard Ten matriculation examination has definitely *"become the tail that wags the dog"* (Rossouw, 1985:60).

This situation has attracted much criticism from Biology educators, academics and especially from school teachers (Jackson, 1983 and 1986; Mooney, 1985; Rossouw, 1985; Opie, 1975, 1985 and 1986 and Watson, 1990). The situation has been described by all as being unhealthy, frustrating and in need of urgent reform. Yet, to date not much has changed. According to the HSRC report (1981), on the 'Teaching of the Natural Sciences and Mathematics', it seems that pupils themselves recognise (and exploit) the problems of the Biology examinations. The vast majority choose to take Biology in Standard Ten, not because of genuine interest in the discipline, but mainly as a reaction to Mathematics and Physical Science, which are perceived as being more difficult and less likely to result in high matric symbols.

The dilemma of the Matric Teacher is well described by Mooney (1985 : 52), when he states:

> *"On the one hand the universities have a firm say in curriculum content to the extent of dominating it; yet on the other, in telling teachers how badly they do the preparation of entrants, they have little idea of the reality of the teaching situation".*

The majority of our teachers have, indeed, had very little say in curriculum objectives, contents, and their reforms. The Joint Matriculation Board seldom consults teachers on such matters (Mooney, 1985:47). More recently, Fraser (1992 : 62-64), has pointed out that very few teachers had the opportunity to contribute to the new National Core Biology Curriculum, which is soon to be implemented in our schools.

Even more frustrating for teachers, perhaps, is the valid claim made by many researchers about the lack of correlation between Matric and Tertiary Biology course results. For example, Dassonville and Myburg (in Fraser, 1992 : 63) state that many students perform well in Biology at university, although they never took it as a school subject. In two related studies (1983 and 1986), Jackson has shown that there is a very low degree of correlation between examination results at the end of the first year General Biology course at the University of the Witwatersrand, and, either of the Matriculation Ratings (based on the overall matriculation result of a candidate) or the Biology H.G. matriculation symbol.

This is supported by Mitchell et al (1987) who showed that the combined Mathematics and Physical Science symbols act as a better predictor of success for first year medical students than the matriculation ratings currently being used by most South African universities. Similarly, a study by Sanders (1986) indicated a no correlation result between Zoology I examination and matriculation results of 'high risk', disadvantaged students who are selected for academic support programmes in the Science Faculty at the University of the Witwatersrand.

Another contentious issue raised by Mitchell's study (1987 : 415) is that the Transvaal Senior Certificate, as compared to other 'white' matriculation examinations, is a poorer predictor of subsequent performance for medical students.

If one of the aims of the matric examination is to select students for tertiary education, there should be some correspondence between what it measures and what is required for success at that level. Jackson (1983) regards knowledge that is conceptually orientated, with basic learning skills and at least the initial exposure to opportunities for making value judgements and decisions based on critical reasoning, as the intangible and essential factors for success at university. This view is supported by Beard (1972) in her scheme of teaching objectives (In Billing, 1973 : 6) and by many of the lecturers in the Science Faculty at the University of the Witwatersrand (Stanton, 1990). Stanton's survey reveals that, in general, the lecturers are not optimistic about achieving these objectives in non-graduate courses. This could be due to the fact that higher cognitive skills are introduced too late to students, only at universities and technikons and not at schools. The many sixth form classes, academic support and bridging programmes being established in a variety of institutions to remedy this situation, lend support to this tentative hypothesis.

Little research seems to have been done to assess the teaching objectives valued by South African, High School, Biology teachers. For example, teachers' intentions versus achievements in the classroom situation or the match between these and the goals of tertiary educators, have been ignored. An exception is a study of the impact of the Biology matriculation examination on teaching methods used in Indian schools by Isaac (1990). The main finding of this research was that objectives attempted in teaching were, in the main, the same as those tested in the examination, as a result of pressures to produce results (Isaac, 1990 : 4). A similar study carried out by Carrick in England (1983 : 205 - 214) revealed that A-level Biology teachers also perceived teaching goals which are likely to lead to students' success in the examination as more desirable than other goals; generally the latter were those concerned with higher order skills.

1.2 STATEMENT OF THE PROBLEM

The Biology Higher Grade examinations currently being used by the various examination boards in South Africa - in particular the Transvaal Senior Certificate - seem to suffer from the following major drawbacks:

(1) They restrict the implementation of many objectives held by Biology teachers and are seen either as being essential in imparting values and life skills to pupils, or, as being vital for future success at tertiary level. They tend to encourage the teaching and rote learning of a large body of factual content at the expense of higher cognitive skills. They discourage and inhibit innovative and process-based teaching methods.

(2) Their results are a poor predictor of success in Biology and other related courses at tertiary level. Yet, universities and other tertiary institutions use matriculation results, or the ratings derived from them, as major criteria for selection of students. In so doing, they reinforce the emphasis on examination results as the primary teaching objective. Moreover, the diverse matriculation examinations used in South Africa are given equal status for this purpose of student selection.

As a direct result of the above, important life skills and attitudes are not being taught in our Biology classrooms and Biology teachers are failing to prepare high school pupils for future tertiary education.

1.3 THE PURPOSE OF THIS STUDY

The purpose of this study is to secure the views of practising teachers and teacher educators about the stated objectives of Biology teaching at senior high school level in terms of:

1. their relative merit and importance
2. their attainment through current teaching practices
3. their evaluation in the Transvaal Senior Certificate Higher Grade Biology Examination (TSC).

By analysing teachers' views and responses, an attempt will be made at evaluating the impact of the TSC on Biology teaching in the Transvaal, both in terms of practices and outcomes. The reality and seriousness of the problems outlined above will be established and possible solutions will be explored.

1.4 IMPORTANCE OF THIS STUDY

A matriculation examination, acting both as a school leaving certificate and as a selection tool for tertiary education, is probably one of the simplest and cheapest method of evaluation of schooling available presently. This is possibly the only method which South Africa can currently afford and which would be appropriate to a non-racial society which is trying to offer equal opportunities to all its citizens.

Major changes are anticipated in all spheres of South African education in the very near future. Separate, unequal matriculation examinations have been a major political issue for many years and new examination boards and systems are likely to be given a top priority in bringing about change. This could indeed provide an excellent point of departure towards a better education system, but for such an examination system to be successful, it will have to be seen by all as being:

1. Valid - in that it will test the objectives set
2. Reliable - in that the results obtained would be independent of the race, gender and location of the candidate
3. Fair - in that it would test what a pupil has been taught and can do.

At the same time, it will have to select the more able from the less able pupils. It should identify clearly those who would benefit from further studies and, in so doing, reduce the alarming drop out rate which currently exists at tertiary level. The key question, which so far remains unanswered, is whether a single examination system can achieve all this. This should not, however, stop us from making improvements to the present systems.

In Biology, with the introduction of the new core syllabus (at national level) in Standard 8 in 1994, the time is ripe for bringing in concurrent changes in assessment procedures. Teachers will be teaching new content and skills and some sort of in-service training will have to be provided. Why not include new assessment techniques, which would prepare pupils for a better matriculation examination in 1996, in the teachers' training programmes? To quote Tamir and Jungwirth (1972 : 33):

"In the last analysis it will be the teacher who will have to implement them (the teaching objectives) *according to his own predilections and idiosyncrasies".*

It is thus imperative to involve teachers in any new curriculum designs, especially in the sensitive field of assessment and evaluation. Studies sampling teachers' views about current examinations could act as a point of departure towards a more relevant, valid and useful matriculation examination - one which could drive the new Biology curriculum in the right direction, whilst also achieving all the other goals which such an examination should achieve.

1.5 RESEARCH QUESTIONS

More specifically, this study attempts to answer the following questions:

1. Which goals/objectives do our current high school Biology teachers value as being important for effective Biology education? How do their opinions compare with the findings of the literature review?

2. How successful do teachers believe they are in achieving the various objectives through their current teaching?

3. Which objectives are seen by teachers as being assessed by the Transvaal Senior Certificate and to what extent do they believe that such objectives are assessed?

4. How competent are teachers in their analysis of questions and in their identification of objectives being assessed? Is there a difference in the views of the different subgroups of the teachers' sample who took part in this study?

1.6 METHOD OF INVESTIGATION

In order to obtain information about teachers' views and beliefs, a survey/correlational approach was used and a two-part questionnaire was designed as a research instrument.

PART I

Taking into account the nature of Biology as a science, the views of the South African Association of Teachers of Biology, the South African core syllabus and its teaching objectives for High School Biology, as well as the research literature on the topic, a list of 35 commonly stated teaching objectives was compiled. The selection criteria used are discussed further in Chapter Four of this dissertation. In line with recent research findings (Wood, 1991 : 4), no hierarchy was implied in the classification of objectives, but these were listed under three main categories in order to facilitate analysis, namely, objectives about ***KNOWLEDGE, SKILLS*** and ***ATTITUDES***. Respondents were asked to rate each objective on a five point scale, according to two criteria: the importance he/she attaches to it and, the extent to which he/she is currently achieving this objective in the classroom. The rating scale was in descending order of favourability from ***VERY IMPORTANT*** (5), to ***NOT IMPORTANT*** (1), and from ***ALWAYS ACHIEVED*** (5) to ***NEVER ACHIEVED*** (1).

PART II

Respondents were asked to analyse the 1991 H.G. Transvaal Senior Certificate Biology examination paper in terms of the objectives they thought it was assessing. Marks allocated for each question by the examiners, had to be distributed under the following four headings: (1) ***RECALL***, (2) ***UNDERSTANDING AND SIMPLE APPLICATION***, (3) ***HIGHER ORDER COGNITIVE SKILLS*** and (4) ***OTHER SKILLS***.

Simplified definitions of the above terms, based on Bloom's original definitions (1956), were included in the questionnaire in order to avoid confusion. (*See Appendix 1*).

1.7 ASSUMPTIONS AND LIMITATIONS OF THE STUDY

One major assumption underlying this study is that the responding teachers had sufficient knowledge of assessment techniques and terminology, in order to understand the questionnaire and that they were able to perform a valid and reliable analysis of the various examination questions. It has also been assumed that the TED 1991 Higher Grade Biology Examination paper is a fair representation of the papers used over the last few years in terms of question types and standards. It was selected for this study purely because it was the most recent paper available when the questionnaire was designed. Because of the length of the examination - a three-hour paper - it was not possible to ask respondents to analyse more than a single paper. The fact that all matriculation examination papers in South Africa are centrally moderated by the Joint Matriculation Board minimises the risk of this assumption being incorrect.

The major limitation of this study is that it does not necessarily represent the views of all South African Biology teachers. As explained further in Chapter Four, it had to be limited to teachers working in the so-called 'white' schools. Furthermore, due to the length of the questionnaire and to the difficulty of getting teachers to respond to it, no sample selection was attempted; questionnaire were answered on a purely voluntary basis. This study is thus, of an exploratory nature and no claim will be made that its findings can be generalised to the entire teachers population. Nevertheless, it represents the views of a fairly large sample of interested teachers/educators from two different provinces and as such should provide valuable information when new examination systems are designed in the near future.

1.8 DEFINITIONS OF TERMS USED IN THIS STUDY

1.8.1 Assessment/Evaluation/Measurement

In Education, these three terms tend to be defined in a variety of ways and are often used interchangeably. It is thus important to clarify the meaning that will be given to them in this study.

> "*Measurement is simply observation which has been quantified and made precise, with the aid of specially designed instruments and processes.*" (Ebel, 1975 : 6).

> "*Evaluation is a process that complements measurement, that is dependent upon measurement.*" (Ibid)

Assessment on the other hand will be defined as

> "*the range of procedures or methods used for educational measurement and evaluation.*" (Isaac, 1990 : 102).

1.8.2 Matriculation

The term *matriculation* is also given different meanings by different writers. For the purpose of this study, matriculation will refer to the exemption a candidate receives to attend or be admitted to a university for tertiary education (Oxford Dictionary : 751)

1.9 CONCLUDING REMARKS

At the start of this research, using evidence from the research literature, our tentative conclusion is that teacher's attitude as well as curriculum and type of matriculation examination, could all account for the poor standard of Biology in schools, as well as for the difficulties Biology students experience later in adapting to the demands of tertiary education.

This study aims at providing some evaluation of the impact of the TSC on Biology teaching in the Transvaal and its effectiveness as an assessment/evaluation instrument by analysing the views and responses of a group of interested teachers/educators.

CHAPTER 2 THE GOALS AND OBJECTIVES OF HIGH SCHOOL BIOLOGY EDUCATION

2.1 INTRODUCTION

According to Billing (1973 : 26), some difficult decisions must be made when selecting the goals and objectives for a specific teaching course, as "*no generally accepted criteria for selection exist*".

A brief survey of the history of science education reveals periods of major change which, according to Bybee (19[illegible] 35), can be attributed to the tremendous pressures of society at [illegible] given time on the structure of science education. He successfully shows how a change in emphasis of, what he calls, the three major aims of science education *'Empirical knowledge'*, *'scientific methods'* and *'Personal development of the student'* was brought about by major societal events. The Biology curriculum including goals, objectives, methods of instruction and assessment, certainly reflects such periodic changes, but recurrent goals can be traced back, at least partly, to the nature of Biology itself - Biology as an autonomous discipline of science. This view is supported by Bloom (1974 : 26), who sees the nature of the subject matter (as put forward by specialists in the field), as a prime source of objectives for a teaching course.

In this chapter, after a brief summary of modern views about the importance and classification of teaching objectives, an attempt will be made at analysing the nature of science and of Biology as a science in order to determine those goals of Biology education which can be derived from the very basic characteristics of the discipline.

However, one has to agree with Bybee, that to be relevant, these goals must also meet the needs of the pupils and those of contemporary society. The major issue of education 'in or about Biology" - a science - will thus be also discussed and the current status and aims of Biology education, in a few selected countries, will be surveyed. Finally, the literature on aims and objectives of tertiary science/Biology education will be reviewed briefly.

The above will lead to a critical analysis of the current goals and objectives of Biology teaching in this country, as outlined by the South African National Core syllabus, for the senior school years and will allow for appropriate selection of objectives for inclusion in Part I of the research questionnaire.

2.2 IMPORTANCE OF SPECIFYING TEACHING GOALS AND OBJECTIVES

Although opinions vary greatly about the way in which educational goals and/or objectives should be specified, there is consensus about the necessity of stating them clearly prior to curriculum construction, implementation or evaluation.

The simplified systematic model of curriculum development, summarised in Fig 1, shows clearly how the 'broad aims' and 'detailed objectives' link up the various components of a curriculum design.

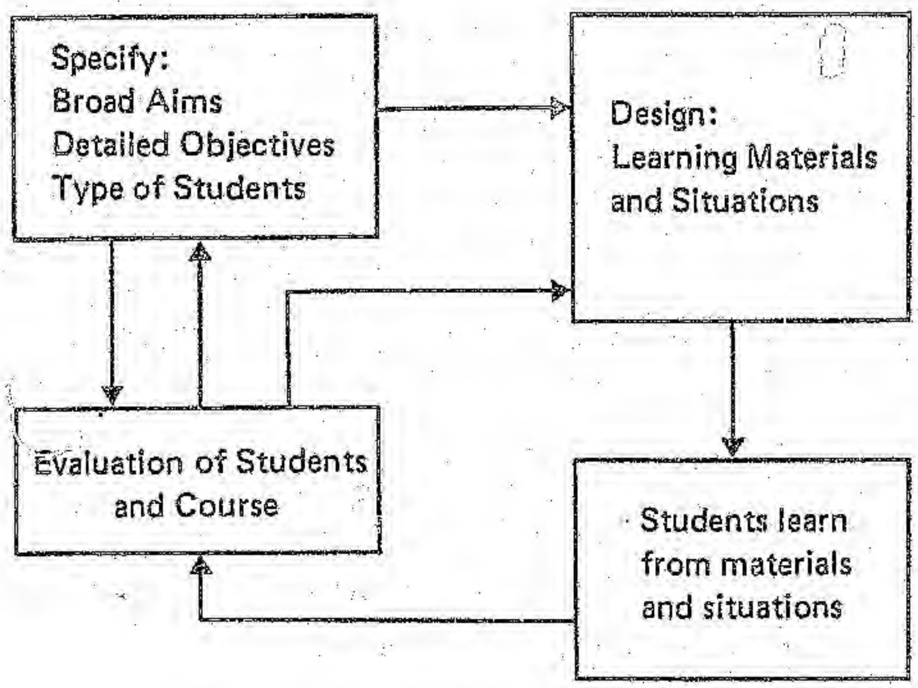

Figure 1: A Curriculum Development Model (taken from Billing, 1973: 2)

Many modern courses in Biology have been designed according to the above approach. The objectives are first specified; then the course content and teaching methods are selected; the design of the learning situations and the construction of materials follows. After the teaching, the same objectives or criteria derived from them, are used to test the students. The tests assess the students' abilities, but they also provide feedback which can be used to improve the course design. Thus, as Frith et al (1984: 12) put it, *"objectives are an important link in the chain between statements of purpose and the realisation of that same purpose"*.

Isaac (1990: 323) provides the following comprehensive list of advantages of having a statement of educational objectives:-

(1) It helps determine whether pupils have the necessary pre-requisites for a particular course or unit of study;
(2) It influences the choice of teaching methods and materials;
(3) It guides the selection of assessment procedures;
(4) It helps the teacher to clarify his/her goals;
(5) It helps pupils organise their own learning;
(6) It helps communication between teachers,on the one hand, and pupils, parents, school administrators, on the other.

In spite of the above obvious advantages, statements of teaching objectives have been subjected to much criticism. Much of this negative response, however, seems directed at the rigid, behavioral approach proposed by Skinner (1968) and Mager (1962). As Tamir (1972 : 31) puts it clearly, few educators would take exception to a broader approach as summarised in Ausubel's statement: *"... no educational outcome is good or bad in and of itself. It's worth can be considered only in terms of how far it accomplishes the ends we are striving to* *achieve through education".*

2.3 MODERN VIEWS ABOUT CLASSIFICATION OF TEACHING OBJECTIVES

One of the earliest sets of objectives to have a "profound effect" on curriculum designs and assessment was the taxonomy of educational objectives produced by Bloom et al (1956). According to Wood (1991 : 1), many of the more recent classification systems used today can be recognised as the progeny of Bloom's taxonomy. This taxonomy contains six broad classes of objectives:

Knowledge	Analysis
Comprehension	Synthesis
Application	Evaluation

which are arranged according to a rigid hierarchy in that objectives in one class are supposed to make use and build on the objectives in the preceding class. Much empirical research done to validate this hierarchy has, however, failed to do so and the accepted conclusion today is that the hierarchy as such does not exist (Wood, 1991:2-4).

Another important feature of Bloom's taxonomy is that it is intended to be content-free in order to allow its application to any discipline or subject. Moreover, the classes of objectives have been defined in fairly broad terms in an attempt to avoid the danger of the subject disintegrating into a large number of separate activities. This broad, content-free nature of the taxonomy could be one of the main reasons for its poor reliability. According to Fairbrother (1988:5):

"To classify a question, using the taxonomy, entails making a judgement about the way students' work and about what they already know when they answer the question.... What is comprehension for a student can easily be application for another ...".

Wood (1991 : 2) agrees whole-heartedly with this statement and regards this as one of the most serious shortcomings in using objectives as specification for examination questions.

Despite these difficulties, however, in many countries the taxonomy has played a big part in moving the emphasis in education, and its assessment, away from recall of knowledge to a variety of cognitive and other skills. Moreover, as long as no hierarchy is implied, Bloom's classes of objectives still provide the terminology and diversity of concepts required to act as an excellent categorisation or specification system for stating and assessing educational objectives. Although attempts at producing different classification systems have been made - e.g. Gagne's (1970) system which is based on learning types - most of the currently used schemes are mere adaptations of Bloom's taxonomy. Wood (1991 : 2) acknowledges this point when he states:

"Twenty years on (after Bloom's publication), *the educational objectives movement has not been replaced by some new orthodoxy, even if it is unfashionable to acknowledge the fact".*

In most modern systems of classification, objectives are made more subject specific and are defined neither in too broad nor in too specific terms. This approach described as 'middle ground' by Frith (1984 : 16) will thus be the one adopted throughout this study.

2.4 DETERMINANTS OF OBJECTIVES FOR EFFECTIVE BIOLOGY TEACHING

Figure 2 below provides a clear picture of the various factors that should be taken into account when selecting goals and objectives for a particular course or study programme. Some of these factors are very obvious and require no further elaborations, but others need to be analysed.

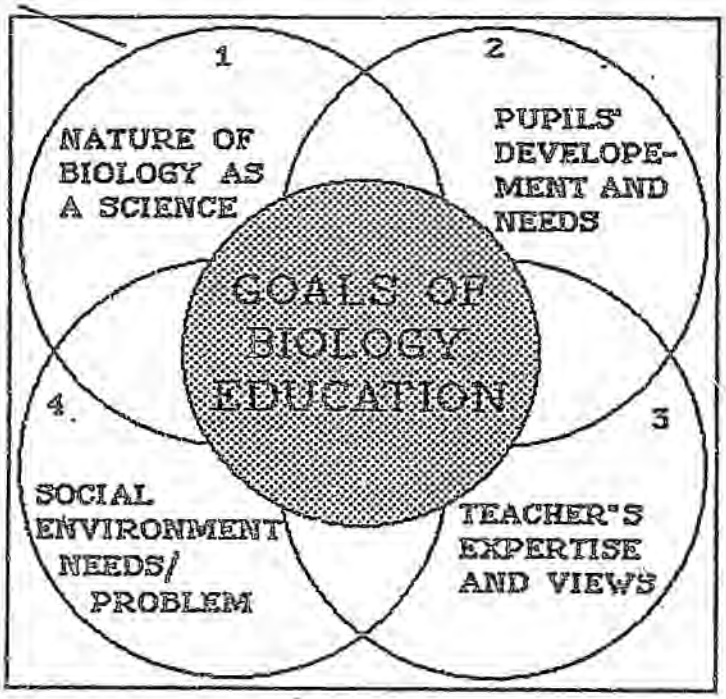

Figure 2: Venn Diagram Showing Interaction of Determinants of Goals of Biology Education

2.4.1 The Nature of Science

The following concise definition of science by GG Simpson (in Yager, 1985 : 2) is one that it is widely accepted by scientists and science educators:

> *"Science is an exploration of the material universe in order to seek orderly explanations* (generalisable knowledge) *of the objects and events encountered, but these explanations must be testable".*

Three basic features of science can be extracted from this definition (although each one needs further clarification):

Firstly, science involves exploration, observation of objects and events in the physical and biological world around us. Hutchinson (1983 : 2) warns us, however, that observations could contain errors:

> *"The scientific method involves the act of faith that in the long run such errors will be eliminated because they are found to be incompatible with new observations".*

He then justifies the 'faith' on the success science has achieved in understanding the world.

Secondly, science entails explanations of which has been observed, but such explanations must produce generalisable or scientific knowledge. Hill (1986 : 112) reminds us that scientific facts or knowledge are only meaningful when they are *"related to laws, concepts, hypotheses and theories"*. Hutchinson (1983 : 62), on the other hand, believes that scientific facts can never be dogmatic statements of the truth. He believes that: *"Our current understanding of the world may not be the truth, or even a good approximation of the truth, but it is the best available and is far more useful than unscientific approaches to understanding and controlling the world".* There is much consensus today about this tentative and dynamic nature of scientific knowledge.

Lastly, the definition emphasises that explanations or hypothesis must be tested in order to prove them true or to falsify them. This argument, first proposed by Popper, is well-known amongst science philosophers. Much debate has centred around Popper's contention that *"scientific hypothesis must be capable of falsification by the performance of experiments"* (Matthews, 1975 : 157). Indeed, in some sciences such as botany, zoology and geology, observation and studious classification are often used in place of experiments to verify hypotheses.

Matthews (1975 : 157) criticises Popper's definition as being an oversimplification of a complex process. He believes that important 'human dimensions' such as those emphasised by Kuhn (1970), in his analysis of 'paradigm cases', are being ignored. Ravetz (1971) shares Kuhn's philosophy about the effects of sociological factors on scientific progress. Scientists, he argues, are not unbiased when they test their hypotheses, but w be influenced by the values, beliefs and attitudes they hold, as well as the 'personal commitment' they bring to their work. He claims that, on the one hand, hypotheses are often modified to fit unexpected results and, on the other hand, the scientific community (who provides the accepted criteria of relevance for scientific knowledge) may reject or suppress highly original or controversial ideas which do not match 'their conservative paradigms' (Matthews 1975 : 158).

Finally, Woodburn and Obourn (1965 : 12) add another dimension when they describe the pursuit of science as being a way of life:

> *"Science is one of the things men do. It is an understanding marked by initiative, energy, boldness, dynamism and intrepid drive. The pursuit of science refers not merely to the data acquired by the scientist, but also to the means of its acquisition. The men and women of each generation who devote their lives to the pursuit of science become a part of the scientific endeavour. To these people, science becomes a way of life, and their way of life becomes an aspect of the pursuit of science - an aspect that must be included in an attempt to comprehend the total spirit, structure and function of science".*

From the above discussion, one must agree with Isaac (1990 : 53), when he describes science as having three main components:

(1) **CONTENT** or **PRODUCT** - empirical, tentative, dynamic explanations of objects and phenomena observed in the physical or biological world around us, forming an inter-related body of generalisable facts, concepts, hypotheses, theories and laws;

(2) **METHOD** or **PROCESS** - the ways in which the explanations were arrived at by the scientists. Different (scientific) methods could be used, but usually experimentation or careful observations are involved. There does not seem to be ONE scientific method;

(3) **THE WAY OF LIFE OF THE SCIENTIST** - the dedication, attitudes and personal commitments of those who chose the pursuit of science as their main goal in life, i.e. the history of science.

It thus seems appropriate to include all three components in any science curriculum which aims at conveying a true picture of the discipline to scholars, i.e. empirical knowledge, processes and methodology, as well as history of science should all feature.

Although many science educators and teachers share the above views (Donelly, 1979; Selley, 1981; Hodson, 1982; Hutchinson, 1983; Hill, 1986), others believe that school science should not be related to 'real science'. Jennings (1980 : 225), for example, argues that school science should emphasise 'facts' instead of the 'scientific method' in order to provide scholars with 'a corpus of knowledge', a basic grammar and that other higher aims should be left for the universities where sciences should be taught *'de novo'*. His main contention, which was severely criticised by West (1981), is that such a 'grammar approach' would be of value in all subjects, as well as in every day life. He also believes that history and philosophy of science would not interest most scholars, and that teachers know very little about how science is carried out!

