SOME ISSUES IN CURRENT BIOLOGICAL EDUCATION

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ABSTRACT

During the past decade, new biological curricula and courses have been formulated and incorporated into New Zealand education. Implied is that this 'new' biology is also a 'better' biology.

However, recently two trends have been noticed. Firstly, the world wide 'drift' from science continues unabated. Secondly, research in biology, especially in 'pure' biology is declining.

The 'drift' and the 'decline' in research continues in spite of new curricula at introductory levels. The drift from biology is obvious at the break between secondary and tertiary level education. Some factors which contribute to this drift can be found in secondary school biological education. Quantification, reductionism and factualism have been described. These factors can be classed as consciously or unconsciously held presuppositions or assumptions which are held by biological educators. They may not know that they hold these presuppositions, but curriculum makers and text writers reveal them when they write. Exploration of the unstated assumptions, possibly held by text writers and curriculum makers, is an important exercise in this thesis. For example, biological educators may never explicitly state that the 'new' biology is a 'better' biology. Instead by their writing it can be concluded that they do indeed make this assumption.

If biological research is declining and a drift from biology is continuing, it seems necessary for some unstated assumptions or presuppositions to be made explicit. Furthermore,

three possible remedies - the upgrading of biological theory, the extension of the observation phase, and the incorporation of the theory and methods of Natural History - are outlined. Biological theory, if encouraged in introductory biological education could promote unorthodox, but fruitful approaches to old and new problems in biology. Secondly, if the three above remedies are incorporated, the drift from biology may be abated. The mixed arts-biology students, could then advance into tertiary biology without being hamstrung by pre-requisites. Moreover, it seems probable that biological research could benefit from this substantial but currently neglected group. They seem to be characterised by having strong theoretical orientations which, if sustained, could benefit future biological research and biological education.

NEW BIOLOGY: A BETTER BIOLOGY?

During the nineteen sixties, prescriptions in secondary school biology were changed. Biological text-books, laboratory guides, and curricula have been modified. The old 'dogfish - earthworm" biology had been transformed into a 'new' biology, which stresses molecular aspects of biology:

> "During the past year or two, the New Biology in full official garb has begun to take the secondary schools by storm in a fashion uncomfortably reminiscent of the triumphant progress of the New Mathematics. Introductory courses in biology are being renovated, with the emphasis shifted from worms and dogfish to the beauties of nucleic acids.
>
> Yet the most exciting and significant aspect of recent progress lies precisely here: perhaps for the first time - or at least more insistently now than ever before - the key theme of a scientific biology is becoming a reality instead of a pious hope.
>
> That theme is the development of a unified and quantitative theory of how living organisms function, expressed in terms of the most fundamental explanatory concepts that can be used."
>
> (Reiner 1969).

Reiner does express some concern about the enthusiasm with which educational policy-makers formulate curricula, but he assumes, it seems, that this change from 'old' biology to 'new' biology can do nothing but good for the future of biology.

In New Zealand, in the nineteen sixties, policy-makers decided that modifications in biological education were necessary. Sixth and seventh form courses were renovated in the manner described by Reiner. A text book, and an accompanying laboratory guide have been published by the Curriculum Development Unit of the Department of Education. ("Biological Science. Processes and Patterns", 1969). This prescribes work for sixth forms. A teachers' guide has also been published with an accompanying cyclostyled laboratory guide which caters for seventh forms. (Form Seven Teachers' Guide, University Bursary/Scholarship", 1970).

It is also probable that the fifth form biology prescription is due for modification and updating in the near future.

The cost of these elaborate and extensive publications, and the finance necessary for raw materials for practical work, is large. The policy-makers had to convince the Department of Education that these new courses would give value for money. That they seem to have achieved plausibility is surely some indication of the enthusiasm of the policy-makers and curriculum developers.

In general the 'new biology' in New Zealand has been based upon the Biological Curriculum Studies courses developed in Colorado, U.S.A. The Nuffield Foundation of the United Kingdom have also been used as a model on which to develop New Zealand biological education. It thus seems that the transformation from 'old' to 'new' biology came about as a result of much careful planning and convincing. The work required in the organisation of 'in-service training courses' to keep biology teachers aware of the types of changes being sought, in the curricula must have been stupendous.

Enthusiasm for change was probably catalysed by an assumption that biology seems to have arrived at a point where a revolution was taking place. This revolution seemed to indicate that biology would be explained in terms of the chemistry of molecules. If this occurs, biology would seem to be attaining a maturity level similar to chemistry. It would therefore appear that changes in biological education toward molecular biology would represent an advance over the 'old'. Furthermore, the recent breakthroughs in the genetic code (since Crick 1953) seemed to indicate that most future biological research would be concentrated at the molecular level.

This situation seems to imply a type of orthogenesis or 'straight-line evolution'. That is, the future will be exactly like the past. The past successes of molecular biology, it is assumed, will guarantee its future. The policy makers in biology seem implicitly to have accepted this situation. Yet it really means that the future will be non orthogenetic. If biology is to 'advance' the future must be continually changing. Thus there seems to be a paradoxical situation. The policy akers assume a guaranteed future for molecular biology, while on the other hand biology in general will keep changing. Also it means that past success is no guarantee of an assured future.

It is the responsibility of biological educators to prepare future researchers beginning at introductory levels so that they can enter research well grounded in the relevant approaches and information. Consequently biological education is very important.

But, despite the newly developed courses in biology being set in motion on a national scale, a major problem has arisen.

The 'Swing' or 'Drift' From Science.

There is evidence indicating trends which are percolating throughout science including biology:

> "Recruitment in the pure and basic sciences continues to show a relative decline. Not only are the basic sciences attracting relatively fewer recruits than the social sciences and humanities, there is evidence that the average calibre of the British recruits (as indicated by A-level pass rates) is also falling!"
>
> (D. Stenhouse 1965)

There is a 'swing from science'. Evidence can be cited from overseas (British and American journals) but it will be shown that the 'swing' is more widespread than this. The major contributing study to the 'swing' or 'drift' from science is the Dainton Report (1968):

> "For the present it is clear that the trends with time against scientific studies are general and by no means confined to Western Europe or even the Northern Hemisphere. It is therefore the more likely that they stem from very deep seated causes relating to the nature of the appeal of science and technology to young people under many diverse educational and social conditions."
>
> (Dainton Report 1968, Paragraph 125).

Evidence suggests that a number of factors may be contributing to the 'swing':

> "The present position, however, is that despite the impressive advances of modern research, and, although in the mortified words of the Dainton Report, 'nothing justifies a movement away from these subjects in schools' sixth formers have revealed something less than zeal for scientific studies. On this point there is small comfort to be derived from recent stories of a reduction in the swing from science if, as seems likely, all that is happening is an adjustment of subject choice to the economics of the higher education market place."
>
> (D. Layton 1972).

Secondly, it is <u>proportionality</u> which is important, and which (according to Dainton) complexifies the situation:

> "On this basis, it turns out that from 1962 to 1967 the proportion of students in the science group fell from 42 per cent to 32 per cent, while the proportion in the non science group rose from 58 per cent to 68 per cent. The Report points out, that because in those same five years, the proportion of the whole age group going on to the sixth form rose steeply from 11.5 per cent to 17 per cent, there was an over all absolute increase in the number of science specialists going into the sixth form; but it stresses the fact that that increase was very small as compared with the large increase in the number of new non-science students, and that, indeed, the <u>number</u> of new science specialists has <u>decreased</u> since it reached a maximum in 1964."
>
> (Thornton 1968).

The situation for Australia is little different:

> "The 1967 numbers are also available. They show that in that year more than twenty thousand new undergraduates entered the Australian Universities, 37.6 per cent of them going into the sciences and 62.4 per cent into the arts fields ... The national figures for 1967, showing in one year a fall of 3 per cent in the proportion choosing science, are striking indeed, and show that the trends of the 1962-66 period were continued in 1967 - and on the face of it, considerably accelerated."
>
> (Thornton 1968).

The effects of the drift may eventually have widespread national repercussions:

> " ... In 1962 the total number of new undergraduates who enrolled at all Australian universities was close to 14.5 thousand. Of those new undergraduates, 53.4 per cent enrolled in arts and 46.6 per cent enrolled in science. In 1966 the total had grown to 22 thousand, and the proportions became 59.4 per cent in arts and 40.6 per cent in sciences. In four years therefore, the proportion choosing science had fallen from 46.6 per cent to 40.6 per cent, a decrease of 6 per cent; at the same time (and necessarily because I am taking a simple and exhaustive dichotomy) the proportion choosing arts increased by 6 per cent rising from 53.4 per cent to 59.4 per cent."
>
> (Thornton 1968).

> "The danger lies in the fact that while our (Britain's) national welfare has become increasingly dependent on engineering, technology, and science, the percentage of 'dedicated young scientists' entering the sixth forms has dropped from 41.5 per cent in 1961 to 31.4 per cent in 1966. This means that science-based activities of society are rapidly losing favour among the brightest of Britain's young people just at a time when our national economy has been experiencing crisis after crisis. This deliberate turning away from engineering, technology, science, medicine and related work, will have far reaching effects on recruitment to those sectors of our national activities which are dependent upon science, and will aggravate the effects on society of the brain drain at high levels of expertise."
>
> (Rosenhead 1968).

Brian (1968) also emphasises the repercussions:

"Boys and girls in upper forms in our secondary schools are increasingly rejecting science as a field of study - the report establishes this as a fact, supported by abundant convincing statistical evidence. This bald statement needs some amplification as the situation is complex, embodying several distinct trends. Thus -

a) More young people are staying on at school - the national sixth form is getting bigger every time.
b) As a result of this general increase, the absolute number of pupils taking scientific subjects is still increasing.
c) Nevertheless the proportion of science students staying on at school is steadily declining, thus there is a relative decrease in science students.

And if the last mentioned trend continues, then in the very near future, the absolute number of candidates coming forward from school to university to study science or technology will decrease.

As the Report emphasises, it is from this stream that we get most of our dentists, veterinarians, scientists, technologists and engineers. We have here the makings of an alarming national situation which could jeopardise national development in the 1970's."

(Brian 1968).

"It is commonplace that the face of science can now transform itself within a decade; less familiar are recent changes in the patterns of recruitment to it. Against every economic of educational prediction, the proportion of young able men and women entering physical science subjects at English universities has begun to decline."

(L. Hudson 1968).

The reasons for the 'drift' are probably very complex. For example, one reason may be that there is opportunity to attempt new subjects at tertiary levels which were not part of the school curriculum. Social factors may also be involved. Evidence for this comes from an American journal:

"Somewhat more than half of those who in high school planned careers in science or engineering change their minds during the freshman year. In subsequent years the ranks are thinned only by about 20 per cent based on those who continue to graduation. One reason stems from appreciating for the first time the heavier work-load and heightened competitiveness that are the lot of science majors; the concomitants are a prospect of a diminished social life, and a kind of isolation because the substance of science is not an easy topic of conversation. The other reason is simply the opening up of new possibilities for study and career areas that had either not been part of the high school education, or had been much less interestingly taught than science."

(Doty and Zinberg 1972).

Friedenberg (1961) places a great deal of blame upon science education:

"I am not enough of a Nationalist to wish to keep in science the ardent and promising youngsters who leave it, nor even convinced that it would be in the national interest, whatever that may be, to do so. But it does seem to me that the experiences that drive them out have far less to do with science as either a method or epistemological system than they do with science as a social institution. Thoseof our best subjects who left did so because of the way scientists are taught and the way they are used; not because of what science essentially is: after all, it is our respondents who believe that science deals with deep and fundamental issues of being, who are correct. But undergraduates do not get much chance to get down to fundamentals. It would seem that the sensible way for a nation to retain such youngsters, as future scientists and engineers would be to improve the way they are taught, and to modify the opportunities open to them in their later employment, so as to provide a legitimate expectation of personal autonomy in their work. But this is not the way our culture is going about it. Instead subject after subject in our study complains that the way the high school led him into science confused him and made it much harder for him to see how his career choice was going to affect his life and his image of himself. From an adolescent, considering what it is he has to do to grow up, this is a very serious charge against secondary education."

(Friedenberg 1961).

"Science teachers around the world are in a whirl. They are aware that their walls are falling down, and that their teaching is being exposed as self centred and inadequate. But where are the new boundaries to be constructed. And what is to be the new teaching? ... We know that the conformist is always safe. Life is laid out for him and responsibility is nil. But that is not what the next step in science teaching is about. Integrated science should plunge into the unkown, with the teacher preparing charts as he goes along."

(Goldsmith 1973).

These trends are clearly indicated in Graph 1 on the following page.