Jennings' views about experimentation and practical work, which according to him, are to be used to learn facts, improve attitudes or gain manual dexterity, and for no other purpose, have also been criticised by many. For example, Van Praagh (1983 : 640) states:

> *"If school science is merely the learning of facts and the performing of certain practical exercises, one wonders whether its inclusion in the school curriculum is worth the trouble and expense involved".*

Biology is one of the sciences which is commonly criticised as being predominantly descriptive. For example, Maynard Smith has been quoted as saying: *"The difficulty with Biology always has been there are too many goddam facts"* (from Hill, 1986 : 116). This view would be shared by many of our students who fail to see in the teaching of Biology any pattern or process and by many Biology educators, who believe that this over-emphasis of facts is not only unnecessary, but is in fact undesirable. As Hill (1986 : 115) argues: *"A clear recognition of the theoretical basis of Biology would more accurately represent its structure and have the merit of reducing the dead weight of factual information that has so often alienated students".*

Many share Hill's views that an integration of theory, laboratory work and carefully chosen examples of research presented within a historical/philosophical framework, should form the basis of the Biology curriculum at high school level. Such an approach would justify currently accepted theory and create a real awareness of what Biology is all about; minimise reduction of Biology to recall of facts and teach relevant problem solving skills.

2.4.2 Biology as a Science

Biology seems to share most of the criteria of a scientific discipline as described above, yet some fundamental differences do exist between it and the other sciences. Hill (1986 : 112 - 116), for example, contends that both the structure (content/product) and methodology (processes) of Biology give it 'autonomy' from such other sciences. He certainly has a point when he states that, because Biology deals with living organisms, it is more difficult to generalise facts into laws or to use the 'reductionist' approach of the physical sciences.

A living organism is more than the sum of its parts and when the natural world is studied at a variety of levels within a hierarchy, there are 'emergent properties' at a certain level of organisation that 'cannot be predicted from a knowledge of lower level properties'.

As pointed out by Mayr (1982), the reductionist approach only answers the question 'how', and is adequate for functional Biology, but is not sufficient for a complete understanding of biological processes. The evolutionary approach, with its ultimate, historically-based questions of 'why' or 'what for', then becomes essential. Such questions are not required in the physical sciences.

Smart (1963) and Mayr (1982) both support the view that laws are less important in Biology than in the physical sciences and suggest that biologists should organise their generalisations into a framework of concepts rather than attempt to make laws. Hill (1986 : 113) concludes that this would reflect *"the concern of Biology with living organisms that can be seen as individual case studies highly restricted in space and time rather than universal entities subject to universal laws"*. He adds that *"a concept thus moves beyond the empirical content of laws and represents a complex of ideas within the domain of thought"*.

To summarise the above, it seems that the structures and methodologies used in Biology are somewhat different to those used in other sciences: (1) Laws should seldom be used and should be replaced by conceptual frameworks, and (2) there should be a greater emphasis on observations as experimentations can prove difficult.

Hill (1986 : 115) uses the example of how social insects have been studied through observation, careful comparisons and analysis in order to test sociobiological theories and concludes that the conclusions are *"as reliable as those obtained by experiment"*. The skill of 'observation' should thus be given special attention in any study of Biology and pupils should be encouraged to ask questions and make generalisations in a specific way, autonomous to Biology.

2.4.3 The Needs of the Child and the Needs of Society

Science (and thus Biology education) during the last two decades has been described as being 'in crisis': Irrelevant, boring, academically too demanding and not attractive to most scholars (Saltman, M (1974); Gallagher, J & Yager, R (1980). The main reasons offered to explain the crisis has been that science education did not evolve to meet the changes and demands of our technological society. Barrentine (1986 : 499) explains that science education was essentially an 'education of science', reserved for the academically gifted who wanted to make a career in science, and these were decreasing steadily. To Good (1985 : 140), this is still the only way to teach science as he believes that science education is *"the quest for knowledge, as well as the knowledge generated by that quest"*. However, in many countries, including America and the United Kingdom, the late 80's and early 90's saw a major shift in emphasis towards 'education through science' and in the United Kingdom 'science for all' up to the age of 16 years, became a major cry in science education.

The main argument is that all members of a society must be provided with appropriate experience of science so that they can demonstrate 'acceptable social and scientific qualities of behaviour' and can thus make informed decisions in the technological society within which they live (Barrentine 1986 : 498). Matthews (1975 : 162) worries about this shift in goals and warns that it could lead to such 'trivialisation' or 'vulgarisation' of science that it would no longer be science education and he predicts that the supply of competent scientists could be disturbed. He emphasises the need for further research to find out *"whether it is inherent in the nature of science, or in the way it is taught, that we are bound to restrict a major human activity to a minority pursuit"*.

Yager (1984 : 12), who defines science education as *"the discipline concerned with the study of the interaction of science and society as well as the impact of society upon science"*, refutes the above argument by calling his own definition a much broader one as it involves looking at *"what scientists do, what they know, how they interact* (with each other and the rest of society), *what the limits are concerning their knowledge and actions, and how science has progressed through the ages"*. Moreover, Yager, Tamir and Huang's (1992 : 349 - 355) recent research on the effectiveness of a Science, Technology Society (STS) approach to Human Biology shows that science content, processes and creative skills learnt under the STS approach, as well as the learners' attitudes, were significantly better than when standard curricular practices were used.

It thus seems that the context of Science/Biology teaching must be chosen with great care if set goals are to be achieved. These goals are broader than they were twenty years ago. What Daniels (1985 : 56) describes as the *"social responsibility of the science teacher"* is being translated into a number of STS-based curricular overseas. Many (e.g. Spargo, 1986) believe that such an approach locally would result in greater enthusiasm for science subjects at school and could reverse the present exodus of more pupils from tertiary science faculties.

Watson (1990 : 49), on the other hand makes a strong call for a less academic, more relevant, Biology education for all South African scholars. Supporting his argument by the data reproduced in Figure 3, he maintains that *"we are missing the opportunity to teach our young people the type of Biology which counts"*. He maintains that as South Africa's major problems are biological in nature, we should aim at creating a biologically literate and biologically functional society.

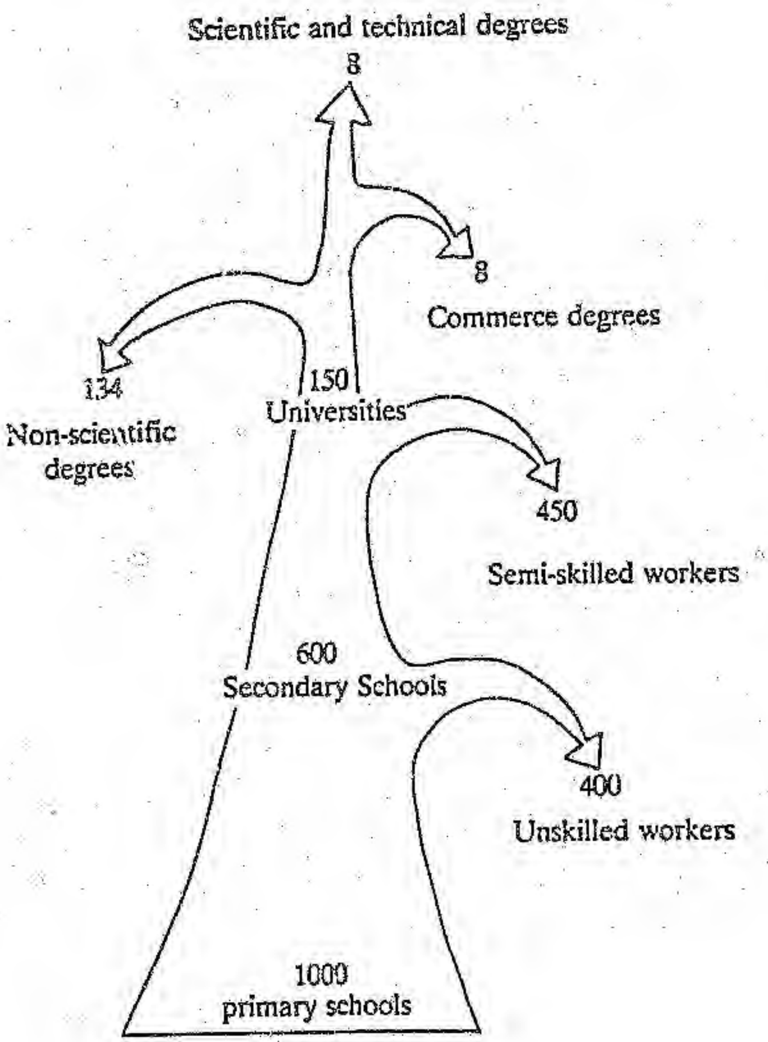

FIGURE 3. Numbers in Educational categories indicating a mismatch between our academic teaching and the needs of our people or country. *(From Watson, 1990 : 50)*

Whereas Watson requests a change in the content of Biology syllabi, and does describe more appropriate topics, he offers no suggestions about teaching processes, or about skills to be learnt.

Another important plea for change in South African school science education comes from Lloyd (1986 : 81-86), who calls for industry to play a greater role in the development of the right type of school science curriculum. He begs the education authorities to allow industry to make contributions to education such as input to curriculum development, career guidance, teachers training and financial support. He sees the present fragmentation of the education system into its many departments as a major stumbling block to greater cooperation between industry and the education authorities. He describes how industry has to 'make do with considerably less than excellence' when recruiting the products of our education systems, whether it is at top managerial level, technical or skilled craftsmanship level. He reckons that better school science with greater emphasis on the skills needed by industry would be beneficial to all.

2.5 STATUS, GOALS AND OBJECTIVES OF HIGH SCHOOL BIOLOGY IN A FEW SELECTED COUNTRIES

Two countries known as leaders/innovators in the field of Biology education will be discussed:

2.5.1 England, Wales and Northern Ireland

School Biology has undergone intensive renewal over the last five years in England, Wales and Northern Ireland. Amongst much outcry and criticism (mainly directed at the speed to which change had to occur), a new school curriculum package was introduced in September 1988 (Baker and Hardie, 1989 : 69).

The Education Reform Bill, published in 1987, identified the proposed national curriculum which aimed at producing a broader, more balanced education for the compulsory school years 5 to 16. In order to achieve this, a number of core subjects, including Biology, became compulsory for all. Both the content and skills to be taught in core subjects were to be standardised and national criteria would be produced for each one in order to clarify required approaches.

Finally, assessment procedures would change from the current *norm-centred approach* to the more positive *criterion referencing method* (discussed further in Chapter 3). Although teachers would become more involved in aspects of assessment, a terminal examination would remain at age 16. The dual examination system introduced in 1963 to cater for pupils of different ability range, i.e. the General Certificate of Education (GCE) and the Certificate of Secondary Education (CSE), would be replaced by a single examination system, the General Certificate of Second Education or GCSE, but different level of attainments based on different objectives would be assessed.

The current A-level curriculum would remain as optional and geared to those 17 -18 years old who require more specialised education in order to attend universities, but its content and approach would be modified to match the earlier training of the GCSE courses (DES, 1985).

According to our previous definition, the A-level examinations thus are the actual matriculation, but as pupils must achieve specific grades in the GCSE to qualify for A-level courses, it is appropriate to include the objectives of the former examination in our discussion. Science, including Biology, is thus taught to all school pupils aged 5 - 16 and to those 17 years old who elect to study it further. The approach up to age 14 is very much a broad, balanced or co-ordinated science course which occupies approximately 20% of curriculum time. The Biology content and the general science skills to be achieved are outlined in the form of 'four levels of attainment target' described in National Curriculum. Emphasis is expected to be on processes and relevance to everyday life. These criteria still apply to the age group 14 to 16, but pupils may then select different science courses or subjects which will lead to their final GCSE examinations (DES, 1985 : 4).

The various Biology syllabi and courses offered by GCSE for the various examination boards (discussed further in Chapter 3) must cover the four themes and three broad objectives laid down by the National Curriculum. These, together with specifications about their assessment, are summarised in Tables 1 and 2 (DES 1985 : 4).

Table 1: The Four National Themes and Their Relative Importance In The Overall GCSE Assessment Scheme

THEME	MARK ALLOCATION (% of total assessment)
Diversity of organisms	Between 5% and 10%
Relationships between organisms and with the environment	Between 25% and 40%
Organisation and maintenance of the individual	Between 25% and 40%
Development of organisms and the continuity of life	Between 15% and 25%

Table 2: The Three Broad Assessment Objectives and Their Relative Importance in the Overall Assessment Scheme

ASSESSMENT OBJECTIVE	WEIGHTING (% of total assessment)
Knowledge and Understanding	Of the order of 45%
Skills and processes (including experimental and observational skills)	Not less than 40% (at least 20% to experimental and observational skills)
Personal, social, economic and technological applications of Biology in modern society	Not less than 15%

An importanι ɜature of the above scheme is the strong emphasis placed on practical work and its assessment. When the National Criteria for GCSE examinations were first published in May 1985, they made it very clear that:

> *"All schemes of assessment must allocate not less than 20% of the total marks to experimental and other practical skills. At least half of these marks must be awarded on the basis of experimental and observation work in the laboratory or its equivalence"* (DES, 1985 : 4).

This inclusion did much to change the character of Biology teaching and its assessment in England and Wales. Peat, 1988 summarises the impact of this criterion extremely well:

> *"School Biology came of age in 1988 with the introduction of compulsory assessment of practical work to all GCSE syllabuses bearing the Biology label. No longer can one gain a nationally recognised qualification in science at this level by resorting to books alone. This state of affairs must surely be good for the status of Biology as a demanding scientific discipline ...".*

The scheme of more detailed objectives proposed by Nuffield for the double-award science course (Table 3), shows that indeed examination boards are now giving much importance to practical work as well as to a variety of other skills.

Table 3: Objectives For GCSE Double Award Science Pupils Should Acquire (from Fairbrother, 1988:7-8)

3.1	Knowledge with understanding of:
3.1.1	scientific phenomena, facts, patterns, laws, definitions, concepts, theories and models;
3.1.2	scientific vocabulary, terminology, units and conventions;
3.1.3	scientific instruments and apparatus, including techniques of operation and aspects of safety;
3.1.4	scientific quantities and their determination;
3.1.5	everyday and technological applications of science with their personal, social, economic and environmental implications.
3.2	The experimental ski[illegible]bilities to:
3.2.1	select or fo[illegible]itions amendable to experimental test;
3.2.2	devise proced[illegible] apparatus and materials suitable for checking th[illegible], conclusions, generalisations, hypotheses and p[illegible]
3.2.3	follow instructions accura[illegible] the safe conduct of experiments;
3.2.4	communicate scientific observations, ideas and arguments logically;
3.2.5	handle apparatus and materials effectively;
3.2.6	work with due regard for safety;
3.2.7	observe, measure and record accurately and systematically;
3.2.8	carry out investigations;
3.2.9	recognise and explain variability and unreliability in experimental measurements;
3.2.10	evaluate critically the design of experiments, experimental observations and other data and draw conclusions;

3.3 The associated skills and abilities to:
3.3.1 extract from information presented in diagrammatic, symbolic, graphical, numerical or verbal form, data relevant to a particular context;
3.3.2 use data, recognise patterns in such data, formulate hypotheses and draw conclusions;
3.3.3 translate information from one form to another;
3.3.4 explain familiar facts, observations and phenomena in terms of scientific laws, theories and models;
3.3.5 suggest scientific explanations of unfamiliar facts, observations and phenomena;
3.2.6 explain everyday and technological applications of science and evaluate associated personal, social, economical and environmental implications;
3.3.7 apply scientific ideas and formulate methods to solve qualitative and quantitative problems;
3.3.8 make decisions based on the examination of evidence and arguments;
3.3.9 recognise that the pursuit of science is subject to practical constraints and theoretical uncertainties;
3.3.10 communicate logically and concisely.

This set of educational objectives also show clearly that the emphasis is on an education '*through*' science, its content as well as its processes and is a move away from pure recall of knowledge. Twenty of the twenty-five objectives listed are concerned with skills. Some of these skills are dedicated to the scientific method; others can be called '*life skills*' as they are readily transferable to other situations. One has to agree with Peat (1988:254) when he says that:

"The skills of observation, measuring, assessing problems, appreciating others and the environment, and interpreting information are useful in all walks of life and justify Biology FOR ALL to the age of 16".

The above list also reflects that the determinants of goals/objectives, (as discussed in Section 2.4 above), have been used to selec objectives that would satisfy the needs of a future scientist, as well as the needs of pupils who will not pursue a scientific career. The nature of science, the needs of the pupil, as well as the needs of society have all been taken into account. Another interesting point to note about this scheme of objectives is that, although it refers to Bloom's terminology and concepts at times, in line with modern research discussed above, no hierarchy was implied and although defined fairly broadly, each objective is specific to science and is criteria based. These objectives are thus much easier to use than Bloom's taxonomy (as described above in Sections 2, 3).

2.5.2 In Israel

Schooling in Israel, as in Britain, consists of 10 years of compulsory schooling followed by an elective 2 years which lead to a matriculation or *'Bagrut'* terminal examination. Teaching in the junior high school follows a broad, general approach, but becomes very specialised in the last 2 years of senior high school (Tamir, 1988 : 43). Biology education is known by world standards to be particularly effective (Jungwirth et al 1990 : 42).

The high school Biology curriculum is based on the once world famous American Biological Science Curriculum Studies (BSCS), but it has been adapted to the needs of the country and developed further, since its implementation by schools on a voluntary basis in 1965. Today, the Israeli Biological Sciences Curriculum study programme (IBSP) has become 'the dominant curriculum' in senior Biology classrooms (Tamir, 1983: 65). The main reasons for the success of this course and for its high world status can probably be attributed to the efforts of the Israeli Teachers' Centre, who have been able to create a perfect match between the relevant curriculum aims and objectives and the matriculation examination. As Tamir (1988 : 43-44) puts it: *"In Israel the curriculum reform in the sciences has been accompanied by substantial adaptations and modifications in the matriculation examinations"* and because of this *"it has made a substantial contribution to the institutionalisation of the inquiry orientation in the classrooms"*. Practical work, investigation of original scientific problems, and genuine teaching of critical thinking and problem solving are focal points of Biology education. Whereas most countries pay lip service to these aspects of teaching, they can be seen to happen in Israeli classrooms *(ibid)*.

Whereas the impact and characteristics of the examination will be discussed further in Chapter 3, the simplified list of teaching objectives for IBSP, summarised in Table 4 gives us a clear idea of what Biology teachers try to achieve in Israeli high school classrooms.

Table 4: Some Objectives of IBSP Biology Curriculum (from Tamir, 1972:31)

Understanding of Biological Knowledge	
4.1	Accumulation and retention of principles and generalisations;
4.2	Skill in recognition and formulation of biological problems;
4.3	Skill in hypothesis formulation;
4.4	Skill in planning of controlled experiments;
4.5	Skill in application of biological principles;
4.6	Developing critical thinking ability;
4.7	Understanding research processes and procedures in Biology;
4.8	Understanding the 'Nature and Aims of Science';
4.9	Understanding the historical continuity of science;
4.10	Understanding the place of science in everyday life and its role in human relations;
4.11	Developing favourable attitudes to science in general and in particular;
4.12	Developing favourable attitudes to science to local flora and fauna, thereby strengthening the emotional ties with the homeland;
4.13	Developing favourable attitudes to rural life.

2.6 GOALS AND OBJECTIVES OF TERTIARY EDUCATION

Beard's scheme of objectives for tertiary education (Billing, 1973) is widely accepted amongst local academics as being a good, general statement of the goals of tertiary teaching (Stanton, 1990 : 94).

A brief analysis of these objectives (Table 5) shows that they tend to reflect the nature of science and the needs of the individual within the context of contemporary society. As suggested in Chapter 1, a closer comparison between objectives of high school and those of tertiary education in Biology could prove useful in solving some of the problems students experience at tertiary level and this will be attempted in Section 2.9.

Table 5: The Beard Teaching Objectives For Tertiary Level

Knowledge - At the end of a University career, a student should:	
K1	Know the basic terminology of his subject;
K2	Know the principles (basic laws and concepts) of his subject;
K3	Understand some of the uses to which is subject is put;
K4	Be acquainted with principles and applications of related subjects;
Skills - University teaching in general should enable the student:	
S1	To write coherently;
S2	To be verbally articulate;
S3	To make his own independent judgements;
S4	To obtain information efficiently;
S5	To think creatively, imaginatively and in abstract terms;
S6	To cooperate with colleagues and other professionals in future careers:
S7	To develop adaptability, i.e. to cope with changing patterns of knowledge (both general technological advance and new ideas in own subjects);
S8	To use specialised equipment.
Attitudes - An aim in university teaching is to foster in the student:	
A1	Enthusiasm for learning;
A2	Scholarly concern for accuracy;
A3	Awareness of moral, social, economic, political and scientific problems of society;
A4	Questioning and enquiring approaches to knowledge.

2.7 THE VIEWS OF THE SOUTH AFRICAN ASSOCIATION OF TEACHERS OF BIOLOGY ABOUT GOALS/OBJECTIVES OF HIGH SCHOOL BIOLOGY IN THIS COUNTRY

Figure 4 summarises the views of those members of the association which attended workshops held in May 1989 and September 1990 to discuss the orientation and focus they would like to see in the new core syllabus which was then being designed. The proposed objectives of the senior high school Biology course were listed in fairly broad terms as 'desirable attributes' that the course should develop in the pupils over the three year teaching period.

These objectives are very much in line with those of the countries discussed above and reflect a good grasp of the nature of Biology as a science.

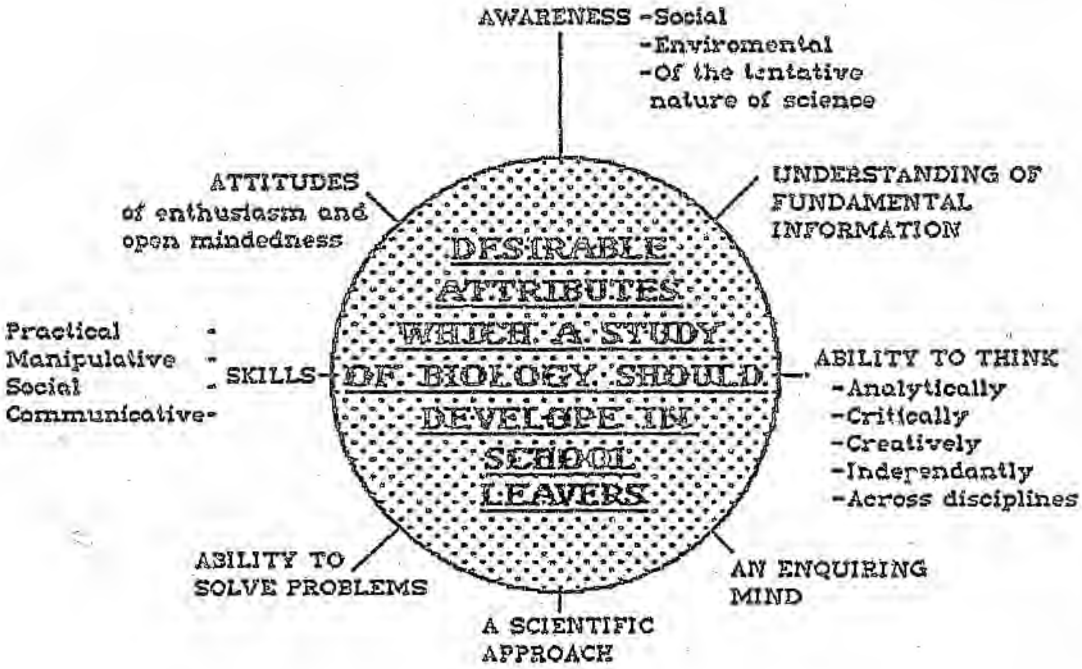

Figure 4: Diagrammatic summary of the views of the South African Association of Biology Teachers about desirable goals/objectives of High School Biology

In a circular summarising the discussions, the association acknowledges the fact that their recommended approach would be more time consuming than the usual ones, but saw them as essential changes if 'pupil learning' was to take place.

2.8 THE GOALS/OBJECTIVES OF THE TED BIOLOGY SYLLABUS

2.8.1 Goals and Objectives of Senior High School Biology in South Africa as Outlined in the National Core Syllabus

In South African High Schools, present teaching, in terms of content, goals and objectives, is controlled (in each subject) by criteria laid down in a national core syllabus produced by the Joint Matriculation Board. Although each of the ten existing examination boards produce examinations which use different assessment procedures, they are in fact based on very similar syllabi, and are all moderated by the JMB.

The Transvaal Education Department syllabus for Senior Biology Standard 8 to 10, currently in use (TED 'new' syllabus: 1986), follows the National criteria very closely.

1. It first states the general aims of the three-year course as summarised in Table 6.

Table 6: Aims of Core Biology Syllabus For Standards 8 to 10

"The aim of the syllabus is to provide a course which will develop the following important attributes in pupils:		
6.1	An understanding of fundamental biological principles based on a study of living organisms;	
6.2	An awareness of biological relationships with reference to the following unifying themes, viz.	
	-	relationship between structure and function
	-	adaptation to the environment
	-	diversity, yet unit in structure
	-	progressive structural development (from the most primitive to the most advanced
	-	genetic inheritance and continuity of characteristics as well as determination of behaviour
	-	regulation and homeostasis
6.3	An appreciation of the fact that knowledge is incomplete, tentative and might change;	
6.4	An ability to make critical, accurate observations of biological material, and to make meaningful records of such observations;	
6.5	An ability to analyse and evaluate biological information and expressing ideas;	
6.6	An ability to communicate clearly when reporting information and expressing ideas;	
6.7	A desire to know more about natural phenomena;	
6.8	An appreciation and understanding of the contributions which scientists have made to the subject;	
6.9	A love and appreciation for the South African fauna and flora and a recognition of the urgent need for nature conservation;	
6.10	A respect for all living things created by God and an urgent awareness of man's responsibilities in the preservation of life, particularly in the SA context."	

2. This is followed by the recommendations set out in Table 7.

Table 7: Recommendations about Teaching Procedures and Techniques

"The approach to the course should, as far as possible, be based upon the following important principles:	
7.1	Pupils should make their own observations of specimens and experiments;
7.2	Pupils should learn how to handle and set up apparatus correctly;
7.3	Organisms should be observed in their natural environments;
7.4	A constant emphasis should be placed upon facts being understood, interpreted and applied rather than being merely memorised;
7.5	Pupils should be confronted with problems from their personal fields of experience and the prescribed subject matter suggested as an explanation of the problem."

2.8.2 Classification of the above aims

An attempt to classify the broad aims of the syllabus (as outlined in section 2.8 above), according to Bloom's taxonomy, show that cognitive, psychomotor as well as affective aims are equally represented, as summarised below:

Cognitive Aims:	6.1, 6.2, 6.5, 7.4 and 7.5
Psychomotor Aims:	6.4, 6.5, 6.6, 7.1, 7.2 and 7.3
Affective Aims:	6.3, 6.7, 6.8, 6.9 and 6.10.

Billing (1973 : 21) reckons that a slightly different grouping of Bloom's domains, as used by Beard, might be more advantageous when objectives have to be categorised and analysed. The advantage of grouping objectives as 'Knowledge', 'Skills' and 'Attitudes' is that 'Skills' can span both the cognitive and psychomotor domains, thus avoiding problems of making a choice when the two categories overlap.

The classification of the core syllabus under this new scheme is as follows:

Knowledge	:	6.1 and 6.2, 7.4 and 7.5
Skills	:	6.4, 6.5, 6.6, 7.1, 7.2 and 7.3
Attitudes	:	6.3, 6.7, 6.8, 6.9 and 6.10.

This new scheme prevents an overlap in classifying Objective 6.5 and would probably be even more useful if aims were defined in more specific terms.

2.8.3 How Does the TED Objectives Reflect the Nature of Biology as a Science?

Previous discussions (Section 2.4.1 of this chapter) showed that if a science course is to reveal the true nature of science, it should cover the three vital components of the discipline: Empirical knowledge; processes and methodology of science, and, philosophy and history of science. All three aspects are clearly covered in the stated aims of the core syllabus.

But whereas the knowledge aspect is comprehensively covered, only certain aspects of the recommended processes and methodology os Science are reflected in the syllabus - for example, Aims 6.1 and 6.2 emphasise the understanding of fundamental Biological Principles, conceptual frameworks, patterns and relationships as being essential components of Biological Knowledge. Aim 6.3, on the other hand, stresses that pupils must become aware that this knowledge is, at times, incomplete and tentative.

In agreement with Hill's views (1986), Aim 6.4 stresses the importance of developing proper observation skills while studying Biology. However, investigations based on experimentation is another important scientific method used by biologists to solve problems; none of the listed aims suggest that pupils undertake such experiments themselves. In contrast, we have seen that both GCSE and IBSP attach much importance to experimental investigations and this is clearly reflected in the general aims and specific objectives of these courses (as discussed in section 2.5 above). The South African Association of Biology Teachers also regards experimental investigative skills as an important attribute to be developed in high school pupils (Figure 3). The historical dimension of science is covered by Aim 6.8, which outlines that 'an appreciation and understanding of the contributions which scientists have made to the subject' should be one of the outcomes of the course.

2.8.4 How Does the TED Objectives Reflect the Needs of Pupils and of Society

Recommendation 7.5 which states that 'pupils should be confronted with problems from their personal fields of experience' suggests that the designers of the core Biology curriculum had some awareness of the pupils' needs. The statement is, however, very vague and could be interpreted in many different ways. There is no guidance about which problems should be chosen or on how to link such problems to the other components of the course. Aims 6.9 and 6.10 are somewhat related to societal needs in that they have to do with the environment and its conservation, but in general, there is little reference in the TED syllabus to pupils' needs or to the needs of society.

The statement of SAATB about the desirability of developing 'social and environmental awareness' in pupils also lacks specificity and direction. Some of the objectives put forward by Nuffield GCSE, on the other hand, give excellent guidance on how to use Biology education to meet the needs of both pupils and society. For example, Statement 3.1.5 suggests that biological knowledge should be used to provide an *"understanding of everyday and technological applications of science with their personal, economic and environmental implications"* and Statement 3.2.6 suggests that these applications are evaluated - in other words, it is suggested that topical issues relevant to the child or to society should be discussed in classrooms.

Similarly, Objective 4.11 of IBSP suggests that Biology teachers should teach their pupils how to understand the place of science in everyday life and its role in human relations.

2.8.5 How Does the TED Objectives Reflect the Objectives of Tertiary Education

The 'Knowledge objectives' of Beard's scheme are very similar to those of the National Core Syllabus except for the last objective which states that university students should be 'acquainted with principles and applications of related subjects'. This objective is seen as a desirable attribute to be developed in school leavers by the SAATB (Figure 4), but not mentioned in the core syllabus.

Many of the 'Skills objectives', namely S3 to S8, stated by Beard, do not feature at all in the school core syllabus. Thinking skills which, as discussed in Chapter 1, were described as vital for success at tertiary level are minimised in the school syllabus. Learning to work independently and cooperatively, information seeking and retrieval, and ability to make one's own judgements are other important skills not mentioned as teaching aims of school Biology in the core syllabus. These aims feature widely both in Nuffield GCSE and Israeli IBSP syllabi objectives (as shown in Tables 3 and 4). They are also well represented in the SAATB recommendations (Figure 4).

The 'Attitude objectives' of the university scheme are also not well represented in the local core school syllabus. Although four of the ten broad aims of the core syllabus are concerned with attitudes, different attitudes than those expected at university, seem to be emphasised. Such attitudes as a 'scholarly concern for accuracy', 'a questioning and inquiring approach to knowledge' and 'awareness of moral, social, economic, political and scientific problems of society', which are listed in Beard's scheme, do not feature at all amongst the school's objectives.

Once more SAATB recognise all three of those objectives as important ones for high school Biology and they are clearly defined in the GCSE and IBSP syllabi objectives.

2.9 CONCLUDING REMARKS

Having examined the overall purpose of goals and objectives in education, it was pointed out in this chapter that it is desirable to select and state such goals with care when designing a school curriculum for any subject. Three major factors were identified as important determinants of the goals/objectives of a high school Biology curriculum: The nature of Biology as a 'general' and as a specific science; the needs of the pupils both in terms of relevance of the course and future career plans, and the needs of society. An overview of the status and goals of Biology education in Britain and Israel - two leading countries in the field of Biology education, and a brief review of the goals of local tertiary science educators - served as a framework for analysing the goals/ objectives of our current TED syllabus for Standards 8 to 10.

This analysis revealed that, although many objectives of the TED syllabus were congruent with the other schemes, others were either absent or defined so broadly that they were difficult to interpret. An identification of desirable attributes, which a study of Biology should develop in school leavers, put forward by SAATB, was shown to be closer both to the two overseas and to the tertiary educators' schemes of objectives. On the above grounds, it was thus decided to use SAATB views as well as objectives of the British GCSE and of the Israeli IBSP to supplement and/or improve the TED's scheme while designing the questionnaire used in this study *(Appendix 1)*.

CHAPTER 3 ASSESSING ACHIEVEMENT OF EDUCATIONAL GOALS AND OBJECTIVES

3.1 INTRODUCTION

The importance of clarifying teaching goals and objectives was established clearly in Chapter 2, where a simple model of curriculum design (Fig. 1) was used to show the link between stated goals/objectives, teaching methods, assessment, evaluation and feedback. The main aims of this chapter will be to focus on the role of objectives in the evaluation process in general, the purpose of evaluation and on the various procedures presently available to assess achievement of stated goals/objectives during or after teaching. Various problems associated with attainment tests and examinations, and research findings on the topic will also be discussed.

Whereas the first part of the chapter will deal with these issues in general, the latter part will concentrate on their application to High School Biology and more specifically to assessment of Biology in the Transvaal, including the Transvaal Matriculation Examination.

3.2 PURPOSE OF SCHOOL ASSESSMENT

Macintosh and Hale (1976) describe the following six purposes to school assessment:

3.2.1 Diagnosis

To monitor progress and to find out how the pupil is assimilating what is being taught. Specific action may be instituted as a result of diagnostic assessment.

3.2.2 Evaluation

To evaluate the effectiveness of the teaching which again can lead to specific action.

3.2.3 Guidance

To assist pupils in making decisions about the future, whether it concerns choice of a subject or a course, or whether it is to help in choosing a suitable career.

3.2.4 Prediction

To discover potential abilities and aptitudes and to predict probable future successes whether in school or outside.

3.2.5 Selection

To determine which are the most suitable candidates for a course, a class or university.

3.2.6 Grading

To assign pupils to a particular group, to discriminate between the individuals in a group.

Frith et al (1984 : 6) divides the above into pupil-centred (3.2.1 to 3.2.3) and teacher-centred (3.2.4 to 3.2.6) purposes and remind us that some overlap between these functions always occurs in practice.

Kempa (1986 : 1) uses a different classification, calling purposes 3.2.1 to 3.2.4 the educational purposes of assessment as opposed to those purposes with a *societal role*. Amongst the latter group he includes 3.2.5 and 3.2.6, but adds a third purpose:

'The use of examinations as a means of defining the content and orientation of the curriculum' and of 'Maintaining educational standards'. He has an important point here (as already mentioned in Chapter 1) assessment driven curricula are more the rule than the exception in teaching.

Finally, Gray (1974 : 23) regards purposes 3.2.4 to 3.2.6 as being uppermost in peoples' minds and recommends that teachers make a deliberate effort to shift the emphasis to the more pupil-centred purposes. He argues that most teachers undervalue/underuse their tests as a source of feedback and thus are not 'helping their pupils to help themselves'.

3.3 WHAT IS TO BE ASSESSED

Assessment was described in Chapter 1 as being essentially a 'measurement process' and as Ward (1980 : 3) points out, it could include both 'attainment testing' (i.e. a measure of what a pupil knows or can do) and 'predictive testing' (i.e. an assessment of what the student might learn, or learn to do successfully, given suitable tuition). School assessment, however, is, in general, more concerned with the first type of testing. Thus, what is to be assessed is usually derived from the syllabus of a particular course which, according to Ward (1980 : 17), should always be 'the starting point' to designing any scheme of assessment.

Most syllabi describe not only the content of the course, but also the skills or abilities and attitudes to be learnt by pupils and, as pointed out in Chapter 2, the modern trend is to state these as goals and/or objectives, prefaced by a phrase such as: *'By the end of the course the pupil should be able to ...'*

Figure 5 provides a summary of the various aspects of a course which a teacher/assessor should consider in order to clarify what should be measured.

3.3.1 Defining Aims/Clarifying Objectives

If aims are defined in too general terms for effective measurement, they should be redefined in more specific terms (Steps 1 and 2 in above scheme). Gronlund (1977) supports the view of many assessment specialists when he states that some taxonomy of Educational Objectives, such as the one designed by Bloom (discussed in Chapter 2) could offer useful guidance in specifying the learning outcomes to be measured. In reviewing the research literature about 'specifications for achievement tests', Wood (1991 : 6) acknowledges the effect of Bloom's taxonomy, but says that any similar blueprint would have had the same effect.

Fairbrother (1988 : 48), on the other hand, warns about problems connected to a direct use of Bloom's taxomony in classifying assessment questions. He recommends that objectives listed in the subject syllabus be used instead; being stated in more concrete terms, they will produce more reliable specifications.

Kempa (1986 : 1) distinguishes between assessment objectives and non-assessed objectives and see the latter as often being characteristic of affective objectives because of the difficulty of formulating them with sufficient precision in order to measure them.

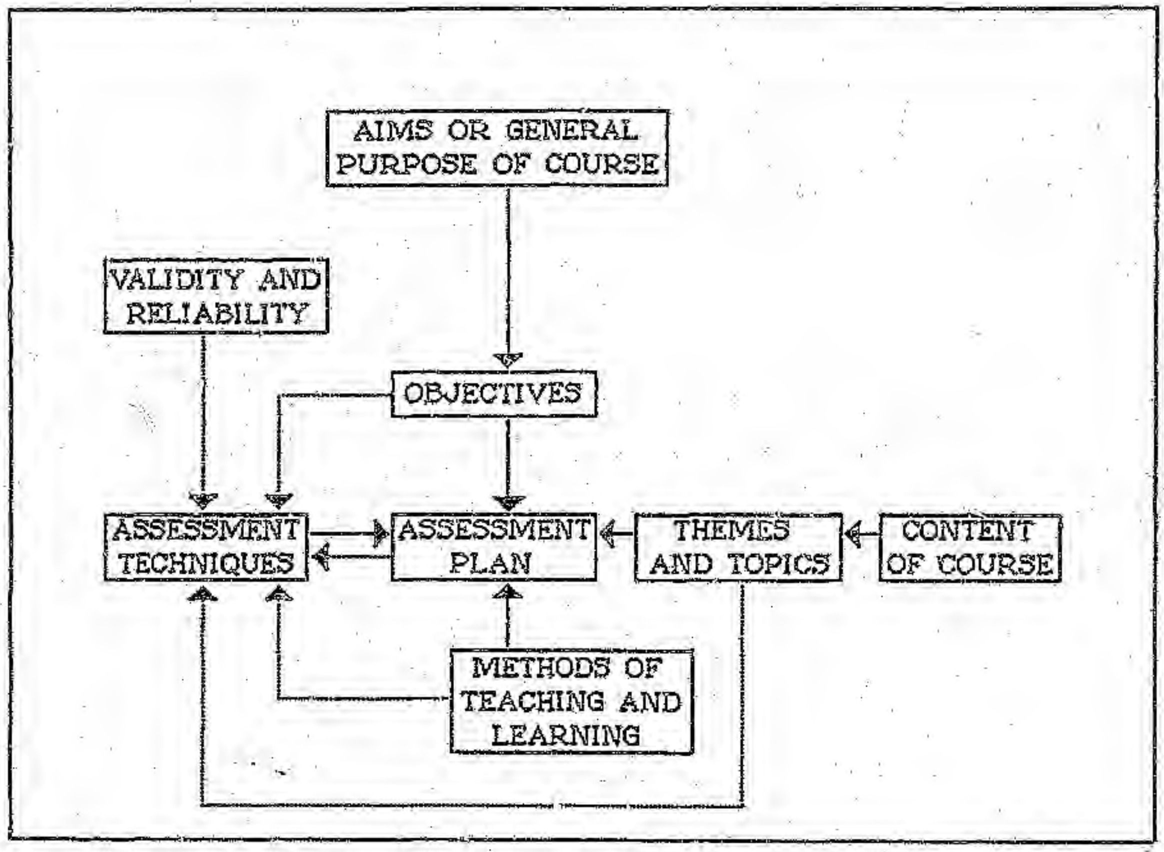

Figure 5. Steps in designing an assessment plan. (Adapted from Schools Council Examinations, Bulletin 28, 1973)

3.3.2 Teaching Content and Methods

In his criticism of the GCSE educational objectives, Kempa (1986 : 13) emphasises the importance of taking the Course Content (steps 3 and 4) and Teaching Methodology (step 5) into account, when designing an assessment plan. He reckons that achievement cannot be tested without the framework of a body of knowledge. According to him (1986 : 14):

> *"...'Science' cannot merely be seen in terms of the processes with which we assume it to be associated. Science, in its totality and through its constituent branches, is concerned with a wide range of 'knowledge items' (facts, theories, rules, concepts, etc. that is no less important a part of science than are science processes."*

In order to achieve balance and fairness in assessment, it is recommended that the assessor takes into account the themes of the subject, as well as the time/depth spent on each one. Ideally, guidance about these two criteria should be included in the syllabus for a particular examination.

Only after careful consideration of the above criteria that the decision on 'how to assess?' can be taken and an assessment plan (Frith et al, 1984) or scheme (Ward, 1980) should then be designed.

3.4 HOW TO ASSESS?

This question can be answered in two ways, i.e. by looking at the various modes of assessment (Rowntree, 1977), or, by describing existing assessment techniques (Ward, 1980). A brief description of both approaches will provide the necessary background for the evaluation of the TED Biology Matriculation examination.

3.4.1 Assessment Modes

Rowntree (Frith et al, 1984 : 17) identifies the following eight "conflicting modes" of assessment:

* Formal versus informal
* Formative versus summative
* Continuous versus terminal
* Coursework versus examinations
* Process versus product
* Internal versus external
* Convergent versus divergent
* Idiographic versus nomothetic.

Although one has to agree with Frith *(ibid)* when he points out that some of these modes overlap and that the distinctions made between them are, at times, very subtle, a brief overview of each one will be undertaken as all these modes need to be clarified before analysing assessment techniques themselves. 'Formal' could be defined as planned assessment as opposed to assessing 'by accident' or 'informally'. Fairbrother (1988 : 2) acknowledges that it is very difficult to avoid the latter, but reminds us that we should not use this form of assessment if we intend *"to pass* *judgement"* or *"take some action which might affect what happens to another person"*, as we could easily be wrong. Frith (1984 : 17), on the other hand, sees informal assessment as having value as an unobtrusive way of gaining insight into the learning progress of a pupil during teaching. He would classify oral questioning occurring spontaneously during a lesson, as well as silent observations in this assessment mode.

In order to distinguish between formative and summative assessments, Frith (1984 : 17) uses the purpose for which the teacher is assessing as main criterion: A formative assessment occurs when the teacher *"sees himself as getting to know the students in order to teach them better"*, i.e. when he is getting feedback about the pupil, the course, or his teaching, whereas assessing in order *"to help others to feel better informed"* (about pupils) is summative assessment. Others (Kempa, 1986 : 19 and Tanner, 1972 : 5) add that formative assessment occurs when instruction is still in progress as an integral part of the learning experience, whereas summative occurs at the end of a topic, module, or course. Frith (*ibid*) disagrees with such an identification of summative with terminal assessment and points out that continuous assessment results, initially used formatively, could subsequently contribute to summative assessment. Frith (1984 : 17) goes even further by pointing out that terminal assessment (e.g. in the form of examinations) could be dispensed of, if a teacher compiles a satisfactory summative assessment from continuous assessment based on coursework:

"The use of examinations cannot be justified merely on the grounds that summative assessment is necessary. A student can be assessed at the end of a course in the light of what has been done during the course and if some terminal task was required, it could be something very different from what is traditionally considered as an examination".

In other words, the terms 'summative assessment' and 'terminal examination' should not (as is done so often) be equated with each other or with examinations.

Differentiating between 'product' and 'process' is recognised by Kempa (1986 : 53) as being particularly relevant in science education and as requiring very different assessment techniques. Although many teachers/examiners assess process through oral questioning or, worst, through written tests, Frith (1984 : 17) reminds us that 'recalling' is not the same as 'demonstrating', as the latter *"helps to determine not only what students do and what students know, but also what they are".*

The last two 'conflicting modes' are closely related and will thus be discussed together. They are also the two modes which seem to be most neglected by teachers and examiners in their assessment of pupils. *Convergent assessment*, which according to Frith (1984 : 18) is more reliable and structured, is often used in preference of *divergent assessment.* Although the latter is somewhat open-ended and somewhat subjective, it allows for assessment of creativity and other 'idiosyncratic' qualities.

Frith sees both *idiosyncratic assessment* (which aims at the unique characteristics of individuals) and *nomothetic assessment* (which collects data for the sake of comparison with others) as being important components of both formative and summative assessment.

In conclusion, it seems that the aim of the assessor or assessment will determine the choice of mode and that in order to obtain an overall assessment of a pupil, or course of study for the purpose of evaluation, a variety of modes should be incorporated in the design of the assessment plan. Other important factors such as reliability and validity will have to be taken into account when choosing assessment modes and these will be discussed further at a later stage.

3.4.2 Assessment Techniques Available and Their Timing

Ward (1980 : 31) offers an excellent summary of the various assessment methods available to assess attainment and she suggests the best timing to be used for each form, in order to ensure maximum reliability and validity:

Table 8: Assessment Methods Available

Timing of Assessment	End of Course	Intermittent	Continuous
Abilities Assessed			
Theory	Written examinations	In-course written tests. Projects and assignments.	Course work assessment of theory
Psychomotor	Practical examinations	Phased practical tests. Practical projects and assignments.	Practical course work assessment
Oral Communication	Oral exams	Oral work	Oral course work assessment
Affective domain		In course tests. Project work.	Course work assessment

All, or most, of the above techniques are used in the evaluation of a pupil's performance and progress during a year of study. However, as this research is primarily concerned with matriculation, only those methods of assessment used, or suitable, for this purpose will be discussed further.

3.4.2.1 End Of Course Or Terminal Assessment

In most countries, including South Africa, matriculation is based on written and in some subjects, practical terminal examinations. These can be done internally or externally. Oral terminal examinations are seldom used, except perhaps for visually handicapped people, but oral questions are often used in practical examinations (Ward, 1980 : 46).

Ward (1980 : 30) lists the following as being some of the main characteristics of a terminal written examination:-

(a) It takes place at the end of the course, on a fixed day, at a fixed time, and is the same for all candidates. It is, as a result, a 'once-for-all affair' so that a student's course results may be unduly influenced by his being 'off-colour' on the day of the examination;

(b) It has a fixed, and often tight time allowance, and is strictly supervised. Usually no talking is allowed and only in certain cases that candidates may use certain specific reference material.

(c) Usually it consists of a series of questions which ranges over the whole of the syllabus for the course, unit or module. Often students are offered a choice of questions.

(d) Usually the tasks which the students has to do is well-defined although the degree of precision varies with the type of questions.

The main disadvantages of this method of assessment are perhaps a little harshly, but well summarised, by means of the following quotation from Rowntree (1979 : 135):-

> "*The traditional three-hour exam tests the student's ability to write at abnormal speed, under unusual stress, on someone else's topic, without reference to his customary sources of information, and with a premium on question-spotting, lucky memorisation, and often on readiness to*

attempt a cockshy at problems that would confound the subject's experts..."

If the terminal examination is an external one it will have, according to the School's Examination Council (Bulletin 27, 1973 : 28) the following additional disadvantages:-

(a) Assessment will be restricted to those attainments which can be displayed in writing; many important process skills are thus excluded. Although in the past practical, terminal examinations were carried out in some subjects, they have been discontinued in most countries due to the problems encountered. This will be discussed further when the assessment of Biology is described.

(b) The freedom of teachers and pupils to follow their own interests and objectives will also be restricted.

The main argument in favour of external terminal examinations as a method of assessment, according to the School's Examination Council (Bulletin 27, 1968 : 27) is that it is the only method which offers the following set of important advantages:-

(a) It is easily administered to a large group of pupils and is probably the most economical method available for such a purpose.

(b) It could ensure rapid dissemination, on a large scale, of what is best and generally accepted in curriculum development.

(c) It allows the concentration of resources for setting, marking, and reporting on examinations.

(d) It forces comparison of achievement of similar students on a national or at least a regional level since all students are assessed by common criteria. This prevents complacency amongst teachers and thus, helps to maintain standards and brings about uniformity of practice.

(e) Results of externally assessed examinations tend to be viewed as more acceptable and less biased when used by employers or educators for selection and other purposes.

3.4.2.2 Intermittent, In-Course Assessment

This method, according to Ward (1980 : 35), usually involves periodic assessment by short tests conducted internally by the teacher. If used for summative evaluation, the results from such tests are aggregated in order to provide the overall assessment. Although this reduces the emphasis on performance on a single occasion; allows better coverage of what has been taught; and, could be less stressful on students, the method does not solve the major problems of terminal assessment. Isaac (1990 : 117) regards this method as a poor substitute for terminal, external written examinations.

3.4.2.3 Continuous Assessment

Continuous assessment takes place throughout the course and is generally based upon samples of the various class-work, homework, assignments or project work, practicals and any other teaching activity. Rigid time limits and other restrictions imposed under examination conditions are often absent. There is usually free access to reference materials and teachers' help. As Ward (1980 : 49) points out, although recall cannot be assessed by this method, more important skills such as the application of knowledge and the pupil's problem solving ability as well as his attitudes can be assessed within a more realistic situation. According to Rowntree (1979 : 124) this should provide a more valid and reliable evaluation of a pupil's capabilities as compared to the single, terminal examination technique.

Ward (1980 : 49) has a valid point, however, when she warns that bias could be easily introduced in course work assessment and that it is often difficult to ensure that the work assessed is done entirely by the pupil. Further advantages and disadvantages of continuous assessment shared with other forms of internal assessment will be discussed in the next section.

3.4.2.4 Internal Or School-based Assessment

The Schools Examinations Council (Bulletin 27, 1973 : 28), identifies the following as being the main advantages of internal assessment:-

(a) Teachers and their students have greater freedom in the choice of teaching objectives, content and activities.

(b) The intermittent assessment tasks reduce the dangers of chance failure or success.

(c) It encourages teachers to assess their students' progress rigorously and frequently. This not only results in immediate feed-back but also encourages students to work continuously throughout the term.

(d) Finally, teachers are encouraged to clarify their objectives and they are provided with an opportunity to assess and adjust their own teaching at regular intervals.

Only one of the above (namely b), is directly related to the a. ssment procedure itself - the other suggested advantages reduced the negative impact which external assessment is known to produce on the teaching procedure.

Perhaps a better justification for school-based assessment is provided by the 1984 Australian Education Report (McGaw et al, 1984) which saw the main strengths of internal assessment to be that they:

> *"... can be used on a substantial sample of student performance, over time and over the full range of the syllabus requirements; ... can assess aspects of a course not accessible to external examination."*

The same report, however, recognises that school-based assessment can also have some serious deficiencies in that they:

"... can be biased for or against students by the relationship between teacher and student; ... can, in some cases, take undue account of early performance in a course and, relatively, too little of the level of a student finally reaches; ... can change the relationship between teacher and student by casting the teacher in the role of judge instead of that of supporter in the preparation for external assessment; ... can be undertaken with variable criteria from school to school."

In analysing the latest research about this topic, Wood (1990 : 72) identifies the first deficiency as *"the one which worries most observers and always will."* He quotes research results by Wood and Napthali (1975), Pedulla, Airasian and Madaus (1980), and Kellaghan, Madaus and Airasian (1982) to show that teachers' assessment could be influenced by such considerations as tastes, preferences, prejudices, knowledge of pupils' I.Q, and observation of pupil's behaviour.

When the above advantages and disadvantages are evaluated, it seems that choosing between external or internal assessment techniques would not be the wisest of decisions - especially in the case of matriculation assessment where so much weight is placed for selection purposes both by tertiary educators and employers. A compromise is therefore called for and resides, it is argued, in mixing both approaches. This compromise would be in line with Frith et al's (1984 : 19) recommendation. The latter, amongst many others, strongly recommend the use of a variety of assessment components in order to measure, as accurately as possible, the various objectives of a course.

The School Examinations Council (Bulletin 27, 1973 : 30) recommends that internal assessment by teachers be used in the following cases:-

(a) Where the objectives are such that no externally administered test can assess them.

(b) In areas which are chosen by students and teachers rather than externally prescribed.

(c) When frequent sampling of student performance is important.

(d) When the essential student activity is not capable of reproduction under examination conditions.

Internal assessment used for summative purposes, especially if it is a component of an assessment plan which will lead to certification, must however follow some standardisation procedures if they are to gain national credibility. Here again the School Examination Council (Bulletin 27, 1973 : 31) offers the following sound advice:-

(a) The assessment must have a common basis of aims and activities couched in broad terms.

(b) It must at least be standardised so that the marks have a common mean.