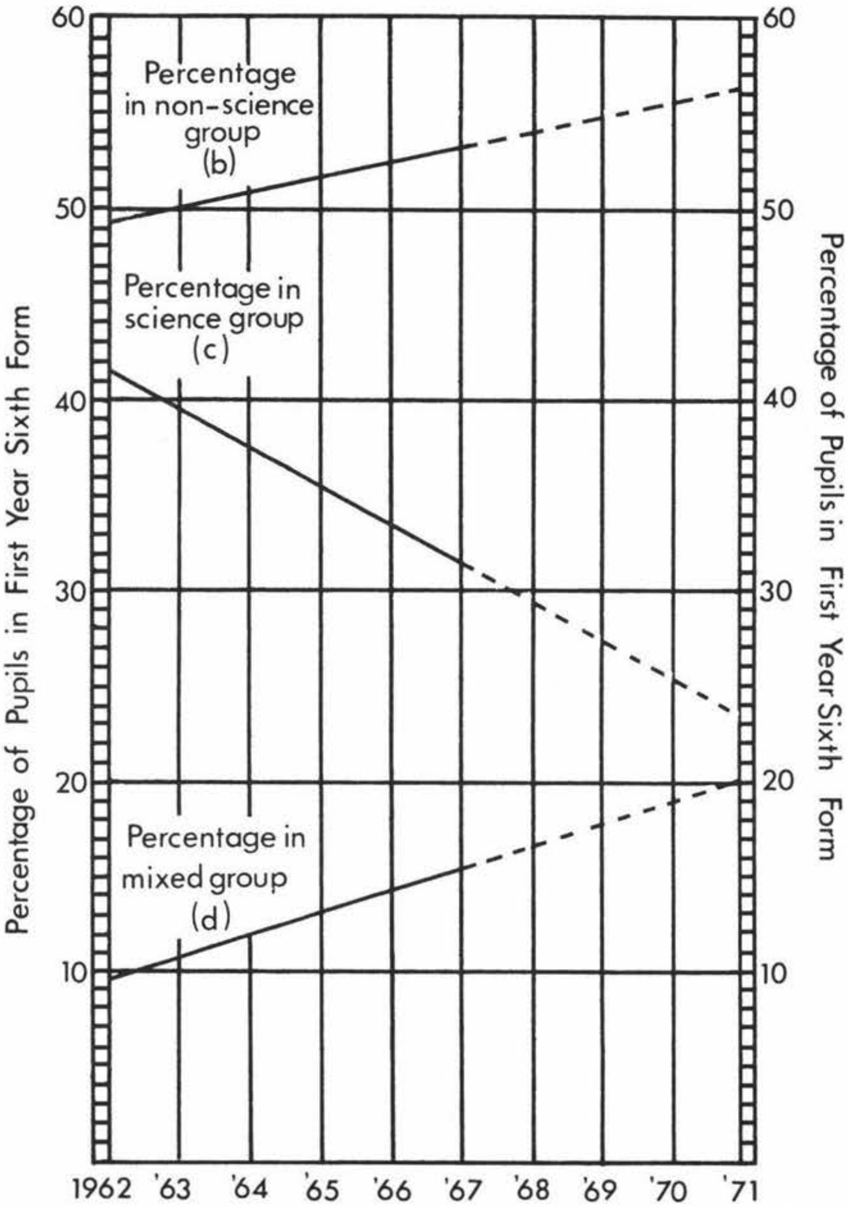
In the countries outlined, Australia, the United Kingdom, and the United States, the educational systems are diverse. Yet it is from these large and diverse educational systems which have been used as a basis for curriculum change in New Zealand.

It would seem therefore, that New Zealand curriculum planners have borrowed from curriculum plans to apply to New Zealand conditions, from systems where a drift from science is already occurring. This mimicking process is fully acknowledged:

> "Many persons have assisted in the preparation of this text-book. In particular the Department of Education acknowledges the generous assistance given by the Regents of the University of Colorado, Boulder, United States of America, on behalf of the Biological Sciences Curriculum Study. The writers have been able to use freely or adapt the text and illustrations from the three B.S.C.S. versions."
>
> (Department of Education Acknowledgements in "Biological Science, Processes and Patterns", 1969).

As already noted, the situation in relation to the 'drift' from science is complex. Many issues overlap and inter-relate.

The complexity of the problem can be noted by the extensive published argument which followed the release of the Dainton Report in Great Britain in 1968. Thornton (1968), Rosenhead (1968), and Butcher (1969) agree with the findings of the Dainton Report. MacPherson (1969) has strongly criticised the conclusions of the Report. Neave (1973) goes even further to cite evidence for a marked swing toward science. This will now be discussed.



Graph1: PROPORTION OF FIRST YEAR SIXTH ON EACH TYPE OF 'A' LEVEL COURSE.

After Butcher, May 1969.

A REPORTED 'SWING TO SCIENCE'

An article by Neave (1973) requires elaboration. The title given to his article is compelling - "The Swing To Science".

He bases his arguments around the apparent inadequate sampling procedures used by the Dainton Committee. This committee did not give sufficient weighting to the then newly established comprehensive schools which featured open admission into sixth forms. Rather the committee based its research around non-comprehensive schools in England and Wales, which had closed entry to sixth forms. That is, entry could be gained only through acceptable examination passes;

> "In none of the major works on this subject has there been any attempt to control school types. Indeed, the general conclusion from most previous studies is that the swing from the sciences is a general phenomenon in secondary education, affecting all types of schools to a greater or lesser degree. My study has revealed that there is not merely a 'swing from science' among students going to university <u>from comprehensive schools</u>, but rather a positive 'swing to science'."
>
> (Neave 1973).

A crucial statement in his articles discusses university intakes:

> "There is, compared to all other university entrants, a clear move to science. 36% of comprehensive students enrol for science degrees. 27% for the rest of the entry from other schools."
>
> (Neave 1973).

It would be a satisfying situation for science if that which Neave outlines actually was the case. But there are a number of inadequacies which make the Neave study far less important and compelling than the more pervasive Dainton Report (1968).

Firstly, Neave confines his study to <u>comprehensive</u> schools alone. His study could therefore suffer from the same weaknesses that he attributes to the Dainton Committee. To maintain that there is a 'swing to science' from a study which is far less comprehensive than the Dainton Report is to convey an atmosphere of confidence in science where research is declining. (Zuck 1964; Brian 1969; Weiss 1970; Mellanby 1973; Levins 1973). Neave sampled from 163 comprehensive schools which had sixth formers during October 1968. Other schools which were 'selective' schools (having examination requirements before sixth forms entry) were not considered, but he did try to compare his findings with those of the Dainton Committee despite the fact that:

> "Dainton's information was gathered in respect of the year-group which entered university three years before ours. Thus an entirely reliable comparison between two groups cannot be made."
>
> (Neave 1973).

Yet, despite this admission, Neave goes on to attempt close and detailed statistical comparison with the Dainton report, to reveal its apparent inadequacies.

Secondly, Neave's study implies that trends are being investigated. But trends are better shown through longitudinal studies, than by a single study. The Dainton Report did attempt to derive data from over a period of years. Neave, on the other hand, did not. Thus it must be accepted that the Dainton Committee produced more comprehensive findings than the Neave study. To maintain a 'swing to science' from a single study seems to give no importance to the findings of a more comprehensive study which claimed a 'swing from science'. Yet Neave does consider some of the statistical data derived by the Dainton Committee to be sufficiently important for him to compare with his own data.

Thirdly, Neave attaches great importance to the 36 per cent of students entering science from comprehensive schools, in comparison with the 27 per cent from other 'selective' schools. This, in itself, according to Neave, indicates a clear 'swing to science'. But is it? Thornton (1968) for example maintains that a drift from science has occurred when the proportion of total entrants to university fell from 42 per cent in 1962 to 32 per cent in 1967 in Australia. Put within the context of trends, Neave's findings do not seem to indicate any marked swing to science at all. 36 per cent of entrants opting for science from comprehensive schools is not very significant when placed within the context of national trends. The slightly higher figure (36 per cent) could readily be attributed to initial enthusiasm of teachers and educational authorities for establishing and encouraging the relatively new comprehensive schools. The need for a longitudinal study again seems necessary, to observe if this initial enthusiasm for 'open entry' into sixth forms, and the more broadly based curricula systems characteristic of comprehensive schools is short lived or not. It would appear that as the enthusiasm subsides, then trends will further reflect those outlined by Dainton.

The 'open entry-selective entry' distinction requires elaboration. Neave does not define 'open admission'. Complete 'open admission' would be unlikely. Headmasters of comprehensive schools probably vary in the criteria they use for entry into the sixth forms. If they did not limit entry, physical plant, expensive laboratories and so on, would not be likely to cater for the numbers. In general, science resources (teachers included) are always at a premium perhaps more so than the arts (Stenhouse 1968). However, it must be accepted that there is a markedly large population of sixth formers in comprehensive schools. If this is so, probably it is, (though Neave does not say so) then proportionality is important. Neave does not account for proportionality which can be explained as follows:

There is a very large number of students in comprehensive school sixth forms. Of this large number, not all would wish, nor would be able, to enter science faculties in universities. Of those who wish to enter university, 36 per cent opt for science. On the surface, this seems to be a healthy state of affairs. But it fails to account for proportionality.

Of this already large number of students in comprehensive sixth forms because of open admission, only a small proportion of this large group may enter university. The 36 per cent therefore may be merely reflecting the large influx of total numbers into sixth forms. Open admission would enhance larger numbers coming into sixth forms and this would be reflected in actual numbers entering tertiary science education.

But the proportion of those wishing to enter university from these sixth forms may in fact be quite small. Neave does not appear to account for this. The proportionality problem has been discussed by Brian (1968):

> "Boys and girls in upper forms of our secondary schools are increasingly rejecting science as a field of study - the Report establishes this as a fact, supported by abundant statistical evidence. This bald statement needs some amplification as the situation is complex embodying several distinct trends. Thus -
>
> (a) More young people are staying on at school - the national sixth form is getting bigger all the time.
>
> (b) As a result of this general increase, the absolute number of pupils taking science is increasing.

(c) Nevertheless the proportion of those staying on at school who take science is steadily declining, thus there is a relative decrease in science students."

(Brian 1968).

Butcher (1969) also puts the situation clearly.

"In terms of numbers, the swing has been relative, not absolute. Faculties of science have expanded, but more slowly than other faculties."

(Butcher 1969).

There is also another important factor which does not appear to be given detailed attention by either Dainton (1968) or Neave (1973). Neave, in placing great importance to the 36 per cent entering science at university, does not account for future dropout rates as the student progresses in a science course. Nor does it account for those students, who after qualifying in science, do not continue in scientific occupations. Friedenberg (1959, 1961); Lewin and Sherwood (1971) have noted this. Butcher (1969) states:

"It appears that in their subject the number of undergraduates studying for degrees in science decreases as their course progresses, but that the opposite applied to students of arts and social sciences."

(Butcher 1969).

Neave's study could be also looked at from the point of view that if it was accepted that there is in fact a 'swing to science', a number of implications for science education would follow.

Firstly, present courses in this case, Nuffield courses, in science must be attracting students at secondary school. Therefore it would appear that there would be no need to change this successful curriculum. This however does not seem to be the case. A number of teachers who have attempted Nuffield science courses with students are highly critical of it. Martin (1970) outlines his case:

> "Teaching is a highly personal art, and the good teacher must, and can only, work from a deep personal conviction. I believe it is useless for him to surrender his intellectual independence and 'toe the party line' ... In fact the very reason why Nuffield Biology is not more popular is that it is such an individual approach, that it does not in fact appeal to a wide range of teachers and pupils."
>
> (Martin 1970).

Ramage (1973) also criticises Nuffield Science in a similar fashion:

> "There is a very real danger that the prestige of the Foundation in other spheres, the frailities of human nature, and the pressures which will be exerted by numerous influential but unwise individuals and groups in the realms of education, will cause the projects, proposals to be accepted too readily and too widely. They would then be prescribed as 'the thing to do' and might even become 'status symbols' for schools. If such things occur, woe betide the heretics among teachers and unfortunate authors of books who do not toe the 'Party Line'. It would be bad for science too."

(The sense of this quotation was first published in 1964, and again in 1967 in the Times Educational Supplement.) The writer goes on:

> "My forecasts proved correct in remarkable detail and woe did betide the heretics, in several ways indicated in the second paragraph of the scientific freedom resolution. However the correctness of one's forecasts provided some compensatory comfort and more is coming with the turning of the tide in our favour. Much of 'Nuffield Science' already looks like an over specialised over elaborated evolutionary blind alley, excessively expensive for payers of taxes, rates, and fees who have had to provide for its implementation in schools. As for the pupils such a surfeit of science at schools could turn away more from continuing with it later than would be attracted to do so."
>
> (Ramage 1973).

Neave implies in his 'swing to science' that currently used courses are successful in attracting students. But other opinions regard these courses as not necessarily good courses. They are being held in high regard to some extent at any rate by a tendency for teachers of science to follow fashion and to toe the party line.

In New Zealand, with centralised administrative control of curricula in biology being held by the Department of Education, the situation outlined by Martin (1970) and Ramage (1973) is compounded. New biology in secondary schools is more than merely being 'the thing to do'. It is in fact compulsory. No choice of curricula or approach for teachers has been allowed. A teacher who for reasons of methodology, does not wish to adopt the prescribed approaches, is therefore more open to being regarded as being 'not competent', 'not responsible', or even 'disobedient' in New Zealand with its new biology courses, than in England and Wales with the Nuffield and other courses. The latter does allow for choice of alternative courses.