(c) Moderating procedures must be applied if standards between schools are thought to be significantly different. These procedures must be capable of rapid application and be economical of resources.

3.5 EVALUATION OF THE ASSESSMENT INSTRUMENT

The following statement issued by the School Examination Council (Bulletin 27, 1973 : 8) applies to all assessment techniques, whether internal or external:-

> *"No assessment can be better than the examining instruments allow. If the instruments are faulty, the assessment will be faulty."*

Although some might call this a truism, too often examination results are taken at their face value without any consideration for the quality of the instrument used to make the assessment. This is especially the case in this country for matriculation examinations. As is generally known, whenever examination papers are evaluated, very little feedback of this evaluation reaches the schools or those who use the examination results for selection purposes. Wood (1990 : 7) adopts a similar stance about the British Examination Boards when he says:-

> *"There is no evidence that what is claimed to be measured is measured and no idea how reliably what is being measured is measured."*

He then adds the following pertinent observation: *"It is no longer possible to suppress the question, 'Why are the boards allowed to get away with producing no technical data?'* He goes on to suggest that examination boards should publish some indication of those procedures they use to ensure the reliability and validity of their examinations or other assessment tools.

The two main criteria which determine the quality of an assessment instrument, are indeed its reliability and validity - as will now be discussed in some detail.

3.5.1 Reliability

Wood (1991 : 132) defines reliability as being concerned with the consistency of the examinee's performance, and the qualification of that consistency (or inconsistency).

Deale (in Frith et al. 1988 : 21) explains 'consistency' as meaning how well the test/assessment procedure would give the same results if it could be done again by the same pupils under the same conditions. He points out that this is however, a theoretical definition since such conditions would be impossible to impose and thus that it is impossible to produce a perfectly reliable test. Elaborate statistical procedures have been produced for the purpose of reliability analysis. Wood (1991 : Ch 12) provides an excellent evaluation of the various techniques: parallel form approaches, test-retest method, split half procedures, mark-remark estimates and the more modern approach of generalisability analysis which he believes, holds much promise for checking school assessment.

'Inconsistencies' in examinee's performance on the other hand, can be caused by variability in (1) marking, either between or within markers (2) grading procedures (3) the candidates' performances (4) teachers' teaching methods. According to Wood (1991 : 132), the reliability of the marking of examination is the source which concerns examination boards the most and is also the one which has attracted the most research. He believes that inconsistencies in marking can be improved by better assessment techniques but will never be eliminated.

This is a view further reinforced by the University of Cambridge Examinations Syndicate (1976 : 9) who argues that

> *"As the number of candidates grows it becomes progressively more difficult to ensure that all examiners are marking to the same standard, and coordination techniques become more sophisticated. A great deal of research into different types of test, method of marking, co-ordination of examiner's standards and statistical analysis of results has been undertaken in recent years... It will be sufficient here to point out that all boards which at present offer certificates based upon external examinations have to take this problem very seriously if they are to maintain any credibility, and that it is probably true to say that none of them will ever completely solve it."*

3.5.2 Validity

As discussed below, items choice, format of questions, mode of assessment and various precautions to eliminate bias could ensure either easier marking or less within-candidates variability, but care must be taken that the assessment tool remains as valid as possible.

Deale (1975) defines validity as: "*The quality which a test should have if it is to achieve the outcome/s that is/are intended.*" It is thus the extent to which a test measures what it is supposed or ought to measure or its appropriateness.

Whereas 30 years ago, Cronbach and Meehl (1954) identified four categories of validity (content, concurrent, construct and predictive), two of these, namely concurrent and predictive, were later combined into criterion-related validity. Many researchers support the view of Messick (1989) who stresses that validity, although multidimensional, is a unitary concept and that it is always difficult to measure one dimension without overlap from the others.

Wood (1991 : 148) is of the opinion however, that most examining boards still view validity in terms of content and predictive validity. Content validity is generally regarded as the degree to which the examiners/assessors translate what the syllabus says into an operational examination. If the content is not selected according to syllabus specifications, then score interpretation is likely to be distorted.

Validity is indeed a complex topic about which much has been published. It therefore comes as no surprise that there seems to be much confusion about how it is best measured. For the purpose of this study however, the simpler approach of concentrating on content/criterion validity in terms of specification derived from the syllabus will be followed. Thus an examination which samples the course objectives thoroughly will be described as having high validity whereas one that does not contain a representative sample will be purported to have low validity.

3.5.3 Analysis Of Assessment Techniques In Terms Of Reliability & Validity

Fairbrother (1988 : 3) strongly recommends that variety is used in the assessment of a subject. He believes that as "*all subjects are complex, understanding a subject and being able to use it means doing many things.*" This in assessing a student's ability, he suggests that the assessor uses the widest possible range of content, processes and situations associated with the subject. He summarises the situation as follows:-

> "*We must try to avoid contrive, false questions which do not accurately reflect the nature of the subject. Questions are sometimes chosen simply because they are easy to write or easy to mark, but they may test only a limited aspect of a student's ability in the subject.*" (1988 : 4)

Table 9 summarises Ward's views about the various methods which are available to assess ten broad groups of abilities. the degree of reliability of each method is also given. (Ward 1980 : 77).

Table 9: Reliability Of Assessment Methods Suitable For Different Abilities

Ability	*Reliability*				
	Poor	*Acceptable*	*Average*	*Good*	*Excellent*
recall comprehension				short-answer or structured questions in exams or tests	objective questions in exams or tests
application		projects course-work assessment	assignments problem-solving questions in exams	short-answer or structured questions in exams or test	objective questions in exams or tests
synthesis		projects course-work assessment	assignments problem-solving questions in exams		
writing and self-expression	essay questions course-work assessment				
comprehension of drawings sketches, graphs				short-answer or structured questions	objective questions
production of drawings, sketches, graphs		projects course-work assessment	assignments	structured questions	
calculations			assignments	short-answer or structured questions	
practical skills			course-work assessment	phased tests practical assignments	
oral skills	course-work assessment				
affective domain	course-work assessment				

3.6 ASSESSMENT OF HIGH SCHOOL BIOLOGY

From Table 9, it is clear that a variety of assessment modes, techniques as well as question type, will have to be used in order to produce a fair, valid and reliable assessment of High School Biology. But as Fairbrother pointed out the selection will have to be done carefully if reliability and validity itself are to be maintained to an acceptable level.

Content and criterion validity will be attained only if the assessment procedures are concerned with determining the extent to which the objectives of the course have been attained (Rowntree, 1979 : 92). Objectives which would ensure effective Biology teaching were discussed in Chapter 2, where it was established that it would be best (for the purpose of this study) to group the specific objectives under Beard's three categories, namely *Objectives about knowledge, Objectives about skills* and *Objectives about attitudes.*

3.6.1 Procedures For 'Knowledge Skills'

Of the twelve 'Knowledge skills' identified in Chapter 2 for inclusion into the questionnaire, *(see Appendix 1),* nine reflet modern ideas about Biology education (i.e K1, K4, K5 and K7 to K12). According to Ward's classification (Table 9 above), all nine could be most reliably assessed through some form of written assessment (tests or exams) consisting of either objective/coded-answer items or short-structured questions.

(1) Multiple-choice questions are according to Wood (1990 : 4) and to Fairbrother (1988 : 51) are particularly suitable to test recall of knowledge as well as simple understanding. Wood (1991 : 32) points out that in spite of the harsh criticisms that this form

of assessment has received, it can be very valuable as a component of a wider assessment tool. Fairbrother (1988 : 27) however, believes that "*questions which just ask for straight recall are unsatisfactory, and should be avoided*". He adds that "*knowledge should not be separated from understanding*" and he seems to imply that by assessing the latter the former will of necessity be assessed too.

Fairbrother also warns about how easy it is when using multiple-choice questions to "*ask for straight recall without any context*". He sees this as being one of the most common mistakes of current GCSE science/Biology examinations in Britain. He however, gives numerous examples (1988 : Ch4) of how this situation can be avoided and how even higher skills such as problem solving can be assessed through multiple-choice or other coded questions.

The advantages of coded answers in general are well-known: they are quick and easy to mark and produce reliable results. Item analysis can be accurately performed on them and pupils with poor writing skills but who can read and think can score highly on such questions. As Wood (1991 : 50) concludes:

> *"Hysterical outbursts that multiple choice tests are no more than gambling machines are quite unjustified. All the evidence is that if tests are properly constructed, presented and timed, candidates will take them seriously."*

Since answers are coded (i.e they have to be selected from predetermined, prewritten answers) this procedure cannot be used *"to test student's communication/self-expressive skills or their ability to formulate answers and responses."* (Kempa, 1986 : 22)

The time taken and expertise required to set good multiple-choice questions are probably their own main shortcomings.

(2) Short answers or structured questions can, according to Fairbrother (1988 : 67), be used to assess the entire range of *'knowledge objectives'*. He defines such questions as those which can be read and answered in anything from about one to ten minutes. Each question is constructed to deal with a *'single theme' or idea in this space of time"* and because each question can concentrate on a specific process or item of content many objectives can be assessed within a relatively short time.

Another important distinction made by Fairbrother (*Ibid*) is between *"completion"* and *"composition"* questions. He regards the latter as possibly being more suitable for higher levels of understanding.

Kempa (1986 : 22) however disagrees with Fairbrother and regards short-structured questions as having the same limitations as coded answers when assessing higher order skills.

3.6.2 Procedures For "Skills Objectives"

Ten of the fifteen objectives listed in the questionnaire about the skills that Biology pupils should acquire can be tested through written tests or examinations. Some can be tested through coded-answer questions, while others will need the structured questions. Again, Fairbrother (1988 : 67 to 85) provides a large number of examples of how this can be done and offer advice on how to avoid wrong questions.

Most of these skill-based objectives can also be tested during the course of practical or laboratory work (S3 to S12) and four skill-based objectives (S4 to S6 and S15) can only be tested in a laboratory or field situation (Burkley and Kempa, 1972; Colussi, 1976; Kelly et al, 1969; Naik, 1986; Sands, 1984; Wood, 1991).

Other skill-based objectives, some not listed in the questionnaire, are probably better assessed through comprehension passages or through essay questions in the longer written tests or examination situation (Fairbrother, 1988; Kempa, 1986; Ward, 1980 Wood, 1991).

(1) Comprehension Passages

Although Comprehension passages are now part of many Biology examination, little has been written about them and many still see such questions as the domain of the language exams. Fairbrother (1988) seems to be one of the few to have written on the topic. He points out (1988 : 86) that:

"A distinctive feature of comprehension passages is that they offer an extended and coherent context in which the students can show their understanding of the subject. They are particular suited to tasks which require the students to use information."

The coherent and realistic context seems to be the main advantage of comprehension-based questions as compared to short, structured ones which could be used to assess the same objective.

Fairbrother *(Ibid)* lists the following three aims of comprehension questions:-

(i) To assess a student's ability to read and understand a passage of a mainly scientific or technical nature. Students could for example be asked to explain specific words or sentences from the passage or they could be asked to summarise parts of or extract information from the passage.

(ii) To set questions in a broad context and then ask for answers which interrelate different bits of content. Students could be asked to translate information from one form to another:- information given in words, numbers, diagrams, graphs, pictures etc, could be changed to any other form. Perhaps more importantly, students could be asked to relate the various bits of information and explain any existing patterns.

(iii) To provide the context in which students can share ideas and express opinions and to encourage the critical reading of scientific literature. Students can be asked to make inferences, deductions or to form hypothesis from given information or they could be asked to extend/apply the information to explain similar situations, give similar examples, or suggest methods of checking quoted results. The students could also be asked to criticise statements and conclusions from the passage, to propose alternatives or to evaluate specific situations.

Fairbrother (1986 : 86) acknowledges that the more open-ended questions based on the comprehension passage might be difficult to mark reliably but, as others before him have done, he emphasises that such questions might be necessary if all stated objectives are to be evaluated and if the assessment is to be valid.

An example of such a Biology Comprehension Text with Questions of various types is the one entitled 'Cape Town's Unwanted Tourists' this is an adaptation of a question from the School Certificate Reference Test of the Boards of Study of New South Wales, 1991. *(See Appendix 2).*

(2) Long Answer or Essay Questions

Any answer which involves extended writing and/or time falls under this category which is well known for its reliability problems (Ward, 1980 : 77).

Kempa (1986 : 25) comments that such questions *"may suffer from a degree of subjectivity in marking, due often to the variety of responses to which a particular question gives rise."* He suggests well-structured marking schedules as an answer to the problem.

Wood (1991 : 67) sees the problem as being far more complex and points out that three aspects of essay marking should be considered when trying to improve reliability, namely: "The existence of different types of writing, constructing questions and marking answers." He then makes some excellent recommendations about how to treat each of these aspects in order to improve the reliability of this approach. He proposes that those responsible for setting the question/s have a clear and elaborate model of which kind of writing they want to assess. In other words, he sees specification of the type/s of writing required, and their weighing in terms of writing mechanics, as part of instructions to teachers and candidates in the examination syllabus. Essay writing in Biology should, for example, be marked according to certain specific criteria which could be different to what an examiner would mark in English or History.

When wording questions, Wood suggests that more care is taken in cuing candidates about what the examiner wants. Using broad terms like 'discuss' and 'compared and contrast' might not be sufficient.

Lastly, Wood recommends the use of double marking (1991 : 68) or, alternatively, the calibration of markers using a "statistical tool embedded in the operational marking arrangements" in order to produce more reliable scores.

The fact that essay questions measure certain skills not measured by other question types is perceived here as sufficient proof to warrant their inclusion.

(3) Practical, Laboratory and/or Field Tasks

The need for different assessment procedures to assess practical skills and the reliability and validity of such assessment has been questioned by many science educators, such as Hodson (1990 : 33) and Woolnough (1990 : 128).

Woolnough (1990 : 130) is very critical of what he calls the 'atomistic' approach to assessment of practical skills. He recommends an holistic approach to the assessment of practical tasks and sees little merit practical tests designed to assess individual manipulative or other skills.

Yet, practical work is seen as playing an important role in Biology teaching and many educators recommend special procedures for its assessment. For example, Tamir (1972 : 175) argues that:

> *"Practical work is more than manipulative skills and does not lend itself to assessment by the usual paper and pencil tests. It is a mode of its own and must be treated as such."*

Research overseas (Buckley and Kempa, 1971 : 24; Kelly and Lister, 1969 :112; Sands et al., 1982 : 131) and locally (Colussi: 1976; Moodley: 1980; Naik: 1986) have shown that the method of *'continuous assessment'* of students' practical abilities is by far, the most effective and favoured mode of assessment in Biology and/or Physical Science. Following Kerr's famous report about *'Practical Work in School Science'* (1963) and his recommendation that *"teachers be given more responsibility for the assessment of practical work"*, many examination boards cancelled all form of external assessment of practical skills through the traditional practical examination method and to date, internal course work assessment is still in use in many countries. The use of criterion referencing and check-lists of expected objectives have been put forward by examination Boards (e.g OCEA, APU) to facilitate this assessment.

In Israel on the other hand, Practical Tests are still being used to assess practical work even at matriculation level. According to Tamir (1982 : 42) this is *"a new kind of test which aims at a comprehensive assessment of the skills associated with inquiry-orientated laboratory work"*. He goes on to explain how, when students have to solve a novel problem, they have to go through the entire sequence of events which characterise the so-called 'scientific method'.

Israeli students also have to perform some ecological or field projects prior to their matriculation and are rated through oral discussions about their work. Some students are also offered alternative practical investigatory projects which they perform with help from their university professor (Tamir, 1988 : 43). The Israeli assessment of practical investigation is very similar to the model put forward by APU (Kempa, 1986 : 72) and summarised in Figure 6.

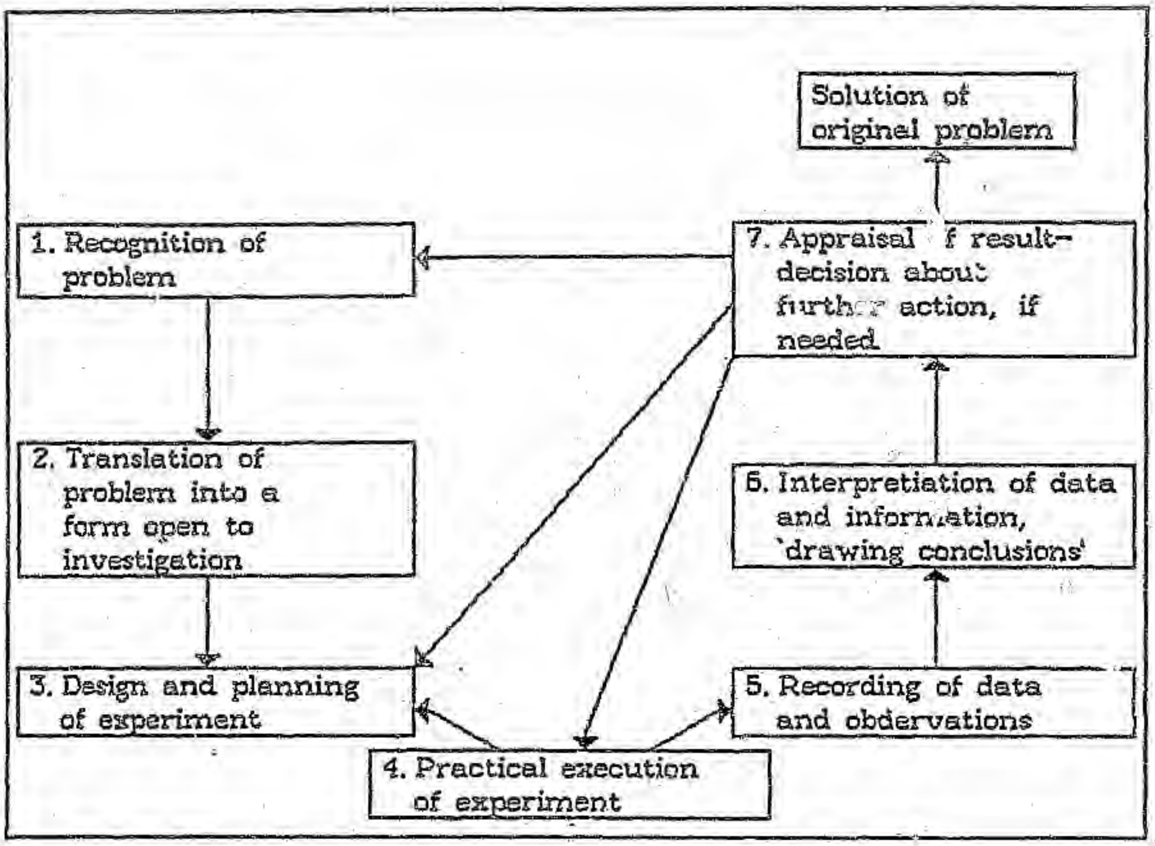

Figure 6. Schematic Problem Solving Model for Practical Investigation.
Based on APU Model 1984, in Kempa 1986 : 72)

3.6.3 Assessment of 'Attitude' Objectives

These have already been described as extremely difficult to measure objectively. Kempa (1986 : 96) describes a few subjective methods and situation when such objectives can be evaluated. It seems that the method of direct observation of specific responses might be of some value. Some of the attitudes listed in the research questionnaire *(see Appendix 1)*, could possible be best evaluated during practical and or project work. The use of self-assessment inventories (Kempa, 1986 : 100) could also prove useful.

3.7. THE TRANSVAAL HIGHER GRADE BIOLOGY EXAMINATION

The assessment of Biology on the Higher Grade by the Transvaal Education Department is based on a terminal, external, three-hour written examination, as well as an internal course assessment mark provided by the student's teacher. The teacher's assessment, based on Std 9 and 10 work, is usually sent to the Transvaal Education Department by the school about a month prior to the written examination.

The assessment mark is moderated through correlation with the external examination results and is said to count for a third of the pupils final marks. The written examination is set by an external examiner and moderated by another. It is also moderated by a representative of the JMB.

The paper consists of three main sections: Section A which includes 30 multiple choice questions and another 3 or 4 coded answer or structured questions. This section is worth one hundred marks. Section B consists of four short structured questions, each worth 75 marks. Finally, in

Section C, the pupil has to answer one of two essay questions, worth 75 marks. The essay question is usually highly structured in order to facilitate marking.

The scripts labelled with assigned examination centres numbers and candidates numbers are marked collectively at a number of marking centres. A chief marker co-ordinates and supervise marking which is done by volunteer teachers. Although attempts are made to standardise the marking through the use of a common memorandum, marking problems often crop up. A marker's report written after the 1990 marking session at JCE is included *(see Appendix 3)* in order to illustrate some of the problems. Although the examiner reports back to teachers after marking, usually only some teachers are informed about it and many teachers never receive any feedback on their pupils' performance in the examination.

Practical work is not assessed directly but questions on experimental procedures and apparatus could be set in any section of the theory paper. Candidates marks are then standardised according to fixed criteria in order to fit a normal curve distribution and standards of previous years.

3.8 CONCLUDING REMARKS

This chapter has looked at the purpose of assessment as well as at the various assessment procedures available for the evaluation of High School Biology. The characteristics of good assessment tests were discussed before describing the procedures used by the TED to assess Higher Grade Matric Biology. Against the theoretical backdrop of research in the field and examples of good assessment procedures provided, the TED examination seems to suffer from certain basic flaws, such as ignoring the assessment of certain important practical objectives and poor marking procedures. On the other hand, many of the techniques described as sound assessment procedures are being used in the theory paper and internal assessment by teachers contributes to the pupils examination result. On the ground that no assessment tool can be set to produce totally reliable and valid results, the TED paper would still be providing reasonable assessment if it was measuring most of the objectives set in its syllabus and known to be conducive to effective Biology Teaching. As outlined in Chapter 1, the aim of this study is to determine this through an analysis of teachers' opinion about objectives and the examination. The next three chapters will therefore concentrate on the research itself in terms of procedures, findings and implications.

CHAPTER 4 RESEARCH DESIGN AND METHODOLOGY

Choosing a survey approach, to collect the data needed to resolve this research, can be justified by the fact that the research problem, as discussed in Chapter 1, is 'present oriented', and whereas such data do not exist the *"settings in which they could be generated do exist"* (Fox, 1969 : 423). The main focus of this study is to sample teachers' opinions and beliefs and, according to Kerlinger (1969: 406), a survey research is best adapted to obtaining this type of data. A mail questionnaire (also described in Chapter 1) was thus used in this study. In spite of the problems which accompany this type of approach, it was chosen as the most appropriate method available in terms of time and cost effectiveness.

4.1 SAMPLE SELECTION

Ideally, random sampling techniques should have been used and the sample should have been selected in such a way that it would represent the entire population of High School Biology Teachers in South Africa. Unfortunately this was not possible, not only because of the obvious labour and cost it would involve, but mainly because of the reality of the current education system - its divisions and inequalities. The evaluative nature of this survey demands skilled, well-trained Biology teachers, with some knowledge of assessment techniques, as respondents. It was thus decided to restrict sample selection to those teachers currently teaching in the so-called 'white schools', as much disparity is known to exist in training and qualifications of teachers from the other racial groups. This will limit the generalisations and findings of this research, and might unfortunately include some racial biases, but on the other hand, will probably increase its reliability and validity.

It was also decided to restrict sample selection to two provinces only, namely the Transvaal and Natal, as it was believed that this would provide a fair representation of teachers' views. The inclusion of teachers from Natal - another province - was seen as important in order to allow evaluation of any effect of analysing one's own examination as opposed to one set by a different examination board.

Lastly, to facilitate distribution of, and to increase responses to questionnaires, SAATB members who met the above two criteria (i.e teachers in white schools from either Natal or the Transvaal) were used as a sample. The rationale behind using SAATB members is due to the nature of this research, a fairly long questionnaire had to be designed and in order to avoid superficial responses, respondents had to be not only knowledgeable, but motivated to the task. Teachers who belong to SAATB are generally known to be the more interested one who often attend workshops run by the association.

4.2 RESEARCH PROCEDURES

4.2.1 Designing The Research Questionnaire

Part 1. To obtain teachers' views about importance and perceived achievements of teaching objectives.

As outlined in Chapter 1, Beard's broad classification of objectives as 'KNOWLEDGE', 'SKILLS' and 'ATTITUDES' was chosen to facilitate analysis of responses about objectives. The reasons for not using a classification hierarchy was discussed fully in Chapter 2.

Selection of the individual objectives for each category was done carefully by combining and modifying a number of already stated schemes of objectives; namely the objectives of the TED syllabus; recommendations of SAATB; Beard's scheme for tertiary education; objectives of Nuffield GCSE and of the Israeli IBSP. An attempt was made to use objectives from all these sources, but overlaps were avoided and an effort was made to clarify obscure objectives. The rational underlying this approach was explained fully in Chapter 2. An original list of 38 objectives were selected. For the KNOWLEDGE category, objectives representing all different trends, conflicting ones, was used in order to find out about the teachers' views without bias or prejudice. It was felt that this approach was unnecessary for the other two categories as negative views about skills and/or attitudes would, as a matter of fact, be rejected.

Part 2. To analyse TED 1991 examination paper.

A copy of the actual examination paper was used and respondents were requested to distribute the allocated marks into four columns according to four broad categories of objectives: Two of these relate to KNOWLEDGE and two to SKILLS. ATTITUDE objectives were not included because of the well-known difficulty of measuring such objectives through a one-shot terminal examination (as discussed in Chapter 3).

4.2.2 Validity and Reliability of Questionnaire

To ensure validity and reliability of the research instrument, a small pilot study was carried out: Questionnaires were submitted to a small group of educators well-known for their expertise in questionnaire design or in Biology education. Their suggestions were used to improve the original design and the questionnaire was only finalised after complete agreement with the pilot group. On the basis of recommendations received from this group, two SKILLS' objectives were modified slightly and three other objectives were discarded to avoid overlaps.

The final list of 35 objectives to be rated by the respondents were set up as shown in Appendix 1.

4.2.3 Distribution of Questionnaires

Questionnaires were mailed to two specific groups of SAATB members:

1. Transvaal Educators/Teachers (150 questionnaires).
2. Natal Educators/Teachers (50 questionnaires).

Sixty-eight percent of Natal teachers replied spontaneously to the mailed questionnaires, whereas thirteen percent of Transvaal teachers chose to do so. Due to this very low initial response from the Transvaal teachers, questionnaires were also issued to teachers, directly or via headmasters, at various conferences and workshops.

4.3 COMPOSITION OF RESPONDENT SAMPLE

Seventy-three usable completed questionnaires were received: 39 from the Transvaal (an initial 19 and a further 20) and 34 from Natal. 75% of the respondents were female - an accurate reflection of the gender ratio of Biology teachers. As shown in Figure 7, the majority of respondents were experienced, mature teachers.