This situation, currently present in New Zealand is bad for biology. Biologists, teachers, curriculum makers and text writers hold that 'experiment' is important for science to improve. Yet to experiment with alternative courses at a pedagogical level is not held to be important. Apparently, it is assumed that all experiments by teachers of biology necessary to improve courses and approaches have already been carried out. The present pedagogical formula is the 'best' and only allowable one. To advocate experiment at a subject matter level as most important, and then to implicitly and explicitly muzzle the same procedure at a pedagogical level is paradoxical, and prevents any possible improvements in biological education. Moreover it may create an increased trend in a drift from biology.

Neave seems to be implying that an educational utopia has developed in science. The above criticisms also serve to indicate that this is not the case.

Secondly, it seems that a 'swing from science' to a 'swing to science' can be invoked merely by applying the courses of comprehensive schools to all other schools, no matter the country. But in other countries a marked swing from science is observed. This does not appear to have occurred. A swing from science is occurring throughout the western world in spite of the type of course being used.

Thirdly, Neave implies from his findings that he could indicate causes of the swing not only from science but to science. He does not do this, except to imply that open sixth forms, and wider option systems may be causes of a swing to science. Other studies have shown that the causes are complex. Premature specialisation (Butcher 1969) may be a reason, disillusionment with the activities of science in general (Kranzberg 1972) may be another. Psychological and social factors also contribute. (Friedenberg 1959; Hudson 166, 1968; Cropley and Field 1968; Stenhouse 1971).

Thus there is a danger of accepting this study simplistically. Other evidence which is more comprehensive, disagrees with the notion that comprehensive school (and open sixth forms) systems will create a 'swing to science'. To take an obviously complex problem, and then maintain that it is really simple, would be to accept 'simplistic' notions. This is a dangerous position to adopt. In doing this Neave attempts to bring a great deal of established and reputable opinion on science education into disrepute. (For example Dainton 1968; Friedenburg 1961; Brian 1968; Butcher 1968; Doty and Zinberg 1968; Hudson 166, 1968; Osborne 1973; Thornton

1968; Kranzberg 1972; Ramage 1967).

Few science educators would accept the implications for Neave's research. His research findings may have significance for newly established comprehensive schools. But to claim that the findings are pervasively significant seems to promote 'hope' at the expense of 'fact'. Moreover, entry into New Zealand sixth and seventh forms is kept generally restrictive, although some relaxation of criteria for entry from fifth forms has occurred. Most schools in New Zealand would therefore resemble the selective schools of England and Wales, which were of the type sampled by Dainton.

The Dainton Report, because of its greater comprehensiveness, must be accepted as being more significant than that of Neave. In fact the parallel between Australia and the United Kingdom is very close.

> "The proportion of students entering science based faculties in universities in the United Kingdom in 1962 was 46.0 per cent; in 1966 it was 40.6 per cent. In Australia in 1962 it was 46.6 per cent; while in 1966 it was 40.6 per cent.
>
> Thus it seems that the 'drift' is not merely a local phenomenon, nor is it a passing one. Instead, it seems to be deep seated and pervasive."
>
> (Thornton 1969).

On this basis it seems likely that the situation in New Zealand will be little different from that in Australia and the United Kingdom.

THE NEW ZEALAND SITUATION

The situation in New Zealand is more difficult to assess because of a lack of published statistics. However, two important empirical studies are available (Osborne 1973 and Taylor 1966). Both studies are limited for present purposes in that the Osborne study deals mainly with the 'drift from physics', and the Taylor study deals with teacher qualifications in science education in New Zealand.

Both of these studies place a great deal of the blame upon a lack of adequately trained teachers as contributory factors in the drift. It is interesting to contrast this with Dainton (1968) who did not seem to regard lack of teacher qualifications as significantly as these studies do:

> "A widely held opinion is that science and mathematics teachers in our schools are less well qualified than teachers of arts subjects, and that this inevitably influences school pupils in their choice of specialization. The Dainton Enquiry examined this possibility carefully, and came to the conclusion that little if any factual evidence could be found to support it. Certainly they found that graduate science and mathematics teachers seem to be in short supply, and that a good deal of school mathematics is taught by teachers without scientific or mathematical qualification. But, despite these shortages, the overall quality of science teachers is as high as in any subject."
>
> (Brian 1968)

In the long-term, however, and contrary to the Dainton Report, a continual short supply of adequately qualified teachers may deteriorate in orthogenic fashion. Osborne exemplifies this process:

> "A sustained shortage of physics and mathematics teachers must eventually result in a low standard of physics achievement in schools, a lowering in the

number of graduates produced and a further deterioration in teacher qualifications."

(Osborne 1973).

It appears that 'teacher training' the numbers of practising science teachers and their qualifications are readily amenable to empirical study. For example, Taylor (1966) also devotes a great deal of attention to empirical data:

> "In an apparently representative sample of 188 schools, approximately 100,000 pupils were taught by 4,170 teachers. Of these fewer than six per cent were not, or were seldom, concerned with teaching science subjects, i.e. over ninety per cent were teaching science, the majority for an appreciable proportion of their time. Of those who were involved in science teaching 30.6 per cent were lacking completed academic qualifications containing any science units at all, while 20.9 per cent (i.e. 246 teachers) lack qualifications in science beyond what they have learned at secondary school, or at Teachers' College, while on a course not necessarily designed to fit them for teaching science in secondary schools. The proportion of teachers lacking a completed degree containing science varies with locality, being lowest 7 per cent in Christchurch, 12 per cent to 16 per cent in the other three main centres, and reaching a 'high' of 50.7 per cent in the secondary departments of the district high schools. Worse, there appears to be a trend towards a decrease in scientific qualifications. In 1954 the percentage leaving post primary teachers' colleges with science degrees was 20.3 per cent; by 1965 this had dropped to 15.7 per cent. It seems unlikely that this trend will be reversed in the near future - unless some major reorientation takes place - since despite the increased economic pressure for people to enter teaching simply to get a job, the pressures against obtaining science qualifications are stronger than ever. University science units are demanding of time due to laboratory requirements, and their failure rates are generally higher than in arts subjects (sometimes they are very high indeed) while their money cost to the student is greater. Thus the hazards of attempting to gain science qualifications are great, while the rewards are disproportionately low. Specialist teaching in science in a school demands laboratory space, equipment and material which is almost certain to be in diminishing supply over the next few years - so major investment in science qualifications is likely to get a teacher into nothing but a swamp of progressively increasing frustration."

(Stenhouse 1968).

Osborne and Friedenberg (1961) are quite explicit, and Taylor (1966) implies that the shortage of adequately trained and qualified teachers as the <u>major</u> if not only cause of a 'drift from science'. Dainton (see the quotation of Brian's) notes that teacher qualification is possibly not the only major reason, and that the shortage of good teachers, though important, is not the only cause of a drift from science. It would appear that data is readily obtainable on hundreds of teachers and their qualifications. The use of data is probably a good basis for forceful and convincing agrument by advocates of a drift in student numbers, and a decline in the standard of science teaching. It seems (on the surface at least) that arguing using data and statistics is the best way of impressing policy-makers who need to be convinced, so that a major reorientation is able to be begun in curricula and courses:

> "If there is a genuine shortage of well-qualified teachers of physics then it is desirable that this shortage should be demonstrated in concrete statistical terms."
>
> (Osborne 1973).

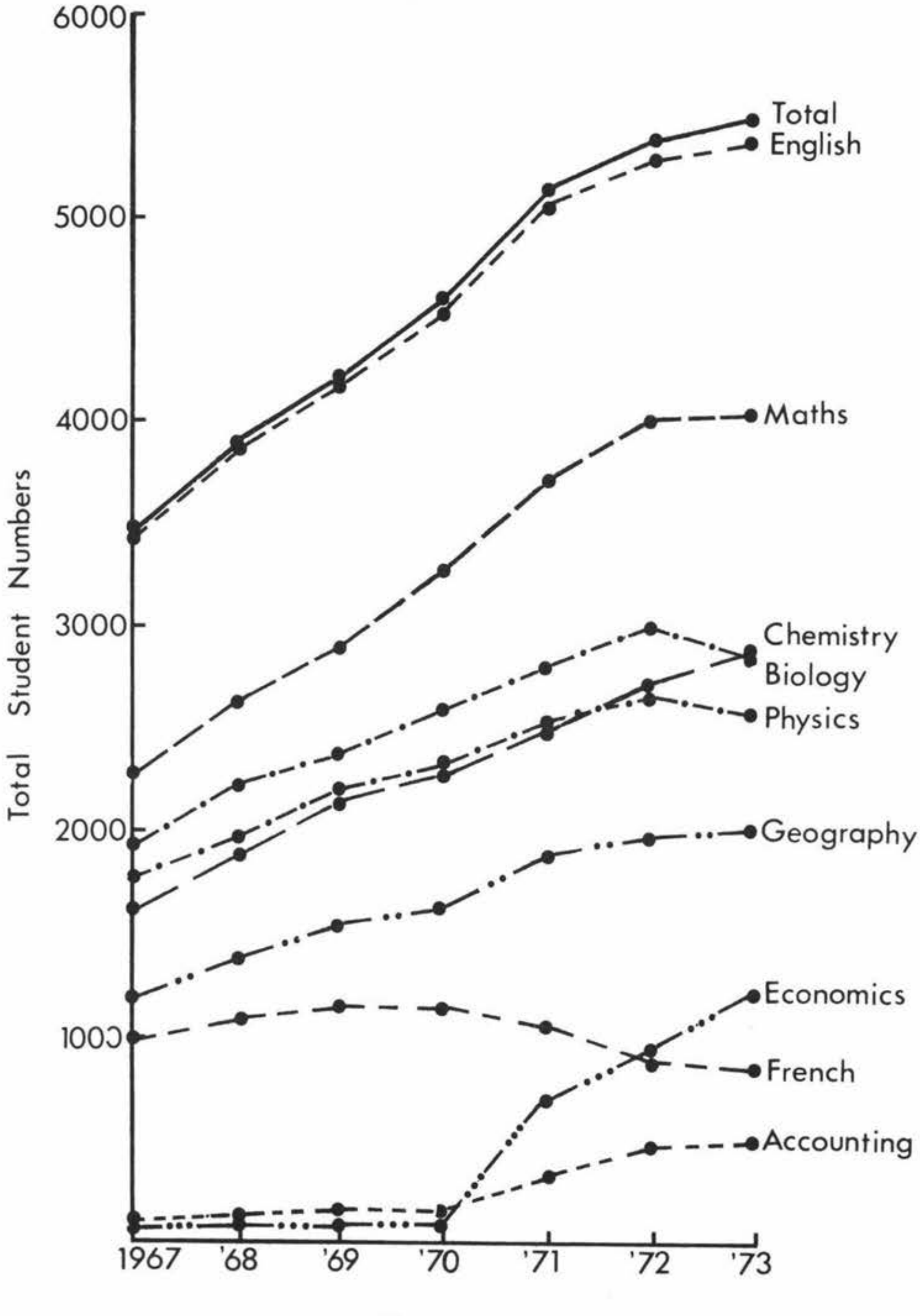
The statistics derived seemed to be 'facts' and few people care to argue with 'facts'. (Stenhouse 1972).

However there are other bases for argument which are probably refactory to empirical methods. Other methods besides the statistical, are necessary to explicate reasons for the 'drift from science'. Some of these reasons, which Dainton describes as complex, will be developed in this thesis, in relation to the 'drift' within the area of biological education. It will be contended later, for example, that 'technicism',factualism' and 'empiricism' are three significant factors which are not able to be quantitatively measured but they do act as contributing causes to a 'drift from biology'. This thesis will attempt to discuss these aspects through argument, and by citing evidence.

However Osborne's study is very important for biological education. It emphasises a need for qualified teachers, and for more teachers. These two factors do contribute (but are not the only causes of the 'drift' or 'swing' from science). It is also an important study, because it is one of the few recent researches made into teacher shortages, and the adequacies or otherwise of teachers. Moreover, Osborne has included more than physics education in his report. He has also been generous in supplying statistics for biology as well, and these deserve discussion.

Firstly, as a general back-drop a graph indicating the situation as Dainton found it in the United Kingdom. (Graph 1 preceding page.) It will be noted that there is a declining trend in the science group, an upsurge in the 'mixed science-arts' group, and an upsurge in the arts group in the sixth forms.

Graph 2 (following page) is a graph kindly supplied by R.J. Osborne which was developed from data supplied by the Department of Education in Wellington. It outlines trends for seventh formers over the years 1967 to 1973. Some discussion of these trends is necessary. Firstly, the numbers of seventh formers is increasing. This is indicated by the Total and by the English curves, as English is a compulsory subject. In reference to the 'basic' sciences, on the surface the situation for biology seems to be fairly healthy. But there is a <u>decline</u> in numbers studying chemistry



Graph2: N.Z. STATE SECONDARY SCHOOLS: SEVENTH FORM ROLL (July 1st returns) After R. Osborne, Nov. 1973.

and physics. A number of elaborations and implications can be made in reference to three sciences.

Firstly, the situation for chemistry and physics is serious. A marked drift in these sciences cannot help but affect entry into special tertiary schools such as mining, veterinary science, medicine, dentistry, areas of applied science, chemistry, and technology. To be faced with a drift in the light of increasing populations of seventh formers to draw from, is a very serious situation. A major implication for biology occurs even at this early stage in the discussion. Current biological curricula are trying to achieve two ends. Firstly, these curricula assume the ultimate unification for all sciences. Apparently biology will become encompassed under the 'physics' umbrella. Secondly, current curricula emphasis is upon biochemistry or molecular biology. New curricula are chemically orientated. The graph shows a decline in numbers of students taking chemistry. If biology continues to stress chemistry, this in itself will create a drift of 'non chemistry' students from biology. Then the trend for biology would possibly be nearer to the pattern for chemistry. Traditional biology did not bar non chemistry students from advancing in biology. Current biology probably does.

Secondly, the situation seems to be advantageous for biology. But this is a superficial observation. The numbers of students studying physics, chemistry and biology <u>as a combination</u> can be no more, probably less, than those who study physics alone. The group with the smallest numbers must be the base. Thus somewhat less than half of the total population in seventh forms studied three sciences in 1972. The situation in 1967 seemed to be better even allowing for the inbuilt coarseness of the graph. What Dainton has described therefore is applicable to New Zealand, and if extrapolations are developed using physics as the 'indicator' subject the situation is likely to become worse. Students studying three sciences, physics, chemistry and biology belong to a group of diminishing size from 1967 to 1973.

Moreover the trends for physics and chemistry have marked repercussions for 'pure' tertiary and applied biology, (veterinary science, dentistry, medicine, food technology, agriculture and horticulture). Perusal of current University Calendars reveals a pattern of pre-requisites for advancing in biology. The pre-requisites, usually invoked at first year levels involve chemistry and physics. A student who does not succeed in either or both of these two subjects is barred from advancement in biology, or any applied fields.

Thus the 'drift from biology' will probably be more marked in university first year courses, than at secondary school. As Rosenhead (1968) has emphasised this trend, now marked in secondary schools, will have far reaching and deletereous effects, especially when New Zealand depends upon biological principles relating to food production and primary industry. The number of pure and applied biologists (including dentists and doctors) is likely to decline in the near future if the selection policies, pre-requisites and orientations presently held in science education in general, and biological education in particular, remain as they are.

The decline noted for physics and chemistry in schools directly affects tertiary level biology. Students who have not studied three sciences - physics, chemistry and biology, are not likely to advance to tertiary biology because of pre-requisites. Thus, just as there is a drift from physics and chemistry, so must there also be a similar drift from advanced biology, despite the apparent healthy state as outlined in Graph 2.

There is also a second important interpretation which must be elaborated upon. Biology is, despite present curricula, an 'odd' subject when compared with physics and chemistry. Many students who are generally 'arts' orientated do opt for biology at senior school levels. Thus a situation may arise where considerable numbers of students in seventh forms study biology but not physics nor chemistry. Graph 2 seems to indicate this when biology curves are compared with physics and chemistry. They may not wish to continue to study advanced biology in future years. If they did wish to do so, the pre-requisites in chemistry and physics would bar them, or at least frustrate them sufficiently to drift away from biology. Therefore the apparent increasing trend in biology, according to the graph may be much worse than indicated. The mixed 'arts/biology' students may in fact be 'masking' a decline which is already occuring at tertiary levels, but which is not readily apparent at seventh form levels. The relatively small increasing trend in biology could then be accounted for by the normal overall actual population increase, and by the effects of students opting for biology as their only science subject, and combining it with arts subjects. Dainton, it will be remembered observed that the mixed arts-science student was increasingly becoming more common. (See Graph 1).

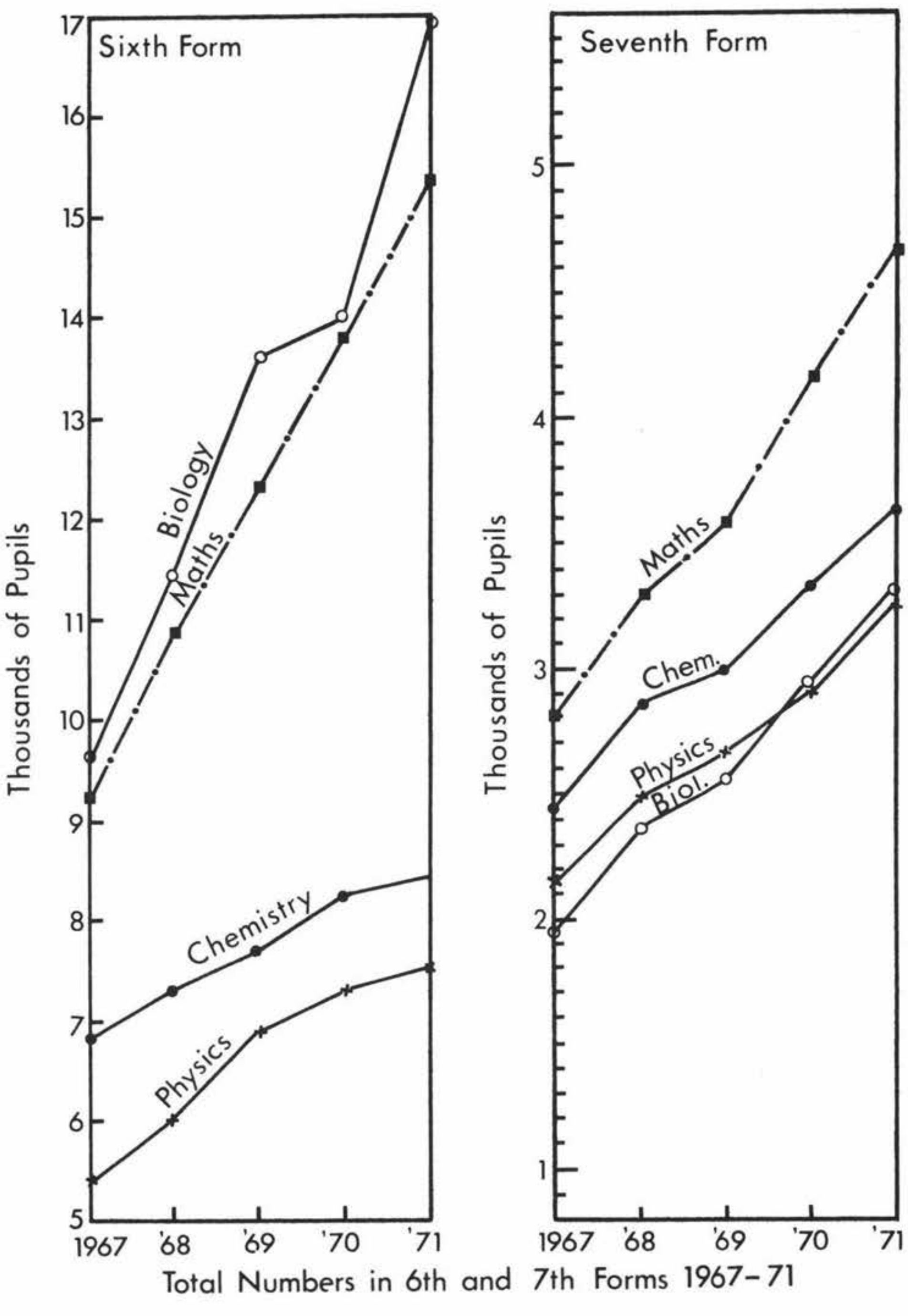
The 'arts-biology' type student is the most likely type of mixed student because current secondary school biology despite mathematical, chemical, and physical concepts being incorporated, is a subject still able to be 'picked up' along the way by students who want a change of option. For example, a seventh former may opt for biology for the first time without previous sixth form study and be successful. To do this for physics or chemistry is more difficult because of the sequential presentation of concepts and principles over a period of years in these two subjects.

It would seem that two factors are contributing to the superficially 'healthy' state of affairs in biology. These are, the effect the increasing overall population of students has on numbers studying biology; secondly, the mixed arts-biology student masks the real situation. But the numbers which advance to tertiary levels are more likely to follow the pattern of physics and chemistry, than the trend noted for biology, because the former two are pre-requisite subjects which are difficult to 'pick up' at tertiary levels. A previous knowledge of physics and chemistry is generally necessary for university physics and chemistry. Attempting to 'pick up' only one of these subjects at university without previous knowledge would be a nigh on insurmountable task.

Thus the situation for advanced biology may be decidely less healthy than Graph 2 indicates. Another most important point to note from Graph 2 at this stage is this. A marked increase in numbers opting for biology occurring during 1970, 1971 and 1972 did <u>not</u> occur as a result of the 'new' biology syllabuses which were instituted during these years. The increase noted could be adequately explained in terms of overall increase in seventh form numbers during those years. An obvious symptom of a need for a 'new' course or syllabus in biology surely must be the dissatisfaction on the part of teachers, curriculum makers of the 'old' course, and students who perhaps are not attracted to the old course or syllabus being used. The new course, apparently a 'better' one, ought to attract more students to it than the older course or syllabus. The attitudes which students hold about the new course will be different (apparently more favourable) than the older course or syllabus. However if reference is made to Graph 2 this does not seem to have been the case. There has been no significant attitude change in the part of seventh form biology students from the old course to the new course which would have created a very marked increase in numbers opting for biology.

Current courses and syllabuses in New Zealand biology maintain that they are able to manipulate 'attitudes'. Traditional courses are not so explicit. By contrast, these older courses never seem to consciously concern themselves with 'attitudes'. It is maintained that 'attitudes' belong to the 'affective domain'. (Bloom et al. 1956). They have deep emotional bases. The 'affective domain' does not seem to be as manipulable as current biological educators maintain that they can be. Selmes (1973) notes some conclusions to an 'attitude' study which he made:

> "The study also found no significant differences between the mean scores of Nuffield and non-Nuffield biology students on the attitude scale used. Several alternative explanations are suggested for this result:
>
> (i) the limitations of the sample of students tested may have produced results which are neither representative of Nuffield or non-Nuffield biology students;



Graphs 3 & 4: TRENDS IN THE SCIENCES AND MATHEMATICS IN SIXTH AND SEVENTH FORMS. After R. Osborne, May 1973.

(ii) both types of biology course (Nuffield and non-Nuffield are producing similar attitudes to science in their students;

(iii) neither type of biology course is affecting the attitude to science of their students."

(Selmes 1973).

Thus it seems to be very difficult to attain measures of attitudes of students in biology.

With reference to Graphs 3 and 4 (the sixth form and seventh forms opposite) some elaboration seems necessary. Taking the sixth form situation first. It will be noted that an increase did coincide with a change in curriculum during 1970-1971. This could be taken as most encouraging for biology. But caution seems to be necessary.

In the first place the increase to some extent is reflected in the actual increase in numbers entering sixth forms, since the recent institution of new more lenient regulations which allow students to enter sixth forms. Secondly, if a course is labelled 'new', teachers are enthusiastic, and students are likely to be attracted to the courses. The past reputation of previous biology prescriptions initially counts for less. A combination of novelty and enthusiasm may therefore be potent influences. Thirdly, the new biology course has not been instituted for a sufficient period to indicate trends at sixth form level. Fourthly, and probably even more significantly the 'mixed arts/biology' student is perhaps more masking in its effects than in the seventh forms. This would account for the large increase in numbers of sixth formers studying biology. There must also be a significant number of sixth form students who do study biology in the sixth form and either leave school altogether or drop out of biology in the seventh form. Moreover, it is probable that the sixth form leavers are likely to be mixed arts/biology types. They see no future in studying advanced biology if it necessitates the study of physics and chemistry. This would probably account for the marked reduction in numbers studying biology from the sixth form to the seventh form. Moreover, as with seventh forms it is the mixed 'arts/biology' student, not an 'arts/physics' nor an 'arts/chemistry' sixth former, which 'masks' the actual situation for advanced biology. Of the three sciences, biology is nearer the 'arts' end of the knowledge spectrum. (Koestler 1964 Page 332). These mixed 'arts/biology' students are less likely to go on to advanced levels in biology because of later pre-requisite problems, where there is frustration and difficulty entailed in picking up physics and chemistry at later stages. Graph 3 and Graph 4 (previously) show that the situation could be explained in terms of a 'drift' of a significant proportion of 'arts/biology' students from biology between the sixth and seventh forms. This drift is further accentuated with the change from secondary to tertiary levels. Few 'arts/biology' students would dare embark upon a biology course at University and expect to succeed.

Yet it can be contended that in losing 'arts/biology' students because of present course structures contributes to a definite disadvantage for both biological education and biological research. It involves the importance of retaining an 'arts-streak' in biology if research is to continue and theoretical biology is to be given due importance. (Koestler 1964).