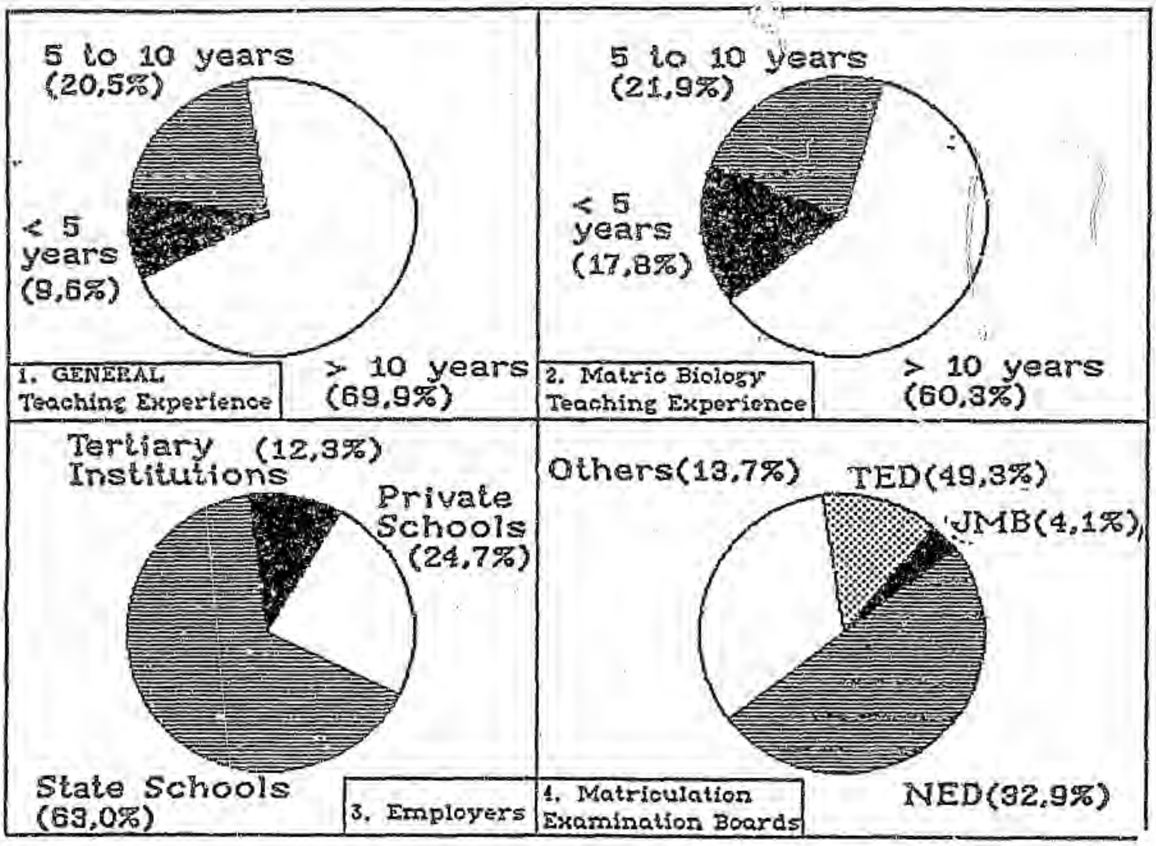

Fig. 7 Pie graphs showing composition of respondent sample

The poor responses from younger teachers would be a cause for concern if they reflected either a lack of interest in this type of research or a poor membership of the younger generation to SAATB. On the other hand, they could perhaps be explained by the pressures encountered in coping with the heavy workload and extensive preparation required as a inexperienced matric teacher.

The respondents' employers and the examinations for which they prepare their matric pupils, two factors which could affect responses, are shown in Figure 7.

The 12,3% response from tertiary institutions (Fig. 7) were from ex-teachers now involved in teacher training at universities or colleges of education. Although they did not fall in the initial sample parameters, it was decided to include their responses in the final analysis as it was felt that a comparison of their views and those of teachers could reveal interesting facts.

4.4 ANALYSIS OF THE DATA

The statistical analyses were done on the mainframe computer (IBM 3830) at the University of the Witwatersrand, using the Statistical Analysis System (SAS) 82.5, Version 6,7 (SAS 1992).

Due to the fact that part one of the questionnaire was analysed by using of a 5 point rating scale, simple, non-parametric tests were selected to analyse the data whenever this was possible. Although the results cannot be generalised to the entire Biology teachers' population as random sampling procedures were not used, the statistical tests would be sufficiently strong to answer the first two research questions stated in Chapter 1.

The available sample of 73 mature teachers would provide a good indication of the views of our more experienced teachers about desirable goals/objectives for effective Biology teaching and about which of these are being achieved currently in the more privileged 'white' schools. They would also be in a position to identify the problems and qualities of the current TED examination.

The two parts of the questionnaire were analysed separately.

Part 1. Rating of Teaching Objectives in Terms of Their Importance and Perceived Achievement

Means and Pearson Product Moment Correlation Coefficients were computed in order to compare the various categories of responses globally. Frequency ratings by teachers were then used to rank individual objectives in the various categories in terms of either importance attributed to them or their perceived achievement through current teaching. The frequency of responses under each possible rating of the 5-point scale was calculated for each objective, assessing the objective as being important or often achieved. The middle rating of 3 was interpreted as showing an indifferent assessment whereas ratings of 2 or 1 were interpreted as a negative assessment, i.e. not important or never achieved. Thus, to rank objectives in order of either importance or achievement, frequency of 5 and 4 ratings were added together and this combined frequency was used to rank the objectives in descending order of importance and/or achievement.

Finally, in order to ascertain the significant relationships between the two ratings attributed to each objective, i.e. importance and actual achievement, Fisher Exact Test was computed. This test was used instead of the more usual chi-square because of the small size of the sample.

Part 2. Analysis of 1991 HG TSC Biology Examination in Terms of Assessed Objectives

Two simple parametric tests were used to establish teachers' views about the objectives assessed in the examination paper: Simple computations of the mean and standard deviation of the marks allocated by the teacher's sample to each objective category for each section or question was carried out. Whereas the means would allow comparisons of marks allocated to each objective type, the standard deviation will provide some idea of agreement/disagreement amongst the different teachers. Bar graphs were then drawn to show the perceived distribution of marks for each section, according to objectives. These simple data would be sufficient to answer the third research question.

Finally, in order to compare responses of sub-groups of the sample and in order to establish influence of various extrinsic variables, such as type of employer or examination, various one-way analysis of variances were computed. This data would allow the last research question to be answered.

4.5 CONCLUDING REMARKS

The research strategy, measuring instruments and statistical methodology have now been set out in some detail. It is felt that sufficient background has been laid for the consideration of the actual findings. These will be outlined in the next chapter and interpreted in Chapter 6.

CHAPTER 5 RESULTS AND DISCUSSION

This chapter will attempt to outline and discuss the main findings of the study in order to answer the research questions 1 to 4 which were formulated in Chapter 1. The results will be interpreted further in the next chapter and recommendations arising from these findings will then be offered.

The ratings given by the entire sample to teaching objectives (Part One of the questionnaire) will first be summarised and analysed in order to answer the research questions 1 and 2. The research literature undertaken in Chapter 2 will be especially used in this preliminary analysis.

Data produced by the teachers' analysis of the 1991 TSC HG Biology examination paper (Part Two of the questionnaire) will then be discussed in order to answer the third research question. Chapter 3 will provide the necessary theoretical framework for this part of the discussion.

Finally, differences in the responses of the various sub-groups of the sample, as described in Chapter 4, will be outlined and used in answering the last research question.

5.1 RATING THE CATEGORIES OF TEACHING OBJECTIVES

The immediate impression gained, even from a cursory examination of the responses, was that for all three categories of objectives, namely 'KNOWLEDGE', 'SKILLS' and 'ATTITUDES', the perceived achievement did not match up to the importance attributed. This was confirmed by the very low correlation coefficients obtained when Pearson Product Moment Correlation Coefficient (r) was computed from the ratings (see Table 10).

Table 10: Correlations between Importance and Achievement of Objectives' Categories (N=73)

CATEGORIES OF OBJECTIVES	IMPORTANCE		ACHIEVEMENT		CORRELATION COEFFICIENT
	% MEAN	S.D	% MEAN	S.D.	(r)
Knowledge	80,9	7,96	66,8	7,98	0,2874*
Skills	88,8	5,24	62,1	11.17	-0,0398
Attitudes	92,6	8,25	69,1	11,52	0,2401*

* *P< 0,01*

It is to be noted that there was no significant correlation between the importance and achievement of skills. It seems that teachers may realise the importance of skills, but cannot teach them successfully. Out of the three groups of objectives, it appears that this is the one teachers are less confident about achieving in the classroom.

The slightly lower percentage mean rating (80,9%) for 'KNOWLEDGE' objectives does not imply that they are viewed as less important than 'SKILLS'. However, as it was pointed out in Chapter 4, some of the knowledge objectives included in the questionnaires were selected as the opposite choices to the current trend of ideas, and should obtain low ratings, whereas 'SKILLS' objectives should elicit high ratings if modern educational trends as discussed in Chapter 2 (e.g. Fairbrother, 1988) were reflected.

The highest percentage mean ratings scored by the 'ATTITUDINAL' objectives imply that teachers are aware of the importance of propagating the values which underpin the teaching of Biology - the fact that some teachers do not achieve there goals is however, a little worrying as Biology is one of the few school subjects which could impart some positive values and attitudes about living organisms, conservation and the environment (Opie, 1986). The lower percentage mean rating about the achievement of these objectives is however quite worrying. Poor attitudes towards Biology as a science and about adequate study practices could, according to Tamir and Amir (1987), have a significant influence on pupils' achievements either immediately or later at tertiary level. It was pointed out in Chapter 2 that good, independent study practices is an important determinant of success at university.

5.2 RATING OF SPECIFIC OBJECTIVES IN EACH CATEGORY

In order to ascertain the importance teachers attach to the individual objectives and their perceived achievement of such objectives, the percentage frequency of respondents giving high ratings (5 or 4) was compiled for each objective (as described in Chapter 4). These data were then used to rank the objectives in each category (Tables 11 to 13).

5.2.1 Knowledge Objectives

Table 11 The *Knowledge Objectives ranked* according to frequency of high ratings (5 or 4) attributed by respondents in terms of importance and perceived achievement.

	OBJECTIVES (At the end of matric HG Biology student should:)	IMPORTANCE % frequency & ranking	ACHIEVEMENT % frequency & ranking
K7	be able to link the components of the course into a coherent body of knowledge	99% (1)	47% (6)
K10	understand some of the applications of biological knowledge	97% (2)	47% (7)
K4	know fundamental biological principles	96% (3)	75% (2) *
K8	become aware of patt[illegible] relationships withir t[illegible]	96% (4)	56% (4)
K5	have become familiar wi[illegible] understanding of the nat[illegible] processes	[illegible]3% (5)	58% (3) *
K1	know the basic terminology used in the biological sciences	[illegible] (6)	86% (1) *
K6	have acquired some knowledge of a wide range of living things	82% (7)	48% (5)
K11	be acquainted with some of the principles of related disciplines	60% (8)	16% (10)
K12	understand some of the applications of related disciplines	49% (9)	10% (12)
K3	have acquired a thorough knowledge of the physiology of a few organisms	36% (10)	37% (9)
K2	have acquired detailed knowledge of the structure of a few living organisms	34% (11)	44% (8)
K9	understand contributions scientists have made to the subject	21% (12)	10% (11)

* Significant (P<0,01) Fisher Exact Test

The data summarised under "IMPORTANCE" in Table 2 shows clearly that the sample of teachers used in this study perceives general principles, concepts and patterns (K7, K4 and K8) as being far more important teaching objectives than knowledge of factual details and terminology (K2 and K3). In fact, at least 70 respondents (96% of the sample) gave high ratings to each of the objectives K7, K4 and K8 whereas only 35% of the respondents gave such high ratings to either of the objectives K2 or K3. It seems that following the modern trend in Biology education, as discussed in Chapter 2, Hill's *'generalist approach'* (1986) is favoured to Jenning's *'basic grammar'* approach (1980).

On the other hand, the majority of respondents (82%) differ from world opinion about the importance of Objective K6. Many respondents seem to think that pupils should study a wide range of living things. Educators from many other countries, as shown by the GCSE and IBSP objectives listed in Chapter 2, favour the study of a few examples of each group together with a basic understanding of the classification systems. Such an approach would have the definite advantage of reducing the factual content.

Application and relevance of Biological Knowledge to modern society (K10 and K5 respectively) were also rated highly in terms of importance by the majority of teachers (K10 by 97% and K5 by 93% of the sample). Again this is in agreement with the findings of Chapter 2, where the idea of an education *'through science'* within the context of relevant, current technological, personal and societal events and issues was outlined as one being favoured by modern educators.

As compared to some of the objectives discussed previously, understanding principles and applications of other related disciplines (Objectives K11 and K12) have been given high ratings by fewer respondents (60 and 49% respectively). Perhaps Biology teachers need to be reminded that:

> *"No intellectual discipline is an island, entire of itself; every discipline is a piece of the Continent, a part of the main"* (Adapted from John Donne's, Meditations XX11).

It is well-known that numerous biological concepts cannot be understood without some knowledge of Physics, Chemistry and Mathematics. Overseas, many integrated science courses are being offered to counteract the tendency of compartmentalising knowledge.

Objective K9 was rated as being important by an even lower percentage of respondents: a mere 21% of the sample. Yet, as discussed in Chapter 2, many science educators regard the teaching of history and philosophy of science as essential components of a balanced curriculum. Woodburn and Obourn (1965), argue that the variety of scientific methods and procedures and the tentative nature of scientific knowledge cannot be otherwise understood.

This low ranking of objective K9 are somewhat surprising in that, as opposed to K11 and K12, this objective (as discussed in Chapter 2), is clearly outlined in the national core syllabus (Aim 6.8 in Table 6).

The data in the 'ACHIEVEMENT' column of Table 11, on the other hand, shows that when the objectives are ranked according to 'perceived achievement' a very different pattern, to the one discussed above, emerges.

Objectives K1, (Knowledge of Terminology) and K4, (Knowledge of Fundamental Principles) are the only two objectives which a majority of respondents (86% and 75% respectively) believe they are currently achieving in their class rooms. As shown in Table 11, these objectives were also ranked highly in terms of importance by many respondents (90 and 96% respectively).

Only about half of the responding sample think that they are currently achieving Objectives K5, K6, K7, K8 and K10. Yet, all of these objectives were given high ratings in terms of importance by most respondents (between 82 and 99%). Out of all the Knowledge objectives listed, K9 was given the lowest number of positive ratings both in terms of importance and achievement. K11 and K12 were also rated by very few as being achieved Knowledge objectives.

The low relationship which exists between perceived importance and achievement of individual 'KNOWLEDGE' objectives was confirmed further by the results of the Fisher's Exact Test: A significant relationship exists for only 3 of the 12 Knowledge objectives, namely K1, K4 and K5, ($P<0,01$).

TABLE 12 THE SKILLS OBJECTIVES: *ranked according to frequency of high ratings attributed by respondents in terms of importance and perceived achievement.*

	OBJECTIVES (At the end of matric a HG Biology Student should:)	IMPORTANCE % frequency & ranking	ACHIEVEMENT % frequency & ranking
S1	use biological information to analyse unfamiliar situations	99% (1)	44% (6)
S11	be able to interpret given information	99% (2)	52% (2)
S7	construct hypothesis about observed biological material accurately	96% (3)	15% (13) *
S5	observe biological material accurately	95% (4)	53% (1)
S6	produce meaningful records of observations	95% (5)	33% (8)
S9	make inference from evidence	95% (6)	25% (12)
S12	analyze quantitative data	92% (7)	33% (9) **
S4	use manipulative skills useful for biological investigations	90% (8)	47% (4)
S10	communicate information by a variety of means	90% (9)	44% (5) *
S2	develop ideas creatively	86% (10)	29% (10)
S3	carry out instructions	84% (11)	52% (2)
S8	design experiments to test hypotheses	82% (12)	10% (15) **
S13	obtain information efficiently from texts	82% (13)	34% (7)
S15	undertake an independent investigative study to solve a biological problem	75% (14)	15% (14)
S14	be better equipped to gain a livelihood as a result of having studied Biology	62% (15)	29% (11)

* Significant Fisher Exact Test ($P<0,01$)

** Significant Fisher Exact Test ($P<0,05$)

5.2.2 Importance and Achievement of Skills Objectives

All 15 objectives listed in this category were rated highly in importance by a very large majority of respondents, but few gave them high ratings for achievements (Table 12).

There is not much difference between ratings given to Cognitive (S1, S7, S9 and S11) and Psychomotor skills (S5 & S6). Both have been rated as equally important but seldom achieved. Only two of the objectives listed (S14 and S15) were given ratings of less than 60 in terms of their importance. S14 was given an even lower rating in a parallel study carried out in England by Carrick (1986). The lower rating of S15 could possibly be attributed to time pressure encountered with the current syllabus and e; amination system. An independent investigative study is indeed time consuming.

It is interesting to note that those 'higher cognitive skills', discussed in Chapter 2 as important for success at tertiary level (S2, S7, S8, S9, S11 and S13), were all ranked very highly in importance, but not in achievement, by the teacher's sample.

As already discussed, none of these objectives are sp ified in the TED syllabus, but were described as very important for s essful Biology Education by SAATB. They also feature in the GCSE and IBPS schemes.

Also ranked highly in importance, but poorly in terms of achievement, are those objectives concerned with transferable 'life skills', as outlined in Chapter 2 (i.e Objectives S2, S3, S6, S10 and S13). It seems that none of these important skills objectives are being acquired in our classrooms in spite of the value teachers attach to them.

Although the Fisher exact values indicate that a relationship exists between perceived importance and achievement of 4 of the 15 'SKILLS' objectives (Table 12), this relationship is a negative one. The percentage frequency ratings show that for all 4 objectives, a high rating in terms of importance is coupled with a low rating for achievement.

5.2.3 Attitudinal Objectives

Table 13 THE 'ATTITUDE' OBJECTIVES: *Ranked according to frequency of high ratings attributed by respondents in terms of importance and perceived achievement.*

OBJECTIVES (An important aim of Biology teaching in the senior class is to foster in the pupil:)		IMPORTANCE % frequency & ranking	ACHIEVEMENT % frequency & ranking	
A5	a concern for conservation of the environment	100% (1)	76% (1)	*
A3	an inquiring mind	97% (2)	42% (6)	
A4	a concern for living things	97% (3)	75% (2)	*
A1	enthusiasm for learning	95% (4)	55% (3)	*
A7	an awareness of the implications of biological knowledge for human society	95% (5)	44% (5)	*
A2	sc[illegible] concern for accuracy	85% (6)	37% (7)	
A6	an awareness of the incomplete nature of our understanding of biological phenomena	85% (7)	45% (4)	*
A8	a desire to take responsibility for one's own learning	85% (8)	37% (8)	

* Significant Fisher Exact Test ($P<0,05$)

Table 13 shows that all eight attitudinal objectives were given high ratings by most respondents in terms of perceived importance (percentage frequencies of high ratings range from 100% to 85%). Out of the three categories of objectives it seems that this category scored the highest in terms of consensus of opinion. Yet only Objectives A5 and A4 (*'concern for conservation'* and *'living things* respectively) are clearly outlined in the South African core syllabus.

The data for perceived achievement of the eight attitudinal objectives again reflect a different trend to those of the perceived importance. Frequency ratings are very much lower for each one.

Those objectives scoring the highest frequency of high ratings (A5 and A4) are the two outlined in the core syllabus and were ranked 1st and 2nd in importance.

The three objectives which scored the lowest frequency of high ratings (A3, A2 and A8) are all concerned with study practices which have been described in Chapter 2 as being important for successful tertiary education in the sciences. *'Taking responsibility for one's own learning'*, a *'Questioning attitude'* and *'Some concern for accuracy'* are not only important for tertiary education but are essential life skills which should be developed in the classrooms.

Only half of the sample of respondents think that they are achieving the remaining three objectives. This indicates that a high proportion of pupils may not be developing any awareness of either the *'Implications of biological knowledge for society'* or of the *'Incomplete nature of our understanding of biological phenomena'* and that many have little *'enthusiasm for learning'*.

These objectives were described in Chapter 2 as being especially important if pupils are to become scientifically literate citizens who will be able to make appropriate choices/decisions in a technological society.

Although the Fisher's Exact Test values indicate that a relationship exists between importance and achievement of 5 of the 8 attitudinal objectives, the degree of this relationship varies greatly, as the above discussion indicates.

5.3 TEACHERS' ANALYSIS OF THE 1991 TED BIOLOGY EXAMINATION PAPER

Table 14 summarises the means and standard deviations of the examination marks (out of a possible maximum of 400) as allocated, by the teachers' sample, to each of the groups of objectives. These statistics were computed for each of the three main sections of the examination paper separately, as well as for the overall paper.
This was done in an attempt to identify any possible relationship between objectives and question types.

Mean percentages were also calculated, for each category of objectives, from the data and are shown in the form of bar graphs 1 to 4 (figure 8).

5.3.1 Knowledge objectives

Examination of the means and mean percentages reveals clearly that respondents perceive the 'Knowledge Objectives' as being, by far, the most assessed category of objectives in the 1991 examination paper. The graphs (Figure 8; p 112) show that in all three sub-sections of the paper most marks were allocated to assessment of knowledge; the percentage means for this category being: 87% overall, 89% in section A, 88% in section B and 80% in section C.

When the marks allocated to Knowledge Objectives are viewed under the two sub-categories of 'Recall' and 'Understanding' another interesting observation can be made; Respondents have allocated many more marks to the first sub-category. If the teachers' analysis can be shown to be reliable and valid, the overall validity of the 1991 Examination Paper could, in turn, be questioned. As discussed in Chapter 3, experts in the field of science assessment, such as Fairbrother (1986), reject the use of pure recall questions on the grounds that they do not measure much on their own. Their advise is to measure recall of knowledge only in an indirect manner, through questions which would also measure other objectives such as understanding and application of knowledge. It was also shown in Chapter 3 that a wide variety of question styles, assessing a variety of the syllabus objectives, was essential in order to obtain an examination paper which can act as a valid assessment tool. The respondents identification of recall of knowledge as the dominant objective being assessed in the 1991 examination support the hypothesis about this paper having low validity.

TABLE 14 MEANS AND STANDARD DEVIATIONS OF MARKS ALLOCATED TO EACH GROUP OF OBJECTIVES BY THE RESPONDING SAMPLE

CATEGORIES OF OBJECTIVES	SECTION A Short Objective Questions (100)		SECTION B Structured Questions (225)		SECTION C Essay (75)		OVERALL (400)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1. RECALL	57,3	19,9	124,8	32,7	37,6	28	219,7	69,5
2. UNDERSTANDING AND SIMPLE APPLICATION	32,1	15	72,9	23,8	22,6	24	127,6	46,4
KNOWLEDGE: (1 + 2)	89,4		197,7		60,2		347,3	
3. HIGHER ORDER COGNITIVE SKILLS	9,9	10	21,2	18,1	13,7	25	44,8	45,5
4. OTHER SKILLS	0,7	2,6	6,1	5	1,1	4,2	7,9	7,9
SKILLS: (3 + 4)	10,6		27,3		14,8		52,7	

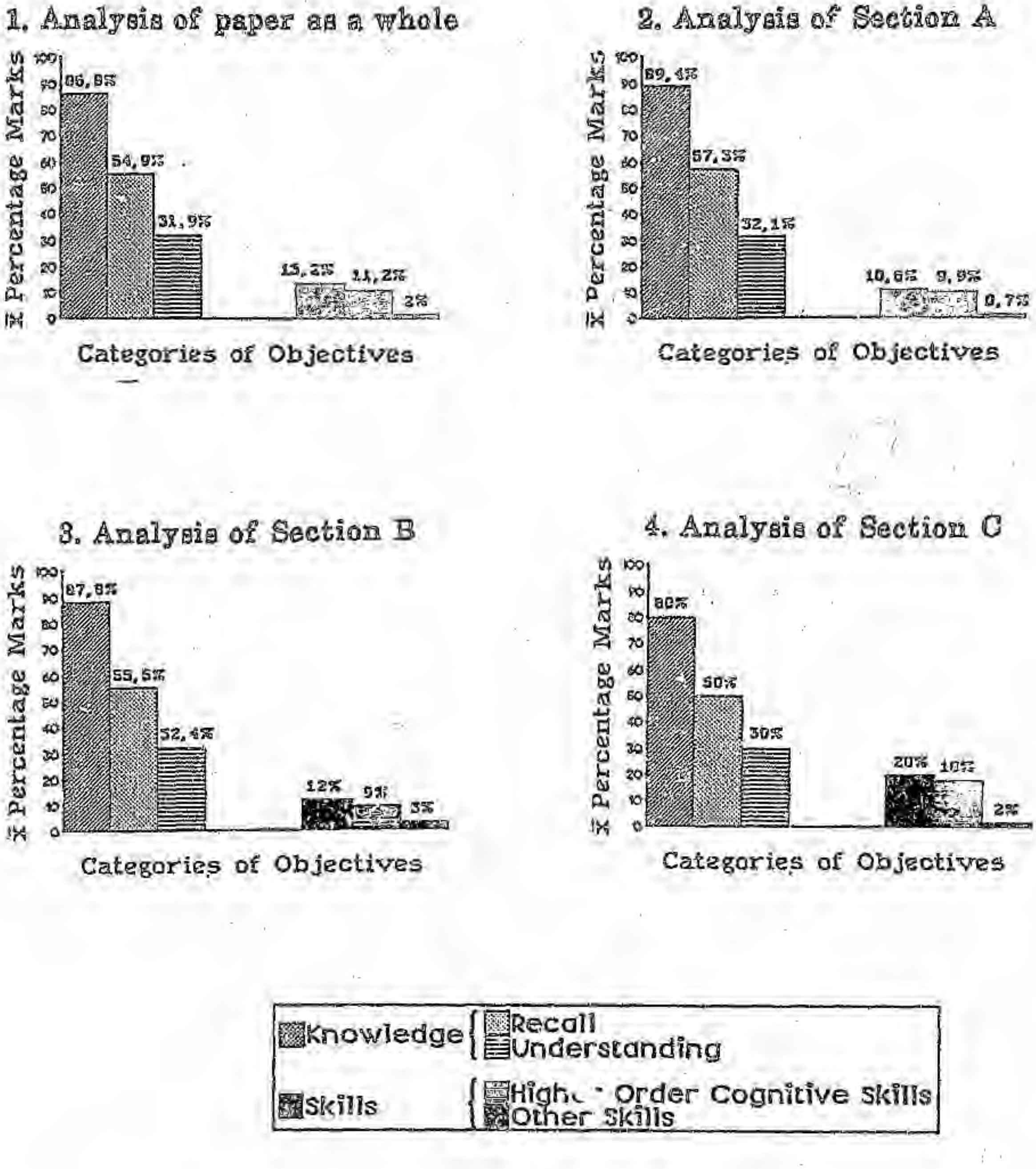

FIGURE 8 Graphs showing the mean percentages of marks allocated by respondents to the Four main categories of objectives sampled in the 1991 H.G. TED Biology Examination paper.