De Beer, a biologist of great repute, had noted the importance of arts in biology prior to World War II. By contrast, present advanced biology no longer attempts to tap this very large and probably fruitful source for biological research. De Beer states:

> "The War prevented me from making progress with the second method of cure, but Sir Henry Tisard tried it with marked success at the Imperial College of Science and Technology in London. It consisted in offering scholarships for study in science on examinations in which there were no compulsory science questions at all. Only mathematics and English were compulsory. The percentage of students elected to scholarships under this scheme who subsequently obtained First Classes was no lower than that of students who had been awarded scholarships after examination in the science which they had been taught at school. The ability to cross over from arts faculties to science with success, was not unexpected, and in itself it serves to break down barriers between the two sets of subjects. The best men of science whom I have known, began with a classical education, and it may be remarked that two of the greatest British scientists of this century, Sir Darcy Thompson, and Sir Cyril Hinshelwood, one a biologist and one a chemist were Presidents of the Classical Association. Paul Valery is another example of a man for whom there were not water-tight compartments in knowledge."
>
> (De Beer 1969).

A traditional biologist recognises distinct advantages in advocating entry of arts students into biology. Hudson (1966, 1968), a psychologist, also presents telling evidence for this:

> "Two kinds of clever schoolboy were distinguished. The converger and the diverger. These differed not only on the bias of their mental abilities, but also in their choice between arts and sciences in their interests, attitudes, and in their expression of emotion. The converger excelled in the conventional intelligence test; specialised in physical science or classics; held conventional attitudes; pursued technical mechanical interests in his spare time; and was emotionally inhibited. The diverger by contrast, excelled at open ended tests (tests, that is, which do not have a single right answer); specialised in arts or biology; held unconventional attitudes; had interests which were connected in one way or another with people; and emotionally speaking was uninhibited. Such differences have implications both for the study of career choice and-or originality.
>
> (Hudson 1968).

It is possibly that divergent thinking and being highly creative are correlated. Moreover this divergent thinking mode is associated with arts students. Biology students may have more arts orientated, divergent students than the other sciences because of the large mixed 'arts/biology' group in sixth forms, and to a lesser extent in seventh forms. Yet current biology neglects, and almost forces these potentially valuable students to drift from biology through invoking pre-requisite restrictions for advancement to graduate levels. Current biology seems to be ignoring an extensive rich source of possible creativity. Moreover, students likely to be sympathetic to theoretical biology, are probably derived from divergent or mixed 'arts/biology' students. This thesis holds that if 'theory' is incorporated into biological education the 'drift from biology' at advanced levels would be stemmed. If incorporated, theory would also possible capture substantial numbers of these students to the great ultimate advantage of biology. The consequences of neglecting 'arts/biology' students is possibly now being felt in biological research levels. (Zuck 1964; Brian 1969; Weiss 1970; Lellanby 1973; Levins 1973). Research findings seem to be declining, if the above reports of authorities are to be seriously considered.

On the surface the solution for biology seems simple. Merely allowing greater access of advancement to some students from the rich sink of originality, (the 'arts/biology' students) does not mean that biology, especially biological research, would go ahead in leaps and bounds. But it may have significant advantage. Some caution is necessary:

> " ... we would be wise to approach the problem of scientific originality with circumspection. And, although my discovery of an arts bias in tests of 'creativity' may seem damaging, the inferences that we can draw from it are bound to be guarded."
>
> (Hudson 1966).

But because issues such as originality, emotionality, and creativity are complex it does not mean that these issues should be completely neglected in biological education. It may be that a 'drift from biology' would be abated at seventh form and tertiary levels if means of access were given to mixed 'arts-biology' students to advance in biology to graduate levels. Moreover, this strategy in biological education may have long term benefit to biology.

A quotation by Koestler seems to be an apt conclusion:

> "In contrast to the artist, the scientist is not supposed to appeal to emotions, and the student of science not to be guided by them. But we have seen that the equation of science with logic and reason, of art with intuition and emotion, is a blatant popular fallacy. No discovery has even been made by logical deduction; no work of art produced without calculating craftmanship; the emotive games of the unconscious enter into both."
>
> (Koestler 1964).

If mixed 'arts-biology' students are generally ignored by biological education, and they 'drift', then where do they drift to? Hudson (1966, 1968) maintains that divergers have "interests in people". Friedenberg noted and published a trend as far back as 1961:

> "Why do so many American students drop the scientific careers which they have spent several years training for with reasonable success? This

question is likely to seem more patriotic than scholarly to anyone who is a respecter of science both as an area of inquiry and as a method of scholarship. The missile race, with the values it expresses, has tended to put off any serious and disinterested study of what has been happening to competent youngsters who set out to become scientists in our society. Yet, quite apart from any imputation that students ought to have stayed in science, either for their own sake or that of the nation, the 'self image' of the scientist, and the relationship of his culture to that of the humanities, both in academy and in daily life is now a crucial issue in itself. The choice of a profession is the one commitment our culture really takes seriously; this is for keeps, it is not a matter, like love or loyalty, to be continually altered to fit the new circumstances. Conflicts in this area if they are serious enough to make youngsters change their plans dramatically, and follow any discernible common pattern, are social phenomena worth studying."

(Friedenberg 1961).

"Present indications show a substantial upsurge in the social sciences in New Zealand. It seems likely that the mixed arts-biology group is attracted to the social sciences."

(Thornton 1968).

Rosenhead has also outlined some factors in relation to a current 'anti-science' phenomenon pervading science education. He states the situation clearly:

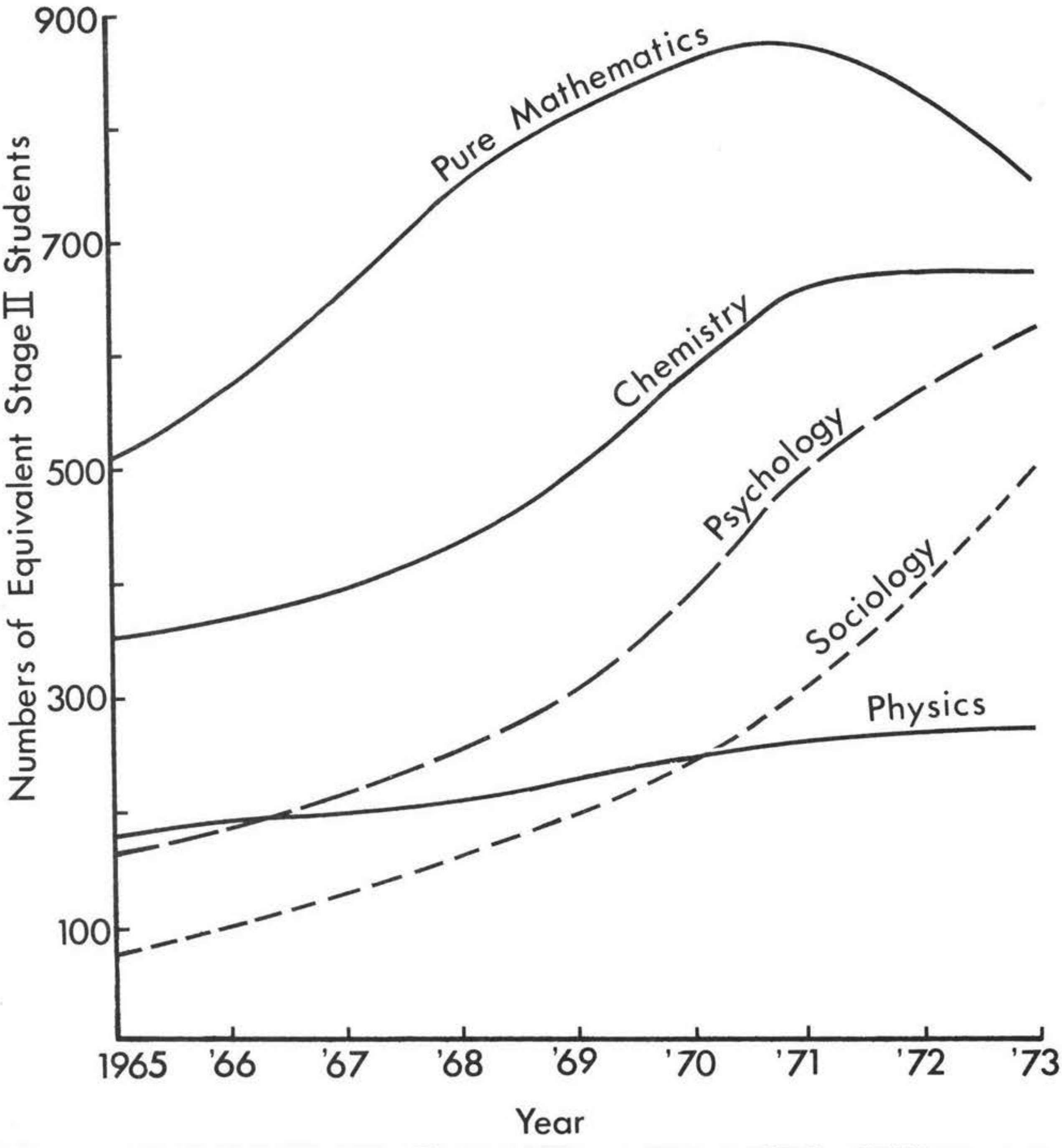
"Of one thing I am sure, and it is that the 'image of science' is no longer as exciting as it used to be. Very few of our young people see themselves as making world-shattering scientific discoveries in a small laboratory isolated from the rest of the world. Science is no longer thought of as the harbinger of the new society, or the vital instrument in the creation of a future in which all men will be brothers. Science they feel,leads to 'the bomb', to bigger and faster aeroplanes, to gigantic electricity generating stations, to computers of frightening complexity, to submarines, to intercontinental ballistic missles - and to the insignificance of individuals and themselves. This picture is distasteful to many and positively repellent to some of our young people, but it is based on a false image of science, and all that engineering and technology can do for people. Further this attitude towards science and to develop-

> ments from it, has arisen in all other highly technological societies of the world, both in schools where science teaching is said to be 'good', and those where it is said to be 'bad'."

(Rosenhead 1968).

A great deal more evidence could be cited in detail on anti-science and disillusionment with science, but t is would be digressing. It is sufficient to say that probably because of distaste for some social implications in science, students may be turning to the social sciences as an alternative. Moreover this trend probably occurs more with the mixed 'arts-biology' student than any other because pre-requisites for the social sciences at university are not as stringent as in the biology fields in which the student may have originally been interested. Furthermore, social scientists would probably not regard this as a drift at all because social science is indeed science. However the swing referred to is that from the more traditional or 'basic' sciences, namely physics, chemistry and biology, (See Graph 5 following). There is sufficient evidence therefore (Osborne 1973) to note that the world drift from science has not neglected New Zealand. Nor is biology immune. Present study trends do indicate a drift from biology at school from sixth to seventh forms and from seventh form to undergraduate courses in biology at university. All this in spite of reputedly updated and 'improved' courses in introductory biology.

From now on the discussion will be confined to the 'swing from biology' which seems to be fairly well established by the evidence and explanation already outlined. It is contended that mere disillusionment is not an adequate explanation for the drift. The causes are complex, deepand educational. As a result, they will be difficult to rectify. But rectification will be less



Graph5 : TRENDS IN N.Z. UNIVERSITY ENROLMENTS SECOND YEAR: 1965 – 1973 (Statistical fluctuations smoothed out) After R. Osborne, Nov. 1973.

difficult the earlier it is attempted. Though the situation for biology is not yet as problematical as that of physics education, the early signs are present and could be dealt with.

There seems therefore to be a paradoxical situation. On the one hand, curriculum makers have enthusiastically modified biology courses. These policy makers were sure that the changes that they were instituting would increase the attractiveness of biology to prospective students. Yet despite this, evidence indicates a 'drift'. What are the factors which are likely to contribute to this drift in biology? Is the 'new' biology as extraordinarily advantageous for biological education and biological research as has been assumed by current policy makers in biological education? Answers to these questions need to be obtained, it is contended, if biological education is to sustain its contribution to national, even global wellbeing. Already it has been noted that the factors which contribute to the drift seem to be many and complex (Rosenhead 1968; Butcher 1969). An attempt will be made to identify some of the factors contributing to this accelerating drift.

Introductory biology is most significant in attracting students to the subject. This places a great deal of responsibility for the drift clearly on the shoulders of introductory biological education. Scientific interests seem to develop at a very early age (Butcher 1968). Many scientific interests begin with biology. Very young children seem to have a natural curiosity for living things (Comstock 1911; Leach 1946; Beggs 1954). Children are favourably disposed to nature-study while at primary school. There is therefore a change from 'pro-attitudes' to biological phenomena (Stenhouse 1968) toward more reluctant - even 'anti attitudes' by the time these formerly keen children have entered seventh forms. We must therefore assume that a large proportion of children reaching secondary school are interested in biology. Science (including biology) is a compulsory core subject for two years until the fifth form. At the start of a fifth form year, choice of subjects can be made through an option system. A choice between arts and sciences is often made at this point. If sciences are chosen, there is little opportunity for a change to arts until the student leaves school. If studying the sciences, the student is committed to the sciences, and the same for arts. The student commits himself for the rest of his school career from the fifth form. Some elaborations have been made about this:

> "Psychological, motivational, economic and sociological factors work together over a period of several years to predispose an individual towards a particular type of occupation, while his opportunities in other directions become limited by his education."
>
> (Nature, Vol. 217, March 23, 1968).