The high standard deviations (shown in Table 14), indicate however, that some respondents' analysis of the paper and their mark allocations differ greatly from the computed means and mean percentages. It is thus difficult to reach definite conclusions at this stage, from these data alone.

5.3.2 Skills Objectives

The marks allocated by the respondents' to the assessment of Skills Objectives, (as shown in Table 14 and in Figure 8), provide further evidence that some of the objectives stated in the core syllabus are not seen by the teachers/educators as being assessed by the 1991 examination paper. The percentage mean of 13 computed from respondents' allocation of marks to this category of objective within the paper as a whole (bar graph 1) is very much lower than the matriculation syllabus stated intention about such marks' allocation. As mentioned in Chapter 3, the core syllabus examination specifications state that approximately 40 percent of the marks should be used to assess *'Higher Order Cognitive Skills'*.

When the percentage means of marks, allocated by respondents to this category of objectives in the different subsections of the examination, is examined (graphs 2 to 4; Figure 8) the following observation can be made. Section C, i.e the essay question, was given a much higher mark allocation for Skills Objectives, (a mean of 20%) as compared to the other two subsections, (10,5% and 12% for sections A and B respectively). This observation seems to support the hypothesis made in Chapter 3 about the need to include essay questions in an examination inspite of the known marking and reliability problems associated with such open-ended questions.

The low percentage mean computed for section B of the examination is somewhat worrying. If the respondents' analysis is valid, a possible conclusion would be that some of the recommendations of assessment experts, as outlined in Chapter 3, were not followed by the examiners. Some of the suggestions made by Wood (1991) and Fairbrother (1986), who both regard structured questions as the ones most geared to the assessment of cognitive skills, have already been discussed in Chapter 3. A closer analysis of section B in terms of questions' style, coupled with a more detailed analysis of respondents' allocation of marks, might give better insight about this observation. This will be discussed further in Section 5.3.3.

The data computed for each subcategory of Skills Objectives show that most of the marks were allocated to 'Higher Cognitive Skills', as opposed to 'Other Skills'. As discussed in Chapter 3, practical or psychomotor skills cannot really be assessed through written examinations and as discussed in Chapter 2, mathematical skills , which was the most commonly identified 'Other skills,' are not outlined as objectives of the core syllabus.

Table 14 shows the standard deviations for this category as being lower than those computed for the 'Knowledge Category'. This supports the observations made in Chapter 2 about difficulties encountered in the classification of the knowledge objectives. The identification of questions measuring Higher Cognitive Skills might be an easier task for the experienced teachers who responded to this survey.

5.3.3 Analysis of Marks Allocation in Terms of Question Types

5.3.3.1 Marks allocated to Section A

Section A of the TED Examination Paper was described in Chapter 3 as consisting of either objective/coded answer items or of very short structured questions. Such questions were described by Wood (1991) and Fairbrother (1986) as being particularly suitable to measure the range of Knowledge Objectives used in this study but could also be used according to Ward (Table 9 Chapter 3, p 75) to measure a number of skill-based objectives.

Question 1A consists of 30 multiple choice questions, with a worth of 2 marks per question:-

When the teachers' analysis of individual questions, in terms of the four subcategories of objectives, is studied, the following can be seen:

Only 4 of the questions were seen as assessing higher cognitive skills by a minimum of 10 respondents; these questions seem to warrant further analysis:-

Q27 (classified by 28 respondents/ 38% of sample as measuring higher skills):-

Both carbon dioxide and water, which is released during respiration, contain oxygen. In which case is the ORIGIN of the oxygen in carbon dioxide and in water indicated correctly?

	Oxygen in carbon dioxide originates from:	*Oxygen in water originates from:*
A	*Oxygen in air*	*Carbon dioxide in air*
B	*Oxygen in air*	*Glucose in plants*
C	*Glucose in plants*	*Oxygen in air*
D	*Glucose in plants*	*Carbon dioxide in air*

Only 3 teacher trainers/educators were amongst the 28 respondents mentioned above. Moreover, some respondents commented about the obscurity and grammatical error included in this question. It is thus possible that this question could have been wrongly classified, as one measuring higher skills, simply as a result of its poor design.

Q16 (classified by 14 respondents/ 19% of sample, as measuring higher skills):-

A patient's urine reacts positively during the Biuret test/test v 'th Millon's reagent. Which condition is probably responsible for this reaction?

A *Too little insulin is secreted into the blood.*

B *Too much glucagon is formed in the blood.*

C *Proteins are present in the urine.*

D *The pancreas does not secrete essential hormones.*

None of the teacher trainers classified this question in the 'Skills' category. It was classified by most as understanding/ application of knowledge.

Q29 (classified by 12/ 16% of respondents as measuring higher skills)

Which of the following factors could possible result in a person excreting more urine than normal?

A	*A low concentration of ADH in the blood*
B	*A high reabsorption in the proximal tubules*
C	*Low blood pressure as a result of little tissue fluid*
D	*Excessive intake of salty foods*

Nine teacher trainers were amongst those who used the 'higher skills' classification. The disparity in responses of teachers and educators could probably be explained by the fact that this has been a regular question in the examination over the years...

Q17 (classified by 8/ 11% of respondents as measuring higher skills)

During which process or processes are ATP converted to ADP?

(i)	*Photolysis*	*(ii)*	*Glycolysis*	
(iii)	*Kreb's cycle*	*(iv)*	*Dark phase*	
A	*(i) and (ii)*		*B*	*(ii) and (iv)*
C	*(ii), (iii) and (iv)*		*D*	*(i), (ii), (iii) and (iv)*

Only 2 of the above were teacher trainers. This low response is somewhat surprising as the design of this question requires the use of analysis and synthesis skills .

When means are computed from the marks allocated by the respondents, to all 30 multiple choice questions, for each category of objectives (as summarised by graph 1, Figure 9, p 119), it becomes obvious that, overall, teachers believe that the multiple choice questions assess mainly knowledge, especially its recall.

Question 1B, worth 10 marks, consists of 2 flow charts and a diagram (see appendix 1). Graph 2 (Figure 9) shows that, again, respondents felt that Knowledge was the most important assessment target. They also criticised the fact that a heat exchange mechanism (diagram 3) was referred to as a metabolic process in the question. Although this criticism is totally valid, it should not have however affected pupils' responses.

Question 1C, worth 10 marks requested pupils to match pairs of statements. As shown by graph 3 (Figure 9) respondents saw this question as assessing mainly pure recall.

Question 1D, worth 10 marks was based on a simple bar graph. Graph 4 (Figure 9) shows some variance in the respondents opinion about what was being assessed. Many in fact interpreted the question as being a mixed one, assessing a variety of objectives.

Finally, **Question 1E,** worth 10 marks, and based on a food test experiment was also interpreted as assessing mainly knowledge - partly recall and partly basic application (Graph 5, Figure 9). Some respondents, however, interpreted it as an assessment of practical skills.

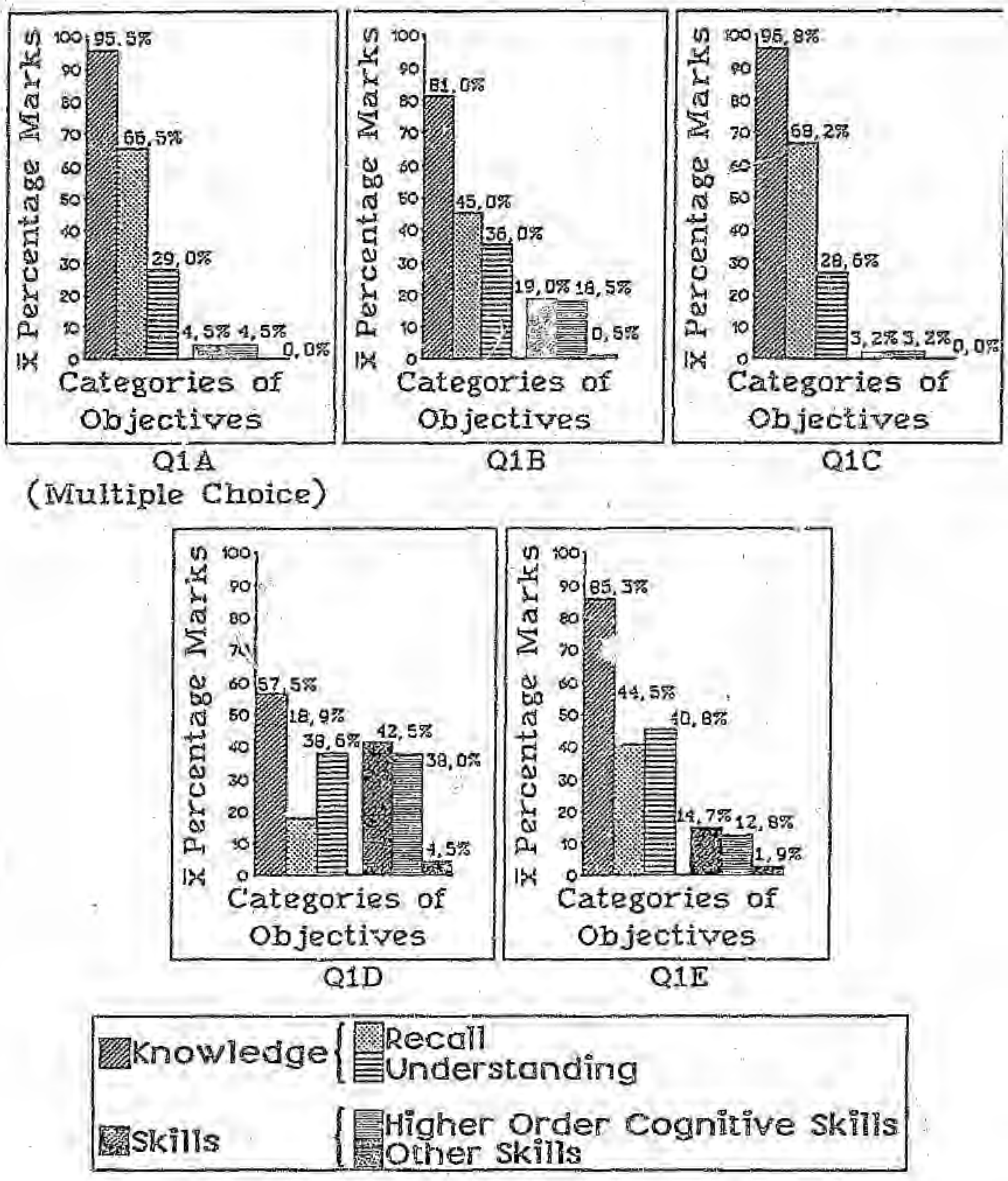

Figure 9. Graphs showing mean percentage marks allocated by respondents to each of the 4 objectives' categories for the subsections of SECTION A, (Q1A to Q1E), of the 1991 TED Higher Grade Biology examination.

5.3.3.2 Marks allocated to section B.

Figure 10 (Graphs 1 to 3) summarises the means for each category of objectives, for each of questions 2 to 4. These were calculated from the marks allocation of the respondents. As already mentioned above, the graphs show clearly that according to the respondents, very few marks were devoted to the assessment of higher skills in this section inspite of the feasibility of such a task (as shown in Chapter 3).

Both Questions 2 and 3, (Appendix 1), were classified, by the majority, as measuring mainly 'Recall'. They, in fact, consist of a succession of fairly 'disjointed' sub-questions, as each question tests 'little bits of unrelated knowledge', totally out of any specific context. According to Fairbrother (1986), this is a clear sign of poor assessment. Many of the questions start with definite recall command words, such as 'state', 'name', 'tabulate', 'list', 'give' and 'draw'. Little attempt seems to have been made to challenge the students in both of these questions. The respondents marks allocation seems to be totally justified in terms of this analysis of question-types.

Question 4 (Appendix 1), as compared to the above, was seen by the respondents as measuring a greater variety of objectives. As shown by graph 3 (figure 10):- Understanding and Application of Knowledge, Higher Cognitive and Other Skills, were all identified by respondents, in addition to recall.

The fact that some of the questions were set on a graph, which pupils had to draw and interpret support the identification of this question as one which tests Higher Skills.

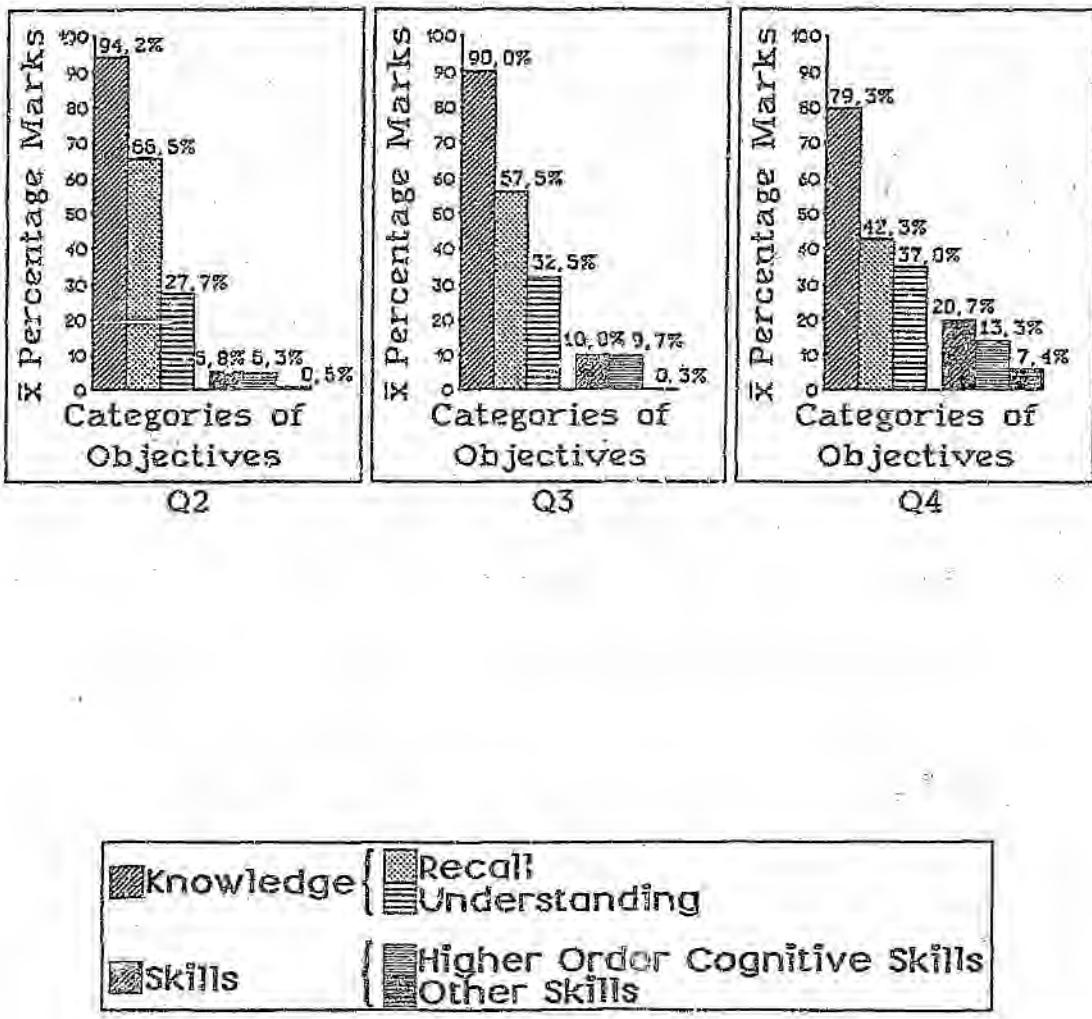

Figure 10. Graphs showing mean percentage marks allocated by respondents to each of the 4 objective categories for the individual questions, (Q2 to Q4), SECTION B of the 1991 TED Higher Grade Biology Examination.

Note, Section C requires no further analysis as the questions have already been discussed (5.3.2).

5.4 DIFFERENCES IN RESPONSES OF THE VARIOUS SUBGROUPS OF THE SAMPLE OF RESPONDENTS.

The results of the various one-way analyses of variance performed on the data will be summarised in tables 15 to 18 and will be discussed briefly according to each of the independent variable used in the analysis, for each part of the questionnaire:-

5.4.1 Differences in Responses to Part I of the Questionnaire

5.4.1.1 Independent variable:- Employers.

The three subgroups in this category were (1) these teachers employed by the state, (2) teachers employed by private schools and (3) teacher educators employed by various tertiary institutions.

As shown in Table 15 (p124), *no significant differences* were obtained when responses of the two teachers' groups were compared. State and Private school teachers seem to share similar views about the importance of the various teaching objectives and about their achievement in the class-room. Any conclusion, about the worth of pupils being taught in a private, versus state school, biology class room, would however be premature as the small and different sizes of the subsamples do not allow an objective analysis.

The only *significant difference*, shown by table 15, occurs between the responses of Tertiary Educators and those of the two groups of teachers in terms of the *Importance of the Knowledge Objectives*. There was better agreement between tertiary educators about the desirability of emphasising only the general principles of the subject than there was amongst the teachers. As already discussed, many teachers saw both the general principles and the knowledge of specific details as being important. Educators also put greater emphasis on knowledge of related subjects as compared to teachers. They are perhaps more aware of the problems of teaching biology at tertiary level without some knowledge of the other sciences, than teachers are.

5.4.1.2 Independent Variable: Examination Board

The subgroups of this category were (1) teachers preparing candidates for the Natal Senior Certificate, (2) teachers preparing candidates for the Transvaal Senior Certificate and (3) Tertiary educators who are not directly involved with the teaching of matriculants. A fourth group, teachers preparing pupils for the JMB examination Board was not included in the analysis as, probably due to the fact that this board was running its last examination in 1992, very few responses were received from them.

Table 15: Results of 1-way analysis of variance with employers as independant variables and ratings given to objectives as dependent variables (df = 2;70).

	DEPENDENT VARIABLES	F	Prob
1.	Differences between importance and achievement ratings for objectives about:-		
a)	KNOWLEDGE	0,37	0,6888
b)	SKILLS	0,22	0,8040
c)	ATTITUDES	0,43	0,6495
2.	Total ratings for importance of objectives about:-		
a)	KNOWLEDGE	3.82	0,0267*
b)	SKILLS	0,07	0,9310
c)	ATTITUDES	1,23	0,2999
3.	Total ratings for achievement of objectives about:-		
a)	KNOWLEDGE	1,43	0,2462
b)	SKILLS	0,22	0,8007
c)	ATTITUDES	0,01	0,9932

* Significant $P < 0,05$

Table 16: Results of 1-way analysis of variance with matriculation boards as independent variables and ratings of objectives as dependent variables (df = 2;67).

	DEPENDENT VARIABLES	F	Prop
1.	Differences between importance and achievement ratings for objectives about:-		
a)	KNOWLEDGE	0,19	0,6888
b)	SKILLS	1,01	0,8040
c)	ATTITUDES	1,45	0,6495
2.	Total ratings for importance of objectives about:-		
a)	KNOWLEDGE	4,06	0,0217*
b)	SKILLS	4,80	0,0113*
c)	ATTITUDES	2,85	0,0651
3.	Total ratings for achievement of objectives about:-		
a)	KNOWLEDGE	2,22	0,1160
b)	SKILLS	0,35	0,7068
c)	ATTITUDES	2,64	0,0787

* Significant $P<0,05$

Table 16, (p 125), shows two significant differences in responses of this subgroup:-

(i) When ratings of the *Importance of Knowledge Objectives* are compared the views of the Tertiary educators differ from those of the two groups of teachers. This is consistent with the results of the previous analysis of variance as discussed above.

(ii) On the other hand, the analysis of the data about the *Importance of the Skills Objectives* reveal that the views of the *Transvaal Teachers* are different to those of the Natal teachers. This latter group, however, shares the views of the Tertiary Educators.

5.4.2 Differences in Responses to Part 2 of the Questionnaire

5.4.2.1 Independent Variable : Employers

When the responses of the subgroups, (same ones as in 5.4.1), to part 2 of the questionnaire, were compared the only significant differences were in the marks allocated to Questions B1 to E1. Table 17 reveals that although there is no significant differences in the marks allocated to question 1 as a whole in the short objective questions B1 to E1 significant differences exist between allocations of tertiary educators as opposed to those of teachers from both state and private schools. Tertiary educators allocated fewer marks to recall as compared to teachers. This could be a result of the teacher's better knowledge of the syllabus.

On the other hand the *State School Teachers* allocated more marks to *Understanding and Application of Knowledge* as compared to the other two groups.

Lastly, Table 17 (p 128) shows a difference in marks allocated to section B of the examination under the heading *Other Skills* to be nearly significant. The two groups of teachers gave more marks to this category of objectives as compared to the tertiary educators. This could perhaps be attributed to the misconception of classifying knowledge of experiments under practical/other skills instead of recall as shown by a number of questionnaires.

Table 17: Results of 1-way analysis of variance with EMPLOYERS as independent variable and marks allocated to objective categories (in 1991 paper) as dependent variables (df = 2;70).

DEPENDENT VARIABLES		F	Prob
1.	Q 1A Multiple Choice Questions		
a)	Recall of knowledge	0,62	0,5412
b)	Understanding of knowledge	0,70	0,5008
c)	Higher cognitive skills	0,12	0,8902
2.	Q 1B to Q 1E. Short/Coded Answers Questions		
a)	Recall of knowledge	3,91	0,0245*
b)	Understanding of knowledge	3,76	0,0282*
c)	Higher cognitive skills	1,91	0,1557
d)	Other skills	1,17	0,3178
3.	Q 1A to Q 1E		
a)	Recall of knowledge	2,11	0,1292
b)	Understanding of knowledge	2,12	0,1276
c)	Higher cognitive skills	1,19	0,3093
d)	Other skills	1,17	0,3178
4.	SECTION B - (structured questions)		
a)	Recall of knowledge	0,98	0,3787
b)	Understanding of knowledge	0,21	0,8123
c)	Higher cognitive skills	1,14	0,3272
d)	Other skills	3,07	0,0528
5.	SECTION C - Essay		
a)	Recall of knowledge	1,79	0,1742
b)	Understanding of knowledge	1,39	0,2564
c)	Higher order cognitive skills	0,48	0,6202
d)	Other skills	0,84	0,4357
6.	TOTAL		
a)	Recall of knowledge	1,77	0,1784
b)	Understanding of knowledge	0,92	0,4120
c)	Higher order cognitive skills	0,89	0,4162
d)	Other skills	1,94	0,1515

* Significant $P<0,05$

5.4.2.2 **Independent Variable: Examination Boards**

Table 18, (p 130), shows four significant results for the analysis of variance of marks allocated by the three subgroups of this category (same as in 5.4.1.2, above).

The analysis of variance and Duncan Grouping test show a significant difference between data allocated to *Recall of Knowledge within the Whole Paper* by the *Transvaal Teachers* as compared to the other two groups. A lower proportion of the marks were given to this subcategory of objectives by the former group, as compared to the *Natal Teachers* and *Tertiary Educators*.

The above is repeated when *Recall* is analysed for each of *Section A* and *Section B* of the paper on their own.

Finally significant differences are shown between marks allocated to the subcategory *Understanding of Knowledge* when the marks allocated to the *Multiple Choice Questions* were considered on their own. There the *Natal Teachers gave lower scores to the category* as compared to the other two groups.

Table 18: Results of 1-way analysis of variance with matriculation board as independent variable and marks allocated to objective categories (1991 paper) as dependent variables (df = 2;67).

	DEPENDENT VARIABLES	F	Prob
1.	Q 1A Multiple Choice Questions		
a)	Recall of knowledge	3,11	0,0513
b)	Understanding of knowledge	2,94	0,0595
c)	Higher cognitive skills	1,8	0,1732
2.	Q 1B to Q 1E. Short/Coded Answers Questions		
a)	Recall of knowledge	4,09	0,0211*
b)	Understanding of knowledge	1,29	0,2568
c)	Higher cognitive skills	1,19	0,3106
d)	Other skills	2,64	0,0785
3.	Q 1A to Q 1E		
a)	Recall of knowledge	4,01	0,0226*
b)	Understanding of knowledge	1,8	0,1734
c)	Higher cognitive skills	2,04	0,1379
d)	Other skills	2,64	0,0785
4.	SECTION B - (structured questions)		
a)	Recall of knowledge	3,65	0,0313*
b)	Understanding of knowledge	1,24	0,2959
c)	Higher cognitive skills	3,07	0,0531
d)	Other skills	1,17	0,3164
5.	SECTION C - Essay		
a)	Recall of knowledge	1,42	0,2494
b)	Understanding of knowledge	0,09	0,9140
c)	Higher order cognitive skills	2,00	0,1438
d)	Other skills	0,43	0,6503
6.	TOTAL		
a)	Recall of knowledge	3,69	0,0301*
b)	Understanding of knowledge	1,25	0,2941
c)	Higher order cognitive skills	3,03	0,0549
d)	Other skills	0,41	0,6679

* Significant difference at $P<0,05$

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The purpose of this study, as set out in Chapter One, was to evaluate the impact of the Transvaal Senior Certificate Examination on the teaching of Biology at a Senior Level. The main findings of this impact were reported and discussed, in the preceding chapter.

In this last chapter, the findings outlined in Chapter 5 will be used to draw conclusions about the reality and seriousness of the problem facing our education system. Finally, alternatives, as surveyed in the literature, will be considered in order to offer some practical solutions.

6.2 INTERPRETATION OF THE RESULTS

In Chapter One, four broad research questions were formulated and used as basis for the study. These questions will be used again in interpreting the results reported in Chapter 5, in an attempt to produce a clear picture of the situation before looking at alternatives.

> **RESEARCH QUESTION 1:-**
> *Which Goals/Objectives do our Current High School Biology Teachers Value as being Important for Effective Biology Education? How do their opinions compare with the findings of the literature review?*

The mean percentage frequency of high ratings calculated from individual ratings of respondents both for the entire sample and its subgroups (*Section 5.2 of Ch 5*) show clearly that respondents were generally well aware of modern trends and methodologies in the field of Biology Education, (as discussed in Chapter 2).