> "Scientific interests are often obvious by 8 or 10, and by mid-teens, the choice between science or arts has usually been made. Because of the way the educational system is organised revision of choice of occupation becomes less possible as an individual progresses up the school."
>
> (Nature, Vol. 217, March 23, 1968).

The system seems to be organised in a manner where choice becomes narrower as one progresses through the secondary school system. The first major opportunity for course change occurs at the break from school to university. This seems to be the point at which the drift most clearly manifests itself.

> "Undergraduate education in science comes after a long and varied exposure to science and mathematics in primary and secondary school. The quality of this earlier encounter is probably the most decisive factor in determining attitudes and motivations of

> students for further science study and in generating the sustained generation that a career in science so often requires. It is typical of the state of educational research that little effort is being made to evaluate this experience."
>
> (Doty and Zinberg 1972).

It would seem that if the population is more or less captive and committed, then there is little need for courses to be made attractive and interesting to students. The 'drift' at the end of a secondary school career seems to indicate that policy makers and administrators find it more expedient to enforce a single unattractive near compulsory course upon students, than to attempt a more difficult task in trying to elucidate characteristics in biology which would attract and hold students and also to develop varied courses and curricula. In the short term the 'compulsory' strategy seems to work. However in the long term, biological research, and biology in general is likely to suffer.

McPherson (1968) puts the dilemma succinctly when he states:

> "If science were compulsory, it must be attractive; if not attractive, it will suffer if made compulsory; and if it were attractive it would not need to be compulsory."

WHAT IS THE 'NEW' BIOLOGY?

Perusal of recent text-books in biology shows that periodic reference is made to the 'new' biology. (Puck 1967; Platt 1968; Chedd 1972). Detailed investigation of this 'new' biology indicates that it has a molecular basis. Many current text-books in introductory biology, have in their introductory chapters, detailed bio-chemistry outlines which are regarded as a necessary pre-requisite for any serious student. This often involves details of sub-atomic structure and valency. (See Weisz 1967, Chapters 3 and 4). Titles of some early chapters in presently used text-books of biology may serve as evidence for this chemical emphases; "Elements and Molecules" (Berrill 1966); "The Molecular Basis Of Life" (Villee 1967); "The Chemicals Of Life" (Weisz 1967); "The Chemical Basis Of Life" (Otto and Towle 1969).

What is this 'new' biology? How does it differ from traditional biology? It is intended in this section to outline some of the characteristics of the new biology. Extensive use of quotations, mainly from text-books, will be used. From these quotations several key issues or essential features pertaining to the new biology will be developed for later discussion. These key issues will be discussed in detail to show what appear to be weaknesses in the new biology. Then some points of rectification for biological education will be discussed.

Over the last few years, there has been in education considerable effort made in formulating and instituting new courses and curricula. These particular curricula are usually prefixed with 'new'. 'New' mathematics, 'New' science and 'new' English are often heard labels. It is not surprising that recently modified courses in biology have also been labelled 'new'.

However the molecular orientation may not be as new as commonly supposed. Simpson (1969) maintains that what is labelled 'new' biology is in fact very old biology - older than what today is called evolutionary biology:

> "It is not true that molecular biology is a new science, which has taken over (or could conceivably take over) where evolutionary or organismal biology leaves off. (For that matter it is not true that evolutionary biology has left off.) The oxygen cycle in both animals and plants was already well known in the eighteenth century, and the origins of molecular biology can be traced even further back. It already had long existed as a speciality when it entered a new era by Wohler's synthesis of urea in 1828. Evolutionary biology hardly existed before 1859. Thus molecular biology is in fact, older than evolutionary biology, although it is true that some organismal aspects of biology antedated them both."
>
> (Simpson 1969).

Layton, an educationalist, agrees with Simpson when he notes that biological education is not 'new' at all.

Curricula in current New Zealand biology place a great deal of emphasis in their preambles entitled 'aims and objectives' upon knowing facts, understanding principles, and knowing the procedures of science. These are considered to be some characteristics of the 'new' biology. Indeed it is sometimes claimed that the inclusion of a preamble stressing these three aims and objectives as 'novel' ("Form Seven Teachers' Guide" 1970 Page 2). Texts also emphasise these three general features. It is claimed that the above features are 'new'. Yet Layton (1972) maintains that these emphases claimed as new marks not the start, but the end of an era:

> "Science has now, like classics, to re-establish itself as an effective instrument of general education. How is it meeting this challenge? To what extent has the breadth and humanity advocated by the Dainton Report been infused into school curriculum?
>
> ... Nuffield O-level biology, chemistry, and

physics projects, far from ushering in a significant period of curriculum reform, are more properly seen as signalling the end of an era. They round off just over a century of science education in which the emphasis has been placed in varying degrees on the achievement of two broad objectives - first, an understanding of the conceptual structures of science, science as a body of knowledge, and second on an understanding of the procedures of science, science as a process. Present day educators have no monopoly on these objectives which date from the origins of school science teaching. Certainly as long ago as the 1840s, Tyndall and Frankland were teaching what we would codify as 'Nuffield Science' at Queenwood College in Hampshire."

(Layton 1972).

What seems to be applicable for Nuffield biology seems to be also appropriate for New Zealand biology. Current New Zealand biological education deals with experimental procedure and accumulated factual knowledge. These characteristics are old.

Furthermore there seems to be differences of opinion among reputable molecular biologists as to the precise nature of 'new' biology. Stent (1968) emphasises this point when he states:

"Kendrew, ... begins his appreciation of "Phage and the Origins of Molecular Biology" by asking what molecular biology actually is. He points out that he is aware of the biochemist's view that so-called molecular biology is naught but the unlicensed practice of biochemistry. But, Kendrew writes, 'Molecular biologists themselves are by no means unanimous about the nature of their subject. To anyone brought up in the British school of molecular biology, as the present reviewer was, it is a little odd to find in nearly every contribution to this book the explicit or implicit assumption that molecular biology had its only real beginnings with the phage group, and that the central theme of the subject is biological information.' This emphasis on information is odd because W.T. Astbury, one of the originators, and first propagandisers of the term molecular biology defined it as follows: 'It (molecular biology) is concerned particularly with the forms of biological molecules and with the evolution, exploitation, and ramification of these forms in the ascent to higher and higher levels of organisation. Molecular biology is predominantly three dimensional and structural - which does not mean that it is merely a refinement of morphology. It must at the same time inquire into genesis and function.'

Thus Astbury's definition does not even mention biological information or genetics. But, by the time the term 'molecular biology' had become popular in the 1950's and many a research and university department had been organised under that name its meaning had evidently widened to include molecular genetics. And as Kendrew points out, though molecular geneticists are interested in such matters as the D.N.A. double helix, their interest in the structure is not 'geometrical so much as topological: the one dimensional (rather than the three dimensional) nature of the information store and the role of the specific pairs of nitrogenous bases in replication.' Thus there have existed and there still exist two schools of molecular biologists - structurists and informationists."

(Stent 1968).

Text-books do not review or note these controversies at all. In the interests of clear uncluttered exposition, they seem to accept a simple formulation for molecular biology:

"The ultimate aim of the modern movement in biology is in fact to explain all biology in terms of physics and chemistry."

(Crick 1966).

Text writers in biology, especially in more recent text-books, seem to accept the position adopted by Crick. The following quotations have been extracted from a selection of commonly used text-books:

Firstly, molecular processes and the unification of all the sciences are emphasised:

"In biology, the most rapidly advancing field at present is molecular biology. This terms refers to the postulate that biological processes should be described at the molecular level. The implication is that if a process has been completely described at the molecular level there is nothing else to describe. This approach has been very successful, and has led to an understanding of gene structure, of the energy turnover in the cell, of the processes of nerve conduction, and many other phenomena. In addition, molecular biology has contributed more than any other single factor to the development of the unity of the natural sciences which we are witnessing at present."

(Caspari 1964).

Experiment, quantification and physical aspects are also stressed:

> "Molecular biology has emerged from an intermingling of biology, chemistry, and physics. Its subject matter is life; its experimental techniques are frequently mathematical and physical. Its language like the language of all science becomes increasingly unnatural, precise and mathematical."
>
> (Smith 1968).

> " ... Science is essentially quantitative and metrical. Until the advent of molecular biology, the science of biology, or large tracts of it seemed to escape this characteristic. Molecular biology is a thoroughly quantitative science."
>
> (Smith 1968)

> "In any case scientific biology has two principal characteristics: the insistent belief that organic structure and function will find their explanation in terms of sub-microscopic units (molecules and their parts) whose properties are in turn expressed by laws of chemistry and physics, and the steady quest for relations among facts rather than isolated facts alone - relations expressed as empirical laws when nothing else is available, but preferably (as soon as the state of our knowledge permits) broader and more fundamental relations, and systems of relations (theories), expressed in a language that is appropriate to science; formal rather than colloquial."
>
> (Reiner 1968).

> "Perhaps for the first time - or at least far more clearly and insistently now than ever before - the key theme of scientific biology is becoming a reality instead of a pious hope.
>
> That theme is the development of a unified and quantitative theory of how living organisms function, expressed in terms of the most fundamental explanatory concepts that can be used."
>
> (Reiner 1968).

Many text-books emphasise the apparent necessity for chemistry as a pre-requisite for biology:

> "Basically, all cells function through the mechanism of chemicals in interaction. The material of which cells are composed is, of course, chemical

as is the mans by which their protoplasm and organelles are formed and their activities carried out. Therefore it cannot be emphasised too strongly how important it is to have a basic understanding of certain aspects of inorganic and organic chemistry in order to comprehend cellular structure and function. Biology at the cellular level is largely chemistry and physics."

(Phillips 1971).

Secondly:

"Biology expanded and altered greatly in the nineteenth century, and has continued this trend at an accelerated pace in the twentieth. This is due in part to the broader scope and more detailed knowledge available today, and in part to new approaches made possible by the discoveries and techniques of physics and chemistry. These technical advances have led to quantitative analysis of the molecular structures and events underlying biological processes, a facet of the science has been termed molecular biology. This includes (1) analyses of gene structure and function, and of the mechanisms by which genes control the syntheses of enzymes and other proteins; (2) studies of sub-cellular structures and their roles in adaptive and regulatory processes within the cell; (3) investigation of the mechanisms underlying cellular differentiation; and (4) analyses of the molecular structure of specific proteins - hemoglobins, enzymes and hormones - in different species. Many of these studies, for technical reasons, have used simpler micro-organisms, bacteria and viruses, but the principles discovered appear in all living things. These investigations, indeed, have re-emphasized the fundamental unity of life."

(Villee 1967).

Analysis is an important strategy at present for obtaining biological knowledge:

"Over the decades the frontiers of biological investigations have been pushed into smaller and smaller realms. Some 100 to 150 years ago, when modern biology began, the chief interest was the whole plant or animal, how it lived, where it could be found, and how it related to other living things. Such studies have been carried on ever since but, in addition, technique gradually became available for the investigation of progressively smaller parts of the whole, their structures, their functions, and their relationships to one another. Thus it happened that during the past few decades, the frontiers of biology were pushed down to the chemical level. And while research with larger biological units continues as before, <u>the newest biology attempts to interpret living operations in terms of the chemicals which compose living creatures.</u>

Biology here merges with chemistry. Today there are already many signs that the next frontier will be the atoms which in their turn compose the chemicals, and biology tomorrow will undoubtedly merge with atomic physics. Such a trend is quite natural; for ultimately living things are atomic things. Penultimately they are chemical things, and only on a large scale are they plants and animals. In the last analysis, therefore, biology must attempt to show how atoms, and chemicals made out of atoms, are put together for form, on the one hand, something like a rock or a piece of metal and, on the other, something like a flower or a human baby. This book is an outline of how successful the attempt has been thus far."

(Weiss 1967).

Weiss (1967) the author of a current text-book commonly used in secondary schools, stresses the ultimate unity of the basic sciences through reducing biology ultimately to physics. He makes minor reference to 'organismic' biology, assuming that the 'newest' is also the 'best'. Key issues emphasised with these quotes are analysis, quantification and the ultimate unity of science. Villee (1967) also makes scant reference to traditional aspects of biology. The 'new' biology is molecular in orientation.

The argument which seems to have been accepted by text-book writers and curriculum makers can be presented as follows:

(A) All matter obeys the laws of physics and chemistry.

(B) Organisms are composed of matter.

(C) Therefore organisms obey the laws of physics and chemistry.

On the surface, this seems to be a perfectly acceptable situation. Just as chemistry (beginning from alchemist origins) has come under the umbrella of the laws of physics, biology, it seems, is also maturing, as it takes on the laws of chemistry and then physics. It would seem that it is but a matter of time before unified science reaches a culmination. After all splintering within the sciences is currently a problem, and a unified single science with similar concepts and methods is most desirable. (Bohm 1970).