The importance of selecting objectives which reflect the nature of Biology, as well as the needs of both pupils and contemporary society, has been outlined in this chapter. When objectives were compiled according to these determinants (with reference to some of the schemes used by overseas countries which are well-known for their effective Biology Education), respondents attributed high ratings to twenty six of the thirty one listed, desirable objectives. This is quite remarkable in view of the fact that many such objectives are not mentioned at all, or are only briefly stated in an obscure way, in the South African Biology Core Syllabus. None of the objectives which reflected outdated methodologies or trends were rated highly by respondents.

Of those objectives identified as being desirable by the literature but not given high rankings by the majority of respondents, three were concerned with 'Knowledge of the subject' and one with 'Desirable skills', none with 'Desirable attitudes'. Two of the 'Knowledge Objectives' were concerned with the importance of acquiring understanding of knowledge from other disciplines which are related to Biology. The third Knowledge Objective emphasised the importance of understanding the work and main contributions scientists/researchers have made to the subject. Whereas the first two objectives are not reflected in the national core syllabus, the third one is. However none of these objectives are being assessed in any of the local, external examinations - as shown by past examination papers from all ten existing Examination Boards. This could perhaps be explained by the fact that the teachers surveyed were not aware enough of the desirability of meeting these objectives through their current teaching. On the other hand, compartmentalisation of knowledge is part of the South African present school curriculum which favours the teaching of specific content by specific specialist teachers from a very early stage in the pupils' school career.

As opposed to many countries overseas, so far little attempt has been made at subjects integration and thematic teaching approaches. The skill objective rated lowest in terms of importance was concerned with the desirability of pupils undertaking some sort of independent, investigative, problem solving, study during their course. Again this low rating could perhaps be attributed to the fact that such a study is not emphasised by the current syllabus which in fact places little emphasis on investigative practical work. Of the ten South African Examination Boards, only three include a practical component of some sort in their matriculation assessment. The Transvaal Senior Certificate is one of the examining boards which does not assess practical work.

RESEARCH QUESTION 2:-

How successful do teachers believe they are in achieving the various objectives, identified as important, through their current teaching?

When teachers were asked to give ratings to those objectives identified as important in terms of what they believe they were actually achieving in the class room, a very different pattern to the one discussed above, emerged. Even a cursory examination of the allocated ratings showed that a great mismatch existed between perceived importance and perceived achievements of these teaching objectives. This mismatch was confirmed by the low correlations obtained when the Pearson Product Moment Correlations were computed for each of the categories of objectives (*Section 5.1 in Ch 5*). Whereas low, positive correlations were obtained for each of the 'Knowledge' and 'Attitude' groups of objectives, a negative correlation was shown for the 'Skill' category.

This result is definitely a cause for concern, especial. in the light of recent demands from industry for an 'employable produc. with skills and usable competencies' from schools (Rian, 1993 : 45). The extent of the problem is emphasised in the last World Competitiveness Report (1993) which ranks South Africa 14th in a 15-way comparison of emerging industrial economies for the adequacy of the education system in meeting the needs of a competitive economy.

The fact that this research was carried out in some of our most affluent schools confirms that the causes of the problem is not one of teacher calibre or of teaching facilities. Something must be stopping Biology Teachers from achieving those objectives they identify as important for effective education. Could the root of the problem lie in our Biology Curriculum itself? It was pointed out in Chapter one that the curriculum. especially in the senior high school, is examination-driven. Data provided by the teachers analysis of the Biology Higher Grade 1991 TED paper (as discussed in Chapter 5), offer some indirect evidence about the impact of this examination on teaching methodologies and outcomes. The third research question focused on the nature of this examination.

RESEARCH QUESTION 3:-

Which objectives are seen by teachers as being assessed by the Transvaal Senior Certificate and to what extent do they believe that such objectives are assessed?

Table 14 and Figure 8 (in Chapter 5) show overwhelming consensus amongst the respondents about which objectives were being assessed in the 1991 paper. A limited range of objectives focusing mainly on recall and simple application of knowledge, were identified. Only a very small proportion of the questions was identified as attempts at assessing higher cognitive skills.

The initial discussion of these results included the possible effect of question style on the nature of the examination. It was shown that in agreement with recommendation of experts on assessment (outlined in Chapter 3), a variety of question styles were used in the examination. However, these questions failed to focus on the variety of objectives set out in the matric syllabus, although they could have been used reliably for this purpose. The various examples collected under Appendix 2 show that most of the objectives identified as important for effective Biology teaching are in fact measurable. It seems that the TED examination paper sacrificed validity for the sake of greater reliability, and that Fairbrother's advice (1988 : 3) about achieving some kind of 'balancing act' between these two main criteria of good assessment, was largely ignored by the examiners.

RESEARCH QUESTION 4:-

How competent are teachers in their analysis of questions and in their identification of objectives being assessed? Is there a difference in the views of the different subgroups of the teachers' sample who took part in this study?

The various one-way analyses of variance performed on teachers' responses to both parts of the questionnaire showed clearly that little difference occurred amongst the various subgroups. The results indicate that there is strong consensus regarding what the examination measures.

There is total agreement that skills are neither measured by the examination nor taught in the classrooms. No difference could be shown in views of the various subgroups about the identification of those objectives which are important for the effective teaching of high school Biology. There was however some difference about objectives teachers believe they are achieving and about classifying Knowledge Objectives as recall or application. The fact that in those cases the views of Transvaal teachers were different to those of either the Natal teachers or of the tertiary educators, could imply that Natal teachers have some advantages over their Transvaal colleagues. The source of this discrepancy could, for example, be a result of greater contact/ cooperation between tertiary educators and teachers or, alternatively, it could be due to a better examination system. The fact that Natal teachers chose to respond quickly and spontaneously to this research questionnaire (whereas their Transvaal counterparts had to be pushed and co-erced to do so) may be an indication of the greater enthusiasm on their side.

Finally, the lack of difference between the views of teachers and tertiary educators indicates that the teachers' analysis can be trusted as being quite reliable and that teachers have a good understanding of assessment.

6.3 CONCLUSIONS AND IMPLICATIONS

The main findings of this research are as follows:-

* Biology teachers are generally aware of modern trends and methods in the field of Biology Education. There is a close match between their views and those of leading Biology Educators locally and overseas.

* Teachers are in general not confident about achieving many of the important objectives during their current teaching. Skill-based objectives are those perceived as being least achieved.

* The TED Higher Grade Biology Examination is seen by both teachers and tertiary educators, as assessing a very limited range of teaching objectives - mainly Knowledge of objectives. A very small proportion of the paper is seen as assessing higher cognitive skills.

* Little difference exists between the responses of the various sub-groups of respondents. Whenever significant variance was found however, the views of Natal teachers were similar to those of Tertiary Educators but different from those of the Transvaal teachers.

The main implications of the above conclusions are that they support the initial hypothesis about the poor validity of the TED H.G Biology examination. Moreover, the examinations could be having a negative impact on the teaching of Biology at senior level in Transvaal schools. And to make matters worse, the fact that Natal teachers' views about achieving identified and important objectives do not differ from the views of the Transvaal teachers, could also imply that this negative impact could well apply not only to the Transvaal and to its examination, but to the country as a whole.

6.4 RECOMMENDATIONS

Recommendation 1:-

It is strongly recommended that a deliberate attempt be made to provide better assessment of the teaching of high school Biology - particularly better Matriculation Examinations - at a National level.

This study, in agreement with the research literature confirms that the current examinations suffers from major drawbacks. In order to limit their negative influences on class-room practices, it would be advisable to draw from the experiences of countries known to have made the best of their matriculation assessment - such as Israel and the United Kingdom - while considering local conditions and restrictions. From the research literature three main aspects of Biology Assessment will require attention in order to improve the present system:-

1. Different modes of assessment must be used in order to do justice to the variety of objectives of Biology teaching. Some form of assessment of practical skills are highly recommended in the Transvaal.

2. A greater variety of question styles including more open-ended questions must be included in the theoretical examination. Assessment of pure recall should be eradicated and replaced by assessment of understanding of knowledge and of all the numerous skill-based objectives which have been identified as important.

3. More valid and imaginative internal assessment by teachers should become components of the matric assessment plan. This would not only remove most of the negative impact of what Ward called 'the once-for-all affair' of terminal external assessment, but would provide better, truly valid, overall evaluation of a candidate's worth. A number of objectives, especially attitudinal ones, can only be assessed through alternative internal assessment procedures. Project work has been described in Chapter 3 as being particularly suitable for this purpose.

Recommendation 2:-

Teachers, being the link between the exam-users and certification, should be actively involved in reshaping the curriculum and in setting and marking the examinations.

The new Independent Examination Board (IEB) is leading the way with its 'User Group System'. For the first time in South-Africa, teachers have been asked what and how they want to teach and how they want their pupils to be assessed. O of the mission statements of the IEB (1993) is the demystification of the examinations, which it plans to achieve by having open communication channels between appointed examiners and the user-teachers. The names of examiners would be published and both prior to and after the examinations, the user group could meet with the latter to exchange feedback. By involving teachers in syllabus and curriculum designs, in the marking of examinations and in the organisation of workshops for user groups, the IEB has opened the door to teachers - the latter at last have a say regarding their teaching and its assessment. It is imperative that other examining bodies follow a similar system, if matriculation is to be used to drive the curriculum into the 'right direction'.

Recommendation 3:-

The universities should reconsider their selection and admission criteria in order to minimise the negative effects matriculation has on class-room practices.

Although it is not possible for universities to run their own admission examinations, both because of the financial implications and of the extra pressure such examinations would put on prospective students, they should look at alternative methods for students selection. For example, pupils' record cards over the senior school years and teacher evaluations could be used. Research has shown consistently that in South Africa, matriculation is not a valid selection tool of students for universities. It is time that universities do something about their so-called 'point system' in order to provide a fair and more effective selection process.

Recommendation 4:-

Universities must also look at alternative and better methods of pre- and in-service training of teachers in order to empower teachers to become effective assessors and evaluators.

Research has shown that only teachers can make a difference to curriculum practices. Unless South African teachers become sufficiently trained to take responsibility for the assessment of their pupils, the external examination will remain the sole selection tool available to universities and employers.

6.5 FINAL CONCLUSIONS

Biology is one of the most popular science courses selected by the majority of pupils as a matriculation subject (HSRC Report: 1980). Many of these pupils, as shown by Watson (1990:50), will not continue with tertiary education. It is thus appropriate for school Biology to offer a broad curriculum in order for pupils to acquire not only Biological Knowledge but also important Skills and Attitudes which will become transferrable and useful in their future careers. The objectives of the current Biology Syllabus cover all these aspects but, as shown by this survey, they are not viewed by teachers as being the objectives of the matriculation examination itself. As emphasised above, the teachers surveyed admit that they are not achieving the majority of these objectives through their current teaching.

Listing syllabus objectives and hoping that they will happen in the classroom is not enough - the implementation of these objectives must also be enforced. As in Israel, the power of examination and certification must be used in South Africa to ensure that this takes place. The external written examination on its own has been shown to be unreliable in measuring all the objectives that are known to be important for effective Biology teaching. It seems appropriate to call for a more diversified assessment plan, of which the written, externally-marked examination, will remain an integral part. This will demand greater effort on the part of Examination Boards, Teachers and Teacher-trainers but as Isaac (1990: 355) points out:-

> *"Assessment is too important in the lives of students, in the work of teachers and in fulfilment of the social responsibility... to allow anything less then the best that is available."*

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APPENDIX 1.

THE RESEARCH QUESTIONNAIRE.

MSc EDUCATION RESEARCH PROJECT

WITS UNIVERSITY

A Questionnaire designed to collate and evaluate the views of practising teachers about :

Teaching Objectives for, and Assessment of, Higher Grade Matric Biology

PART 1 : BIOGRAPHICAL DETAILS

INSTRUCTIONS :

Put an 'X' in the appropriate block, to indicate the correct information.

1. SEX

Male	
Female	

2. AGE GROUP

Below 30	
30 - 40	
Over 40	

3. YEARS OF TEACHING EXPERIENCE : (GENERAL)

Less than 5 years	
5 - 10 years	
More than 10 years	

4. YEARS OF EXPERIENCE AS A MATRIC BIOLOGY TEACHER

Less than 5 years	
5 - 10 years	
More than 10 years	

5. TYPE OF SCHOOL IN WHICH YOU ARE PRESENTLY TEACHING

State School	
Private School	

6. TYPE OF MATRICULATION EXAMINATION WRITTEN AT YOUR SCHOOL

T E D		
N E D		
J M B		Specify:
Others		

PART 2 : OBJECTIVES FOR EFFECTIVE BIOLOGY TEACHING AND THEIR ACHIEVEMENT IN THE CLASS ROOM

INSTRUCTIONS :

Read each of the following statements carefully before placing an 'X' in the appropriate block under Columns A and B.

GOAL / OBJECTIVE	COLUMN A: To what extent do you consider this goal/ objective to be important?					COLUMN B: To what extent do you believe that you are currently achieving this goal/ objective				
	5	4	3	2	1	5	4	3	2	1
<u>ABOUT KNOWLEDGE</u> At the end of matric, a Higher Grade Student should										
K1 know the <u>basic terminology</u> used in the biological sciences										
K2 have acquired a <u>detailed knowledge</u> of the structure of a <u>few</u> living organisms										
K3 have acquired a <u>thorough knowledge</u> of the physiology of a <u>few</u> living organisms										
K4 know <u>fundamental</u> biological principles										
K5 have become familiar with the <u>current</u> understanding of the nature of life processes										
K6 have acquired <u>some knowledge</u> of a <u>wide range</u> of living things										
K7 be able to <u>link the components</u> of the course into a coherent body of knowledge										
K8 become aware of <u>patterns</u> and relationships within the living world										

	COLUMN A					COLUMN B				
	To what extent do you consider this goal/ objective to be important?					To what extent do you believe that you are currently achieving this goal/ objective				
GOAL / OBJECTIVE	5	4	3	2	1	5	4	3	2	1
K9 understand contributions scientists have made to the subject										
K10 understand some of the applications of biological knowledge										
K11 be acquainted with some of the principles of related subjects										
K12 understand some of the applications of such related disciples										
ABOUT SKILLS Biology teaching on the Higher Grade should enable the pupil to :										
S1 use biological information to analyse unfamiliar situations										
S2 develop ideas creatively										
S3 carry out instructions										
S4 use manipulative skills useful for biological investigations										
S5 observe biological material accurately										
S6 produce meaningful records of observations										
S7 construct hypothesis about observed biological problems										

GOAL / OBJECTIVE	COLUMN A: To what extent do you consider this goal/ objective to be important? 5	4	3	2	1	COLUMN B: To what extent do you believe that you are currently achieving this goal/ objective 5	4	3	2	1
S8 design experiments to test hypotheses										
S9 make inferences from evidence										
S10 communicate information by a variety of means										
S11 be able to interpret given information										
S12 analyse quantative data										
S13 obtain information efficiently from texts										
S14 be better equipped to gain a livelihood as a result of having studied biology										
S15 undertake an independent investigative study to solve a biological problem										
ABOUT ATTITUDES An important aim of biology teaching in the senior classes is to foster in the pupil:										
A1 enthusiasm for learning										
A2 scholarly concern for accuracy										
A3 an inquiring mind										
A4 a concern for living things										

	GOAL / OBJECTIVE	COLUMN A: To what extent do you consider this goal/ objective to be important?					COLUMN B: To what extent do you believe that you are currently achieving this goal/ objective				
		5	4	3	2	1	5	4	3	2	
A5	a concern for conservation of the environment										
A6	an awareness of the incomplete nature of our understanding of biological phenomena										
A7	an awareness of the implications of biological knowledge for human society										
A8	a desire to take responsibility for one's own learning										

PART 3 : ANALYSIS OF THE TED SENIOR CERTIFICATE, HIGHER GRADE, BIOLOGY EXAMINATION IN TERMS OF OBJECTIVES MEASURED

INSTRUCTIONS :

The various objectives listed in Part II above have been grouped into 4 broad categories:

1 - RECALL OF KNOWLEDGE

This refers to the ability to remember previously learnt material. It may involve the recall of specific facts , complete theories, generalisations, patterns, etc. It is nothing more than the exact reproduction of learnt material.

2 - UNDERSTANDING
AND SIMPLE
APPLICATION OF KNOWLEDGE

The ability to translate and interpret learnt material and the ability to apply knowledge to new situations, especially for simple problem solving.

3 - HIGHER ORDER COGNITIVE SKILLS

These involve three main abilities:

3.1 The ability to analyse, i.e. to break up informmation or a communication into its constituent elements and recognise the relationships and structure of these elements.

3.2 The ability to synthesise, i.e. to reorganise facts and ideas in such a way that they constitute a pattern or structure which was not clearly there beforehand.

3.3 The ability to evaluate, i.e to judge the value of the material for a given purpose, using definite criteria.

4 - OTHER SKILLS

These involve any skills not already described above such as mathematical skills- the ability to use/ compute/ graph numerical data or manipulative, practical skills.

* Decide which objective/s is/are being assessed by each question and write the allocated marks in the correct block. (Note: If you believe that a question is assessing more than one objective, divide the allocated marks accordingly).

* If you use the category 'Other Skills' please indicate the specific skills, you think is being assessed.

BIOLOGY HIGHER GRADE

HG 27

TRANSVAAL EDUCATION DEPARTMENT

SENIOR CERTIFICATE EXAMINATION NOVEMBER 1991

TIME: Three hours

REQUIREMENTS: Answer sheet TED 136

SECTION A: Answer ALL the questions.
SECTION B: Answer ALL the questions.
SECTION C: Answer any ONE of the questions.

SECTION A

Answer Question 1A on the ANSWER SHEET TED 136.

Write your examination number on the ANSWER SHEET and place it inside the front cover of your ANSWER BOOK.

QUESTION 1A

Various possibilities are given as answers to the following questions. Indicate the correct answer with a cross over the appropriate letter on the ANSWER SHEET.

EXAMPLE: Saliva is secreted into the

A mouth.
B oesophagus.
C stomach.
D duodenum.

ANSWER:

~~A~~	B	C	D

1. The molecule most often used by animals as a long term source of energy is

A glycogen.
B fat.
C starch.
D glucagon.

2. Bile has a pH of approximately

A 6.
B 6,5.
C 7.
D 8.

3. Which one of the following is NOT a by-product of respiration in plants?

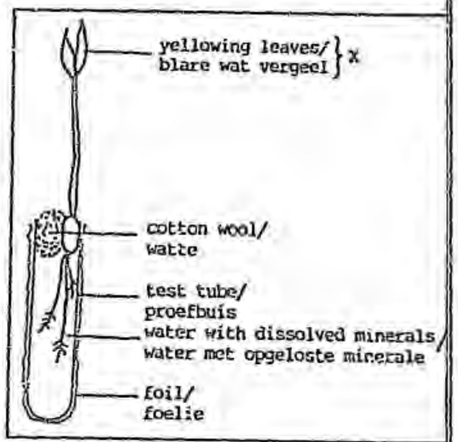
A Water
B Oxygen
C Ca.bon dioxide
D Alcohol

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

4. The respiratory centre in the brain is most sensitive to change in

A ATP levels in the mitochondria.
B glucose levels in the blood.
C the carbon dioxide concentration of the blood.
D the oxygen concentration of the tissue fluid.

Questions 5, 6 and 7 are based on the accompanying diagram of a water culture experiment.



5. Adding an additional amount of which mineral could prevent the condition of the leaves at X?

A Calcium B Phosphorus
C Sodium D Magnesium

6. This plant needs dissolved nitrogen and sulphur for the synthesis of

A cell walls. B enzymes.
C co-enzymes. D chlorophyll.

7. The minerals mentioned in question 5 are chiefly made available to the plant by means of

A adhesion. B osmosis.
C active uptake. D diffusion.

Questions 8 and 9 are based on the following food sources in a diet: dairy products, fish oils and egg yolk

8. These food sources are especially rich in

A Vitamin B. B Vitamin D.
C Vitamin E. D Vitamin K.

9. Which deficiency could possibly result from a diet which is lacking in these foods?

A Night blindness B Profuse bleeding
C Beri-beri D Rickets

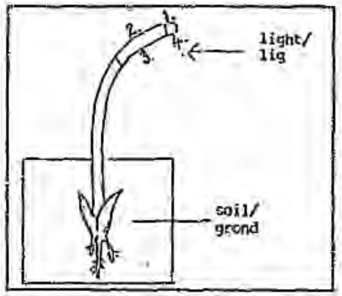
10. Which of the following structures are directly involved in the process of osmoregulation in the earthworm?

(i) coelom (ii) blood capillaries
(iii) nephrostome (iv) urethra

A (i) and (ii) B (i) and (iii)
C (i), (ii) and (iii) D (i), (ii), (iii) and (iv)

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

Question 11 is based on the accompanying diagram.



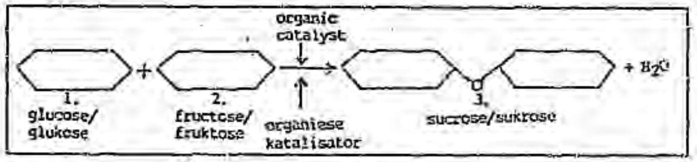
11. The concentration of growth hormone will be the highest at number

A 1. B 2.
C 3. D 4.

12. Which two other factors, together with root pressure, could cause guttation?

A high humidity; high light intensity
B low light intensity; high air temperature
C low light intensity; high humidity
D low air temperature; low air circulation

Questions 13, 14 and 15 are based on the accompanying diagram.



13. The reaction represented here is known as

A hydrolysis.
B denaturing/denaturisation.
C glycolysis.
D dehydration synthesis/condensation.

14. In which structure would this reaction occur in the opposite direction?

A Chloroplast B Mitochondrion
C Mouth D Small intestine

15. If the fructose molecule (no. 2) were to be replaced by a glucose molecule, no. 3 would be a ___ molecule.

A ribose B maltose
C lactose D cellulose

16. A patient's urine reacts positively during the Biuret test/test with Millon's reagent. Which condition is probably responsible for this reaction?

A Too little insulin is secreted into the blood.
B Too much glucagon is formed in the blood.
C Proteins are present in the urine.
D The pancreas does not secrete the essential hormones.

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

17. During which process or processes are ATP converted to ADP?

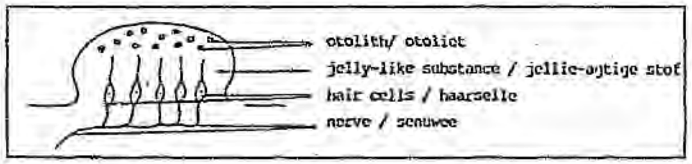
(i) Photolysis
(ii) Glycolysis
(iii) Krebs's cycle
(iv) Dark phase

A (i) and (ii)
B (ii) and (iv)
C (ii), (iii) and (iv)
D (i), (ii), (iii) and (iv)

18. The consciousness of balance originates in the

A semicircular canals.
B cerebrum.
C cerebellum.
D sacculus and utriculus.

Questions 19 and 20 are based on the accompanying diagram of a macula.



19 To what stimulus is this receptor sensitive?

A Smells in gaseous form
B Position of the head
C The tonus in muscles and joints
D Tastes in dissolved form

20. In which part of the human body are these receptors found? In

A the mucous membrane of the upper turbinate bones.
B the utriculus and sacculus of the inner ear.
C the ampullae of the semicircular canals.
D a V-shape on the back of the tongue.

21. Which of the following are absorbed by the walls of the colon?

(i) water
(ii) some vitamins
(iii) soluble mineral salts

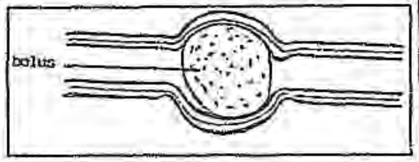
A Only (i)
B (i) and (ii)
C (i) and (iii)
D (i), (ii) and (iii)

22. The grey matter in the brain and spinal cord consists mainly of

A cell bodies of neurons.
B myelin sheaths.
C Schwann cells with nuclei.
D axons.

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

Questions 23 and 24 are based on the accompanying diagram of a longitudinal section of a part of the human digestive tract.



23. The reflex centre for the control of the movement which is carried out here is the

A hypophysis (pituitary gland).
B autonomic nervous system.
C thalamus.
D medulla oblongata.

24. Which substance is known to stimulate this movement?

A Bile
B Hydrochloric acid/HCℓ
C Adrenaline
D Secretin

25. Which one of the following methods can be used by reptiles to control their body temperature?

(i) body orientation
(ii) basking in the sun
(iii) hibernation
(iv) panting

A (i) and (ii)
B (i) and (iii)
C (i), (ii) and (iii)
D (i), (ii), (iii) and (iv)

5. Which food ingredient would deaminate in the liver when it is found in the body in large quantities?

A Proteins
B Starch
C Fats
D Sugars

27. Both carbon dioxide and water, which is released during respiration, contain oxygen. In which case is the ORIGIN of the oxygen in carbon dioxide and in water indicated correctly?

	Oxygen in carbon dioxide originates from:	Oxygen in water originates from:
A	Oxygen in air	Carbon dioxide in air
B	Oxygen in air	Glucose in plants
C	Glucose in plants	Oxygen in air
D	Glucose in plants	Carbon dioxide in air

28. The property of starch which makes it a suitable form of storage in plant cells is that it is

A soluble in water.
B osmotically inactive.
C easily transported through cell membranes.
D a carbohydrate.