But this position, if it is agreed to, creates problems. Physics apparently is the ultimate 'mature' science. All other sciences therefore must be at different temporary stages of development toward maturity. Molecular biology is closer to physics than the 'old dogfish/earthworm' biology. Already the laws of physics and chemistry can be invoked in molecular biology. If this is the case, then it follows that molecular biology is a temporary subject for biological research and for biological education. 'New' biology is thus merely a passing phase in biological education. Furthermore, if curriculum makers continue to formulate these temporary courses, then it would appear that they could be guilty of inculcating emphases which may be more fashionable than permanent or educationally valuable. (Ramage 1973).

Moreover, would reputable molecular biologists admit that 'new' biology is but a short term temporary affair? If they agree to the statements by Crick and others, then they must also agree that ultimately, molecular biology will become anachronistic in research, and in biological education.

It may be that 'new' biology is indeed temporary, if heed is taken of the following statement which is part of some conclusions of a national study in the United States of America:

"The basic research performed by federal and state agricultural research organizations is of meagre quality, suffers from a "shocking lack of intellectual leadership", and is guided by policies detrimental to the interests of agriculture. This is the opinion of a number of well-known academic scientists who studied the agricultural research enterprise under the auspices of the National Academy of Sciences. (The report states that) ... The present health of agriculture - related to biochemical research is not only poor, but deteriorating.'

... Basic work on photosynthesis, the panel asserts, is 'almost without exception carried on in private and state universities and research institutions without support from the U.S.D.A. (The Department of Agriculture).

... of 56 papers on photosynthesis presented by U.S. participants at the 1969 International Botanical Congress, only two acknowledge support from the U.S.D.A."

(Science, Vol. 180, No. 4084, April 27, 1973 Pages 390 - 393).

The quotation indicates that in the field of molecular botany, the amount of significant research seems to be declining. A reason for the apparent "shocking lack of intellectual leadership" may rest with the basically 'non theoretical' position upon which current molecular botany and 'new' biology in general adopts. This important quotation will be discussed in detail later. All that is intended at this stage is to use extensive quotations to show what characterises the 'new' biology.

Mounting criticism can not only be found about the 'new' biology in biological research. Biological educators, albeit few in number, have voiced concern. Much of what is said is of the following tenor:

"As a biologist who has been engaged in biological further education for fourteen years, I feel compelled to express my growing concern over the current obsession with one-sided syllabus developments.

Certain educationalists in high places have become convinced that biology can be equated with one discipline such as biochemistry.

No biologist today can fail to be aware of the great excitement and intellectual stimulus of recent developments in, for example, the field of nucleic acid control of cellular events, b t may I appeal, somewhat plaintively, to any biologists who feel that other aspects of our subject such as embryology, gerontology, genetics, evolution, ecology, animal and plant phsiology, parasitology, and immunology are important, to stand their ground in the face of increasing pressures and to speak out in favour of some of these studies, which may otherwise become neglected, or totally disregarded because of pressures to get time for more chemistry supporting more biochemistry. I also feel the danger that non-biologist principals and influential members of committees <u>may come to regard biochemistry as synonymous with biology</u> and that they may be prejudiced in this direction by specialist advice which is not necessarily representative of the majority of contemporary biologists. After all, nobody would expect modern physics syllabuses to become exclusively concerned with nuclear physics, and surely a hasty swing towards one branch of our own subject may produce harm in succeeding generations of students."

(Bennet 1968).

WHAT ARE THE ESSENTIAL FEATURES OF THE 'NEW' BIOLOGY?

Noting the quotations previously outlined, a few essential features of the 'new' biology can be observed. It is intended to outline these as essential features:

I Emphasis upon detailed functional mechanisms.

II Stress upon quantification.

III Emphasis upon 'practical-experimental' biology, in contrast to 'mere' observation.

IV A 'unified science' is possible.

V 'Enquiry processes' are important.

VI The downgrading of botany in biology.

VII Educational 'precociousness' in biology.

VIII Emhpasis upon the 'central dogma' of molecular biology.

IX The downgrading of 'theory' in biology.

This is not an exhaustive list. Other features could be outlined, but the above seem to be some major ones.

Essential Feature I - Analysis And Detailed Functional Mechanisms.

It is assumed that the more biology analyses and describes, the more basic the processes will be when observed.

Analysis simplifies biology. The 'principle of parsimony' is important. All apparent complexities or intervening variables are pared away. Eventually a stage is reached in the analytical process where apparently only the 'essentials' remain. This analytical strategy tacitly assumes that the level below is more basic than the level above. Biological text-books commonly outline 'levels' in the following manner:

The Hierarchy Of Levels In The Organisation Of Matter.

Elementary Particles

Atoms

Compounds

Organelles

Cells

Organisms

Populations

Communities

Biomes

Biographic Regions

Biosphere

(After Weiss 1967).

Current biology stress the range from cells to elementary particles, but neglects the other levels. Crossland (1971) has developed a method which conveys relative emphases of levels in biological text-books. This method has been extended to include 'theory'. The graphs which follow have been developed using Crossland's method.

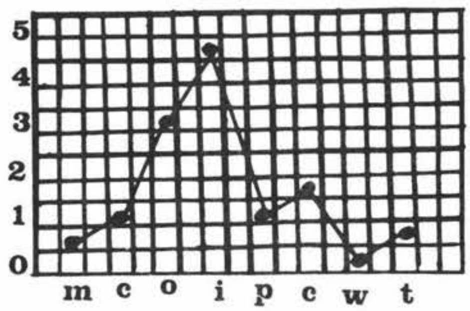
Key To Levels Of Biological Organisation.

Molecular Level	-	M
Cellular Level	-	C
Organ and Tissue	-	O
Individual Organism	-	I
Population	-	P
Community	-	C
World Biome	-	W
Theory	-	T

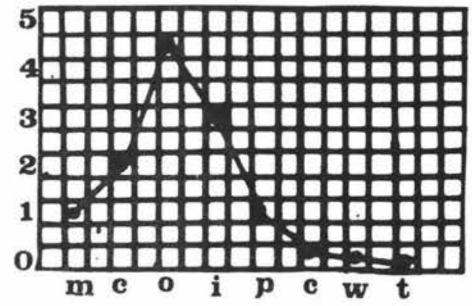
(After Crossland 1971).

Method.

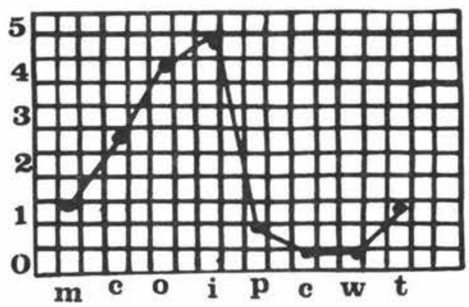
The evaluations of the texts were obtained by Crossland using some text readers (teachers, and biology gradustes). After reading a text, a reader selected the level, which in his opinion, was given greatest emphasis. The greatest emphasis was given a maximum of five on a 0 - 5 scale. The reader then estimated the other levels by comparison with this highest level. Then the results were graphed. Crossland's graphs in the following group, are those relating to Nuffield Biology (1966 - 67), Cooke, Burkitt and Barker (1953), and MacKean (1965). The others were developed by the author but with some senior secondary school students of biology to assist as readers. The graphs are as follows:



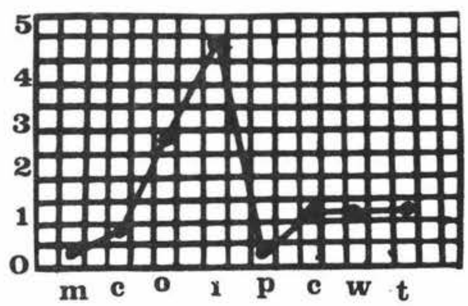
Cooke, Burkitt, Barker.



Mackean.

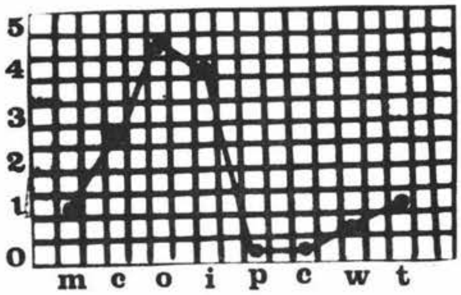


Mavor.

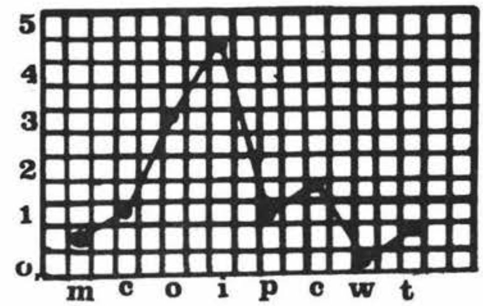


Wheeler.

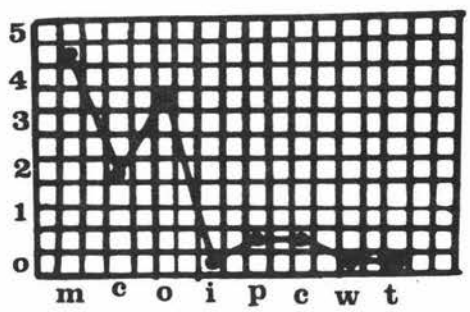
PROFILES OF RELATIVE EMPHASES ON BIOLOGICAL LEVELS OF ORGANIZATION. TRADITIONAL BIOLOGY TEXTS.(Letters indicate levels. Numbers indicate emphases.) Developed from Crossland, March 1971.



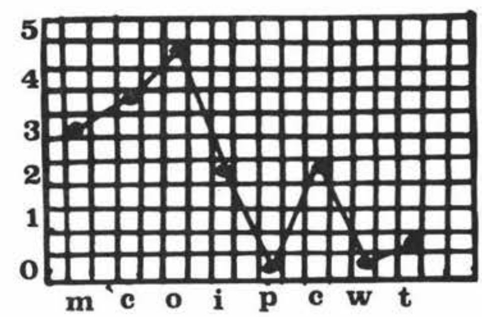
Berrill.



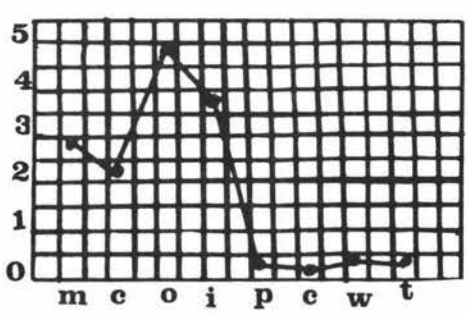
Department of Education



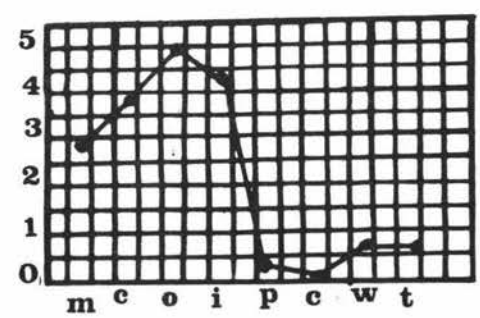
Phillips.



Smallwood and Green.



Villee.

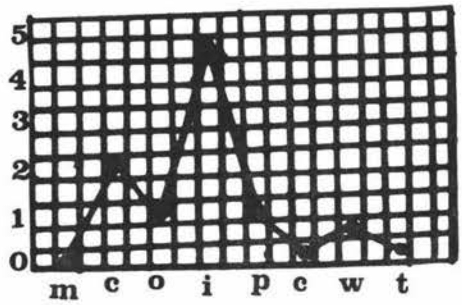


Weisz.

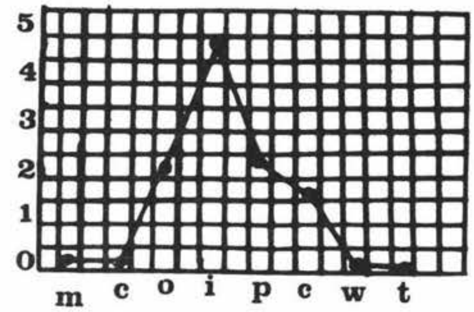
PROFILES OF RELATIVE EMPHASES ON BIOLOGICAL LEVELS OF ORGANIZATION. NEW BIOLOGY TEXTS.

(Letters indicate levels. Numbers indicate emphases.)

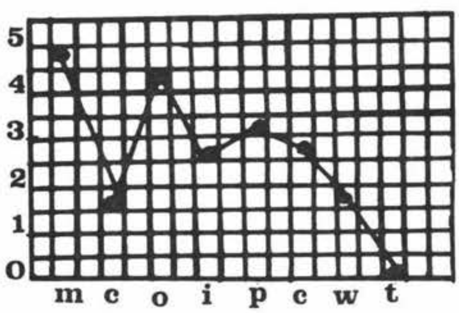
Developed from Crossland, March 1971.