29. Which of the following factors could possibly result in a person excreting more urine than normal?

A A low concentration of ADH in the blood
B A high reabsorption in the proximal tubules
C Low blood pressure as a result of little tissue fluid
D Excessive intake of salty foods

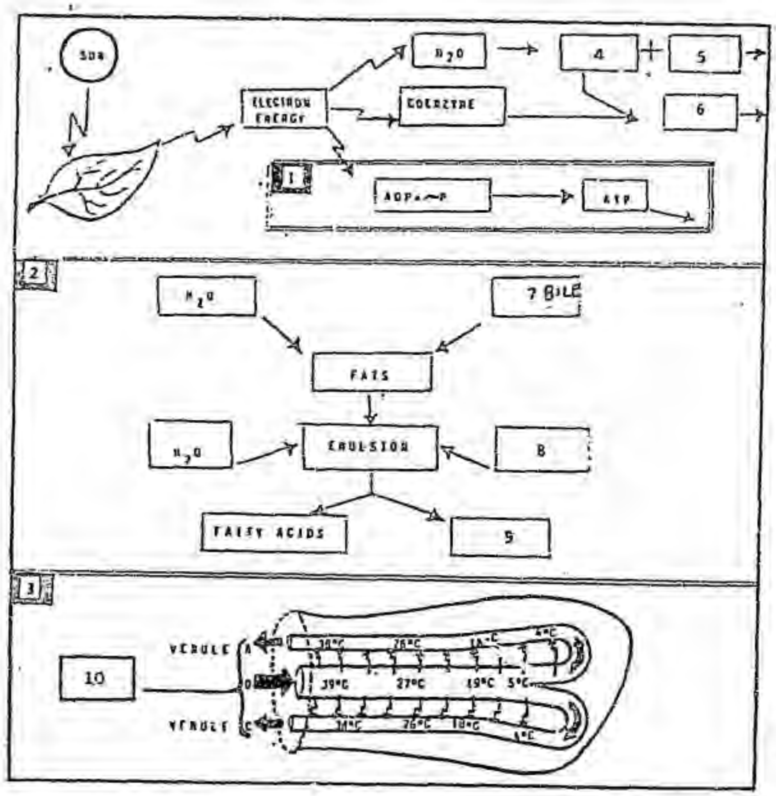
KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

30. Which one is NOT a function of the autonomic nervous system?

A Flow of saliva
B Perception of pain
C Peristalsis
D Heartbeat (30x2) (60)

QUESTION 1B

The answers to these questions relate to the numbers on the accompanying three diagrams which illustrate certain metabolic processes (or parts of them). Identify as answers to questions 1, 2 and 3 the processes illustrated in diagrams 1, 2 and 3 respectively. Answer questions 4 to 10 by giving those terms/words which would complete the diagrams correctly. Write each number with its answer on a new line.



(10)

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

QUESTION 1C

Write the letter of the description in Column B which can best be associated with the term in Column A opposite the corresponding number in your ANSWER BOOK. Write each number with the relevant letter on a new line.

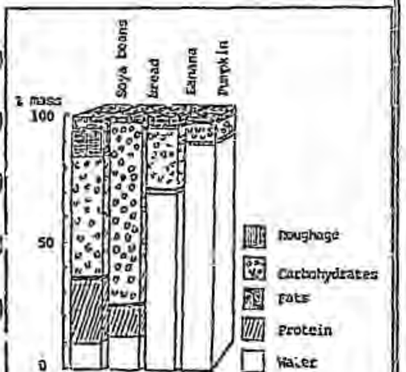
COLUMN A	COLUMN B
1. White matter	A Is the seat of higher mental functions.
2. Medulla oblongata	B Plays a role in muscle contractions and blood clotting.
3. Hypothalamus	C Sustains co-ordinated muscle movements.
4. Cerebrum	D Is the inner region of the spinal cord.
5. Pituitary gland/ Hypophysis	E Is the inner region of the cerebrum.
6. Auxin	F Stimulates cell division in meristematic tissue.
7. Secretin	G Plays a role in the functioning of the thyroid.
8. Calcium	H Is responsible for tropisms in plants.
9. Phosphorus	I Is a component of cell membranes and nucleic acids.
10. Gibberellins	J Regulates the respiratory process.
	K Controls basic emotions such as fright, anger and aggression.
	L Stimulates the secretion of pancreatic juice.
	M Stimulates the elongation of stems.

(10)

Questions 1D and 1E are based on the accompanying graphical information and practical investigation. Carefully study these diagrams and answer the questions opposite the corresponding numbers in your ANSWER BOOK. Write each number and its answer on a new line.

QUESTION 1D

1. Which food will mainly be digested in the stomach? (2)
2. Which food contains the highest percentage of roughage? (2)
3. Which food contains the least kilo-joules (energy)? (2)
4. Which food is best able to prevent malnutrition (kwashiorkor)? (2)
5. Which food would release the most energy/mol in the shortest period? (2)



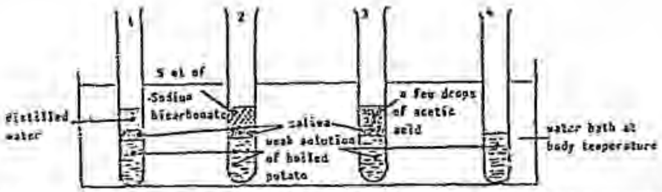
The nutrients in some foods

(10)

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

QUESTION 1E



1. Which enzyme would be responsible for the digestion which occurs in this investigation? (2)

2. Which indicator would you use to determine whether digestion has taken place? (2)

3. Name the end product of the digestion which has occurred. (2)

4. State TWO factors about the specific nature of enzymes which are illustrated by this investigation. (4)

(100)

SECTION B

Answer ALL the questions in this section in your ANSWER BOOK.

QUESTION 2

2.1 2.1.1 Discuss only the phase of photosynthesis during which carbon dioxide plays a role. (10)

2.1.2 State FOUR more factors which are essential for photosynthesis. (4)

2.1.3 Give FOUR structural adaptations of leaves to allow the phase of photosynthesis which was discussed in question 2.1.1 to take place effectively. (8)

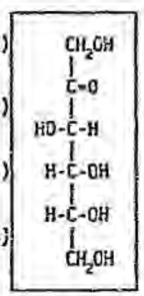
2.2 The accompanying diagram illustrates the chain formula of a fructose molecule on which questions 2.2.1 to 2.2.3 are based.

2.2.1 State TWO reasons why it may be classified as a monosaccharide. (2)

2.2.2 Name TWO other monosaccharides with the same chemical combination. (2)

2.2.3 Give the name of the solution which is used in a laboratory to test for the presence of fructose. (1)

2.2.4 State THREE functions of carbohydrates for living plants. (3)



2.3 2.3.1 Draw a labelled diagram of a longitudinal section of a villus with a section of the small intestinal wall on which it is found. (10)

2.3.2 Briefly discuss the absorption of fats by the villi and explain how the absorbed matter is taken up into the blood stream. (10)
(50x3÷2) (75

QUESTION 3

3.1 A nerve impulse reaches the spinal cord from a receptor through the back (dorsal) root.

3.1.1 Draw a fully labelled diagram of this neuron. Also indicate the direction in which the impulse moves. (10)

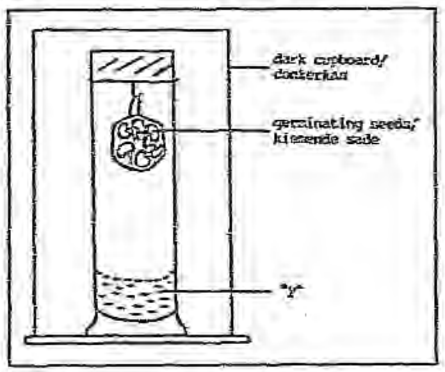
3.1.2 According to its structure, what is a suitable name for this type of neuron? (2)

3.1.3 State TWO macronutrients which play a role during the transfer of nerve impulses. (2)

3.2 3.2.1 Tabulate THREE differences between nerve co-ordination and hormone co-ordination. (6)

3.2.2 Briefly explain the concept of negative feedback by referring to the interaction between the hypophysis (pituitary) and the thyroid gland. (7)

3.3 The accompanying diagram illustrates the apparatus used in an experiment to determine which gases are involved in a specific metabolic process in plants. Study the diagram and answer the questions which follow:



3.3.1 Which metabolic process is involved in this experiment? (2)

3.3.2 (i) Which chemical may be used at "Y" in the experiment? (2)

(ii) What colour change will the chemical undergo? (1)

(iii) What deduction may be made if such a colour change were to take place? (1)

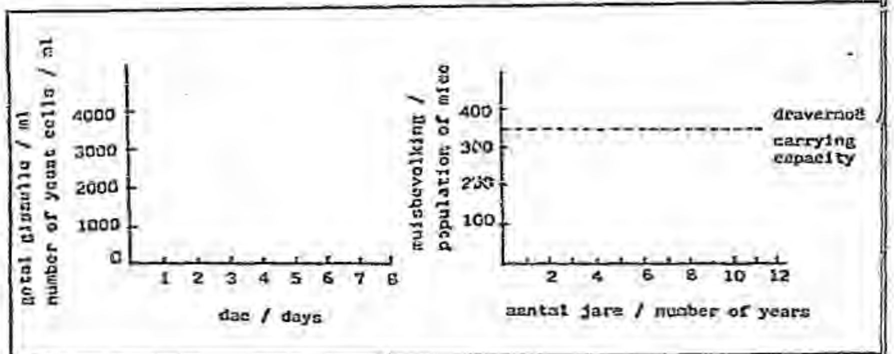
3.3.3 During this metabolic process, the carbohydrates in the seeds are broken down to pyruvic acid. Explain how this pyruvic acid is completely broken down. (13)

3.4 State the ways in which fermentation diffe. . from the metabolic process mentioned in 3.3. (4)
(50x3÷2) (75

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

QUESTION 4

4.1 Draw an enlarged version of the accompanying graph axes below one another in your ANSWER BOOK. Then on each axis draw a graphic representation of the data given in questions 4.1.1 and 4.1.2 respectively.



4.1.1 An initial population of 500 yeast cells/ml shows a geometric growth form in a certain culture. On the sixth day when the optimum limit of 3500 yeast cells/ml is reached, the total population of yeast cells is, however, suddenly destroyed by the formation of excess alcohol. (5)

4.1.2 An initial population of 50 mice in a certain habitat shows a logistic growth form over a period of 12 years. However, after 5 years the numbers exceed the carrying capacity, drop to 300 in the seventh year and then stabilize over a number of years to stay in balance with the environment.

Also list and indicate the THREE most important growth phases on this graph. (7

4.2 Explain how the eye adjust to view an object over a distance of approximately 8 metres in bad light. Specifically note the exact path which the light stimulus follows, as well as the changes which take place in the eye which make sight possible. (14

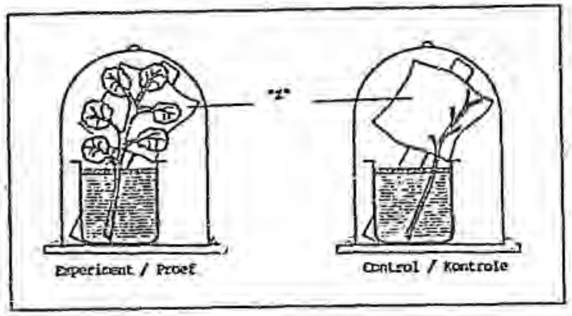
4.3 4.3.1 Distinguish between the following terms:

(i) Breathing (2
(ii) Respiration (3
(iii) Gaseous exchange (2

4.3.2 State FOUR requirements for an effective gaseous exchange organ. Explain in each case how the human lung meets these requirements. (8

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

4.4 Study the accompanying diagrams of the apparatus set up for a specific experiment.



4.4.1 What is the aim of this experiment? (2)
4.4.2 What is the aim of the control during any experiment? (2)
4.4.3 Which indicator is used at "Z" in the diagram? (2)
4.4.4 What do you expect to observe after approximately two hours? (3)

(50x3÷2) (75)

SECTION C

Answer ONE question from this section in your ANSWER BOOK.

Select the facts in such a way that only the most important are used to answer the question. No diagrams or sketches are required and your answer should not exceed 600 words (± 3 pages).

QUESTION 5

Proteins are important organic compounds for human beings. Discuss the following aspects of proteins to substantiate this statement:

- Composition, characteristics and functions
- Digestion
- Absorption and transport
- The homeostasis of excess proteins in the human body (75)

OR

QUESTION 6

Homeostasis in the human body is, amongst others, dependent on the role of the

- pancreas (endocrine function only)
- kidneys (excretion and osmoregulation)
- skin (regulation of body temperature only)

Discuss the maintenance of a constant internal environment in the body in terms of the contribution made by the above organs. (75)

TOTAL: 400

KNOWLEDGE		SKILLS		
RECALL	UNDERSTANDING AND SIMPLE APPLICATION	HIGHER ORDER COGNITIVE	OTHER SKILLS	SPECIFIC NAME

APPENDIX 2.

A MARKERS REPORT GIVING FEED-BACK ON A MARKING SESSION OF THE HIGHER GRADE TED MATRIC BIOLOGY PAPER.

H.G. BIOLOGY MARKING 1990

JOHANNESBURG (J.C.E.) CENTRE

1. A MARKER S REPORT AND FEEDBACK

I experienced the following problems with exam questions and/or memo.

QUESTION 1 E

Marks were allocated for providing correct labels without candidates having to provide the mistakes on the drawing. To me this is UNACCEPTABLE as some candidates scored 5 marks without detecting the errors.

QUESTION 2 (Note: I marked this question)

2.1. Drawing of human respiratory organs

A good question spoilt by a very poor marking memo.

1. Marks were ONLY allocated for labels (rote learning).

2. Candidates could sco e full marks as long as they wrote 13 correct labels - it did not matter if they had 13 incorrect labels too! For example, I had to give full marks to a candidate who had mixed up all his labels for C/S of the Kidney and Breathing system.

Why was this question not used to assess more important biology skills too?
e.g. Correct drawing and labelling techniques as used in biology.
Position of various parts in relations to one another.
Drawing the parts in proportion etc.

2.2.

A difficult question to mark objectively - marking instructions were far too lenient.

E.g. If candidates discussed exchange of gases at the lungs instead of muscle tissue, we were instructed to give 4 marks out of 7 (FOR A WRONG ANSWER!)

Other relevant facts, e.g. Bohr effect, given by some candidates were not marked.

2.5.

In Q 2.5. too many marks were allocated for 2 basic terms - Osmometer (2) dialysis tubing (2).

continued.../

2.7.

Too few marks were allocated (6 marks). Only terminology was assessed in some cases. Some candidates, having given the names of the structures involved, scored full marks although their answers showed that they had no understanding of how the various structures function.

QUESTION 3

3.1.1.

1. A bit of an unfair question - syllabus mentions only 10 internal structures of the brain and yet the memo asked for 12.

2. Incorrect labels were marked correctly e.g. Grey/White matter } Incorrect
   } on
   Foramen of Munro } memo

3. Meninges - correct label - in syllabus - not marked.

4. All criticisms about ignoring assessment of drawing techniques (as in Q. 2) applies here too.

TO BE NOTED ESPECIALLY

Question 3.4. - a good ...ion messed up by a WRONG MEMO! What a disappointment to those ...hers who teach data analysis!

Chief mark...s should be instructed to pay more attention to teachers' objections!

The memo was INCORRECT - it has been MARKED INCORRECTLY and this is TOTALLY UNFAIR. The more observant candidates were penalised. As a result some candidates scored an extra 12 marks they did not deserve - (inflated marks will affect distribution of marks).

Those who answered correctly and were marked wrong could have lost their A's!

I have personnaly checked the answers with WITS UNIVERSITY - (both department of BIOLOGICAL SCIENCES AND STATISTICS) and the only possible answers are:
x) CO2
y) Water-vapour - NOT oxygen (could never reach such a low % in atmosphere).

therefore at 12 p.m. stomata are wide open CO2 diffuses in and is used up - maximum rate of photosynthesis - therefore less in atmosphere.

H2O vapour escapes as a result of transpiration
- rate of transpiration fluctuates as shown on graph - 12 p.m. = maximum. as stomata are wide open and possibly higher temperature - at night stomata close therefore less H2O vapour escapes.

continued.../

To be fair all candidates with A's and B's should be REMARKED, on this question, at this stage.

Question 4.2.1. - MISTAKE ON MEMO

Common bile/pancreatic duct is further down.
Label points to bile duct only.
Both should have been marked correctly.

II. PROBLEMS WITH MARKING AT MY CENTRE

1. Many markers were in the same room as where their school papers were marked and markers could choose which papers (e.g. from a friend's school) that they wanted to mark. This is NOT ACCEPTABLE as this is an IMPORTANT EXTERNAL EXAMINATION.

   Suggestions - papers from one region/centre should be sent to a different one for marking e.g. Pretoria should be marked in Johannesburg and vice-versa.

2. Markers should not be allowed to see/mark from their own schools.

3. Some afrikaans speaking markers - NOT FLUENT in english joined the marking team half way through marking time - not fair.

4. 12 hours of marking in one stretch is pushing human capabilities a little too far. Why not mark over 4 days of 8 hours? Many mistakes were picked up on checking. How many were not?

APPENDIX 3.

EXAMPLARS SHOWING SOME POSSIBLE QUESTION STYLES WHICH COULD BE USED TO ASSESS SOME OF THOSE 'SKILL' OBJECTIVES NOT ASSESSED BY THE TED PAPERS.

EXEMPLAR 1

Comprehension text with skill based questions - adapted from the School Certificate Reference Test of the Board of Study - New South-Wales, 1991.
(Skills assessed: S11, S12, S13).

OCTOBER 14, 1990

CAPE TOWN NEWS

CAPE TOWN'S UNWANTED TOURISTS

Light-Loving Moths Make a Mess of the House of Parliament at Dusk

Kim Kong
Science Writer

From next Monday the lights on the House of Parliament will be switched on one hour later than their regular evening times.

This is part of a six-week test to see if the National Parks Board can trick a tiny moth that has been a problem for years and is the main reason the surfaces of the buildings have become stained and damaged.

Professor A. Moore, a famous entomologist with the National Parks Board, has hypothesised "*that the moths are attracted to light*".

The moths are most active when the light fades after sunset. As night falls on spring evenings, the moths leave from the edge of the various ponds found in the parliament's grounds after spending winter as larvae in the mud. They see the floodlit buildings and fly towards the lights.

Many splatter themselves against the building services. Others get confused and lay eggs on the walls. Some leave droppings on the walls.

"If the night lights on the buildings are not switched on until sometime past sunset", Moore said, "the moths won't be attracted to the building. Instead they will stay at the various ponds during their active period. By the time the lights are switched on, the moths will no longer be active."

Professor Moore designed an experiment to test this idea. On Mondays, Wednesdays and Fridays the outside lights on both buildings will come on an hour after sunset. On Tuesdays, Thursdays and weekends, the lights will come on at sunset, the regular time.

Every night the lights will be switched off at midnight, the regular time.

Equal areas will be marked off on different walls of the buildings. Each night Professor Moore will count the number of moths in each area.

Use the information in this article to answer the following questions:

1. Write an 'aim' for Professor Moore's experiment. (1)

2. Marking only one area on the wall would not be a good design for this experiment. Explain why not. (2)

3. Why does Professor Moore turn the lights on an hour later on Mondays, Wednesdays and Fridays? (2)

4. At what times should Professor Moore visit the buildings to count the moths? (2)

5. If Professor Moore's hypothesis (that the moths are attracted to light) is correct, what result would you expect from the experiment? (2)

The sun warms the buildings during the day. A resident believes that the moths are attracted by the heat given out by the buildings after sunset. The resident conducted a *simple* experiment and obtained the results below:

RESIDENT'S RESULTS

DAY	X	Y
Monday	19	621
Tuesday	21	243
Wednesday	18	697
Thursday	23	660
Friday	22	590
Saturday	17	642
Sunday	20	559

6. Suggest a label for X and Y in the table. (2)

7. Does the data support the resident's belief? Explain your answer. (3)

8. A well designed experiment to test the residents belief would be different from Professor Moore's experiment in two main ways. What are the two ways? (4)

[18]

EXEMPLAR 2

Chart/evolutionary tree with skill-based questions.
(Skills assessed: S1, S11, S7, S5, S10, S2).

JURASSIC PARK

Study the attached fact file about evolution of dinosaurs before answering the following questions.

1. Write as much information as you can about Triceratops using only facts given on the chart. (10)

2. Using the information on the evolutionary chart, construct a bar graph to compare the relative sizes of the eight dinosaurs shown. (5)

3. The sex of certain reptiles is known to be determined by the temperature at which their eggs are incubated. In the alligator, 30°C produces females and 33°C males. It is possible that this was also true of the dinosaurs. It is known that the end of the age of the dinosaurs coincided with a lowering of the Earth's temperature. Based on the above information, construct a hypothesis to account for the extinction of the dinosaurs. (4)

4. Assume that instead of a lowering of the earth's temperature at the end of the cretaceous period temperatures rose to very high levels and that dinosaurs adapted to these new conditions. Use a sketch to show what the 'adapted ' dinosaurs could look like. Annotate your sketch, briefly explaining your choice of design. (6)
[25]

EXEMPLAR 3

Experimental design question - (Torrance, 1992).
(Skill assessed: S8).

Observations: A certain brand of rooting powder (RP) which contains auxin promotes growth of cuttings taken from hardwood plants such as roses.
Cuttings dipped in water and then in RP pick up more powder and 'take' more easily than cuttings dipped only in RP before planting.

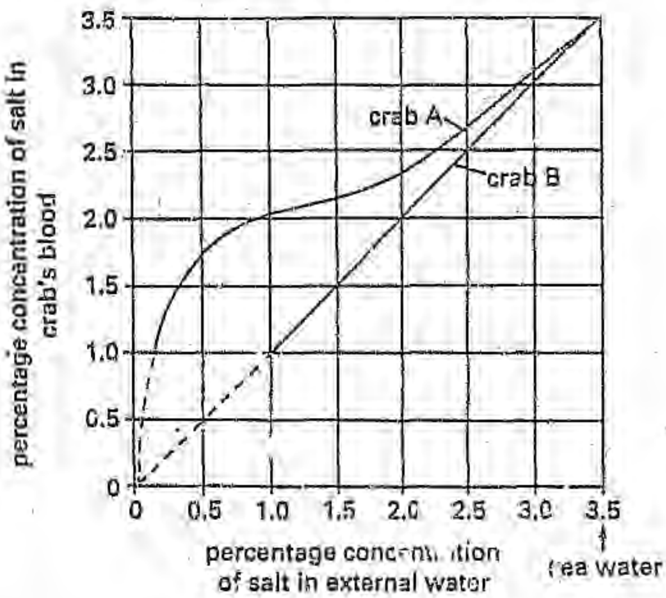
Hypothesis: Water-dipped cuttings grow better because a higher concentration of auxin stimulates a greater amount of root formation.

Problem: Design an experiment which would enable you to test the validity of the hypothesis above. (Assume that RP is water soluble.)
Your design should include reference to:
- relevant control(s),
- measurements need to provide valid data,
- method of calculating percentage stimulation of root formation.

EXEMPLAR 4

Data/graph analysis.
(Skills assessed: S1, S11, S9, S12).

Several specimens of two species of crab (A and B) were submerged in sea water (3.5 per cent salt solution) and given time to acclimatise. A sample of each crab's blood was then taken and analyzed to measure its salt content.
The experiment was repeated using 3 per cent salt solution and successively more dilute salt solutions. Average values of blood salt content for both species of crab in each external salt solution were calculated. The graph of the data is shown below.



1. Which species of crab has blood which is always isotonic to the surrounding water? (1)

2. a) Which species of crab has blood which remains hypertonic to the surrounding water as the salt content of this external medium decreases below that of sea water? (1)
   b) At which per cent concentration of salt in the external water is this crab's blood most hypertonic to its surroundings? (1)

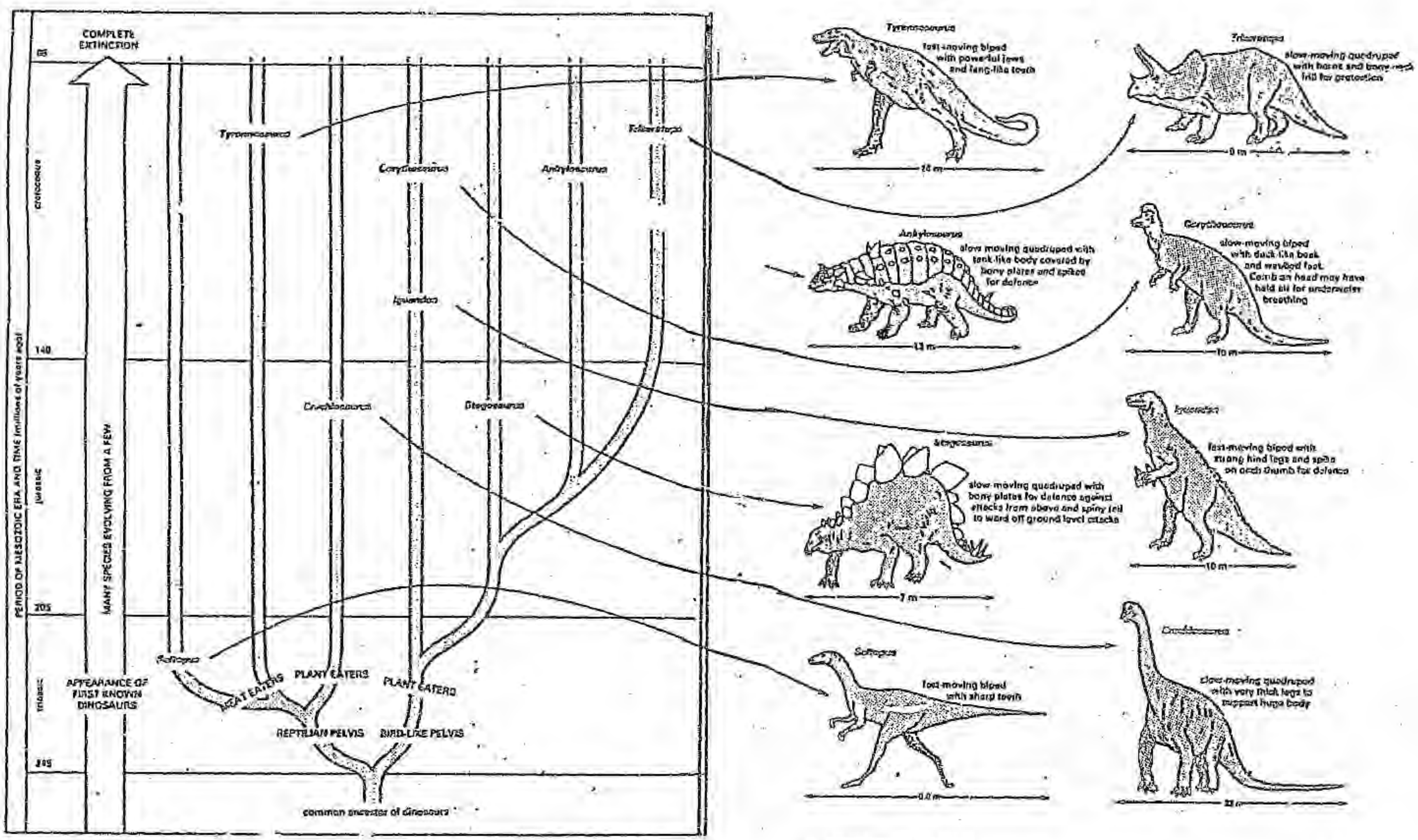
3. a) Which crab is able to exert some degree of osmoregulation? (1)
   b) Why is oxygen required for this process? (2)

4. Copy and complete the table below by identifying which species of crab is suited to life in each of the habitats and briefly explain why.

habitat	species of crab	reason
river estuary		
deep sea water		

(4)
[10]

JURASSIC PARK – FACT FILE



Evolutionary tree of dinosaurs