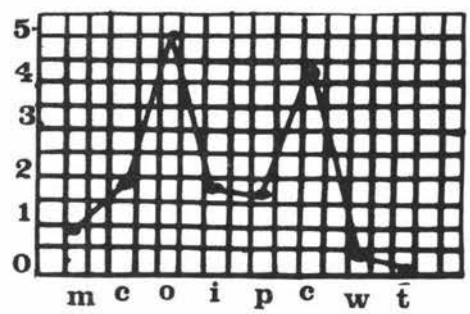
Nuffield 1.



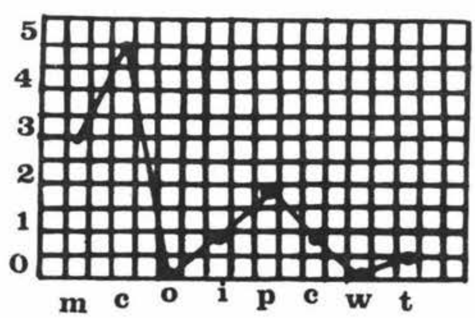
Nuffield 2.



Nuffield 3.



Nuffield 4.



Nuffield 5.

The analysis of course is open to criticism. Namely that it is not detailed and objective. Yet it does serve to stress general emphases in biological education.

The major point of discussion is the emphasis presently used texts place on the left hand side of the graphs; the marked neglect of the right hand side. The molecular and cellular levels are given a much greater amount of emphasis. In traditional 'old' biological texts, stress is placed upon the 'organ-tissue' and 'individual' levels. However both the traditional and the modern biology texts seem to emphasise the organ-tissue level. But on further investigation it is found there are marked differences at this level. For example, a traditional text-book would emphasise tissue structure and briefly describe a few essential functions. Modern text-books, by contrast, go into a great deal of analytical and causal detail. Much of this 'function' is at molecular, atomic, and even ionic levels. For example, the greatly detailed sequential steps of the respiratory pathways are commonly outlined in current texts. Photosynthesis, excretion, muscle contraction and protein synthesis are further examples. Though the 'organ-tissue' level is usually near top priority whether in new or old biology texts the emphasis within the level has changed. If analysis is given importance, then the number of descriptive labels must also increase.

A major consequence is that students today find that they are required to deal with masses of descriptive detail. This problem will later be discussed under 'factualism' in biology.

Essential Feature II - The Emphasis Upon Quantification in Biology.

> "The highly developed language of science makes the subject matter opaque to the uninitiated. Any form of mathematical treatment - and after all mathematics has been said to be the language of science - immediately diminishes the potential readership."
>
> (Smith 1968).

Quantitative biology is emphasised in two ways. Firstly, there has been an upsurge in the use of statistics with the incorporation of population biology. Secondly, biochemical aspects are amenable to mathematical formulations. The 'new' biology thus incorporates a great deal of information at the physiological level, which is amenable to quantification. Smith (1968), (quoted) seems to regard favourably the reduction in potential readership through mathematical pre-requisites for biology. (Apparently 'quality' of biology students holds greater priority than 'quantity'). In view of the marked 'drift' from science, and this drift does not exclude biology, this tactic if applied at introductory levels, would probably enhance the trend. Smith goes so far as to imply that the drift is a good thing. Other reputable scientists disagree. (Brian 1969). Current courses, curricula and text-books stress mathematical aspects. For example, the following outline refers to the use of statistics in a current biological prescription:

> "Students should be familiar with the following ideas and techniques by the end of the course:
>
> - randomness, change and probability
> - methods of data presentation; frequency distributions, graphs and tables
> - simple differences between samples and populations; statistics and parameters
> - sampling techniques including simple random sampling and simple systematic sampling

- hypothesis formulation and testing using the Student's t and/or Mann-Whitney U tests and Chi-square
- the nature of type I and type II errors, two tailed and one tailed tests. "

("University Bursary/Scholarship Biology" Form Seven Teachers' Guide, Department of Education. N.Z. 1971 Page 53).

Essential Feature III - The Emphasis Upon Practical Experimental Biology In Contrast To "Mere" Observation In Biology.

Current biological curricula in New Zealand also appear to stress 'the practical aspects' of biology. A situation seems to have developed where 'the practical' is opposed to, or surpasses, 'the theoretical'. In doing this, curriculum makers in New Zealand biology courses would appear to agree with the following commonly held conceptions:

> "Throughout the course great emphasis is placed upon practical work, and the development of associated skills ... Emphasis is placed upon the development of intellectual and practical skills which are fundamental to an understanding of biological science."
>
> ("University Bursary/Scholarship Biology" Form Seven Teachers' Guide. Department of Education. N.Z. 1971. Page 5).

In advocating practical biology, biological policy makers seem also to be deriding theoretical biology. Theory, and theorising seems to have become antithetical to the practical. The notion 'practical biology' needs further elaboration. Practical biology takes on a number of meanings. Five will be elaborated which are currently applicable to biological education.

Firstly, 'practical' biology can be regarded as 'applied' biology. 'Applied' biology is that biology which is closely related to national economics. The work of an 'applied' biologist is 'useful' in the immediate sense. 'Pure' biology contrasts with 'applied' biology, in being not immediately useful to the national economic interest. Usually 'applied' biological research is more readily funded than 'pure' biological research, even though the 'pure' biological research may, at some time in the future, even take on 'applied' characteristics. For example the study of echo-location in bats, originally 'pure' biology, later became 'applied' with the development of radar and 'seeing' spectacles for the blind.

Current biological education places great emphasis upon 'applied' biology:

> "A close contact of seventh formers with working biologists is very desirable both to see the job relevance of biological studies as well as some of the practical issues involved, in the application of biological concepts and methods. If possible, students should have opportunity to meet practicing biologists in malt-works, medical laboratories, sewage treatment plants, fisheries, landscape design, farm management etc. Discussions with these people could be followed up with project work and related experimental work."
>
> ("University Bursary/Scholarship Biology. Form Seven Teachers' Guide. Department Of Education. N.Z. 1971. Page 2).

Being practical within the context of current biological education in New Zealand may therefore mean 'associate with 'applied' biologists and observe them at work'. This emphasis places a vocational stress upon current biology. It may be carried on with the specific intention of gaining recruits into 'applied' biology. Attractive salaries with accompanying high social status may act as a further potent incentive. 'Pure science' and/or 'theoretical science' would probably appear much less attractive to novice students.

Moreover, the marked stress where practical work encompasses 'applied' biology seems to reveal a concern by curriculum makers that introductory biology must have 'relevance'. This could be called an <u>instrumental function</u> of present practical work. It is an attempt to show students that not all they learn is 'vague and unimportant'. In emphasising this aspect, curriculum makers seem to be assuming that a great deal of biology is, or has been, irrelevant in not being vocationally orientated. It would also appear that the curriculum formulators are not fully aware of the function and nature of 'pure' biology. It can be noted that 'applied' biology must rely upon 'pure' biology. Brian (1969) notes the need for advocating both in biological education:

> "I can speak from experience of the value of teaching pure and applied science in the same department. At the University of Glasgow, agricultural botany and pure botany have for many years been taught in the same department, agricultural zoology and pure zoology similarly. The two sets of students share some courses in common but separate for others. The intellectual stimulus to the students themselves arising from the interaction of two different backgrounds is immense and it is possible to provide far better teaching for both lots than two small departments could achieve."
>
> (Brian 1969).

A second meaning to 'practical work' could be 'field work'. Ecological type exercises are emphasised in most biology courses. In general these activities stress quantitative procedures (transects and quadrats). Little attention is paid to extensively observing organisms in their natural habitats in the manner of a natural historian. This is apparently subjective. Counting, data collection and collation take precedence over extensive observation. This relates to current deriding of theory in biology. Theory and observation are closely related. (This will be discussed later.)

Thirdly, being 'practical' may involve doing laboratory work with equipment (microscopes and glass-ware). This meaning is also emphasised.

> "The prescription seeks to develop the following skills ... the use of practical techniques of biological investigation: the ability to handle scientific apparatus, to observe and record accurately, and to handle the quantitative information, and assess error and degree of significance."
>
> (Department Of Education. N.Z. 1971. op.cit).

Fourthly, doing practical work may be taken to mean working through exercises from supplied laboratory manuals. Stress is currently placed on laboratory manual work.

Some Features Of Laboratory Manuals.

Published with some text-books and courses, are specially designed laboratory manuals which, if worked through, aim to develop skill in handling biological apparatus. For example the Department of Education in New Zealand has published a Laboratory Manual for sixth forms entitled "Biological Science: Processes And Patterns Of Life", Laboratory Manual, '9/O. A cyclostyled manual has been supplied for seventh forms.

Many exercises in these laboratory manuals involve strict obedience to a particular sequence of steps in the manner of a cookery book. If not, the 'answer' (in this case usually an observed colour-change or a measurement) is not obtainable.

Teachers and students are frustrated if a laboratory exercise does not 'work'. That is, the exercise does not consistently reveal the 'right' observation at the end of a sequence of instructions. They could of course, use the 'wrong' result as an avenue for discussion. But time is at a premium, and most teachers will not repeat laboratory exercises which have previously not 'worked'. Therefore a selection process has occurred. Most which are published will, with care, 'work'. However this selection process has brought with it major sacrifices.

It has been found that exercises dealing with whole live animals are difficult to carry out because they never seem to obtain the aimed-for 'observation'. Usually a teacher or student has some idea as to what is the consequence of a laboratory exercise. The trouble arises when the animals will not 'behave' in the appropriate manner. Thus it is found that laboratory exercises involving live and mobile animals have been culled from current laboratory manuals. Alternatively animals may be used in laboratory exercises, but so completely out of context of the habitats in which they have evolved that it makes the exercise biologically naive. Slaters may move away from a blazing light bulb, and this may be carefully noted by students, but the evolutionary significance of negative phototaxis in slaters may not be mentioned. Theoretical aspects which would complexify the laboratory exercise are generally not accounted for. Finally, whole organisms are sometimes difficult to obtain when needed. Most biology teachers have suffered from the dilemma of trying to find sufficient wetas from the field for an insect dissection for a class.

However chemicals and extracts are more readily obtainable from the laboratory shelves. There is a marked tendency for laboratory exercises to be 'in vitrio' exercises. This is confirmed by the immediate and sometimes spectacular observation (colour change or measurement) which can be noted at the conclusion of the instructional steps with 'in vitrio' practical exercises. Moreover, a great deal of current 'applied' biological techniques are 'in vitrio'. The skills necessary for 'applied' biology can be begun at school. Consequently, current laboratory exercises are likely to involve chemicals and test-tubes in laboratories than live organisms in their own habitats.

The following table of analysis serves to exemplify this:

Table 1 Analysis Of Weightings To Three Factors In A Laboratory Manual.

"Biological Science Processes And Patterns Of Life" Laboratory Manual 1970. (A Sixth Form Manual).

Total Number of Exercises.	No. of Exercises Devoted To Whole Organisms In Habitats.	No. of Exercises Involving Chemicals And Extracts.	No. of Exercises Devoted To Mathematical Techniques.
50	21	22	16

It can be seen that by far the majority (thirty-eight) of the laboratory exercises are devoted to working with either mathematical type exercises, or with 'in vitrio' type exercises. In fact only five involve field observation. Some involve aspects from all columns. This is why the total is greater than fifty. The selection of practical exercises therefore contributes to the non-theoretical nature of current biological education.

Fourthly, practical work may mean carrying out individual project work:

> "To achieve the aims of the course, STUDENTS MUST HAVE THE MAXIMUM OPPORTUNITY TO CARRY OUT INDIVIDUAL RESEARCH (in the literature the field or

> the laboratory) and a MINIMUM OF EXPOSURE TO LECTURES AND FORMAL LABORATORY EXERCISES."
>
> ("Department of Education Form Seven Teachers' Guide" op.cit. Page 1. Their emphasis).

In conclusion, observation is played down. A quick glance at a colour change, or change in smell, or a measurement or a statistical solution may be all the observation which is necessary. Practical work is emphasised. A great deal of this work is chemical and mathematical rather than biological.

Essential Feature IV - A Unified Science Is Possible.

At present concern is felt about the splintering of the sciences. Technique centred specialist areas have proliferated (Weiss 1970). Apparent new sciences have developed. This diversity created by specialisation prevents communication between each science or between each specialist area:

> " ... science is partaking of the general conditions of fragmentation. Thus, there are sharp divisions between applied science and pure science, between theory and experiment, between one specialized field and another, and between different branches of each speciality."
>
> (Bohm 1970).

The three 'basic' sciences are physics, chemistry and biology. Modern chemistry had its origins in alchemy. From these origins it has developed into a respected science. In its development, chemistry has been encompassed by the laws of physics. It has apparently matured. Physics is considered the most 'mature' of the sciences. Similarly with biology. It is assumed by many current biologists that biology will follow the pattern of chemistry as it matures. Already, it seems, the principles of chemistry have embraced biology.

> " ... the fundamental paradigm of explanation - the goal of all science - has been to reduce or explain all phenomena in physico-chemical terms.
>
> ... The history of science is routinely described as a progressive approximation to this goal. This is the metaphysical and methodological explanation for the fact that molecular biology is the queen of the biological sciences, and the basis on which other biological (including human) sciences seek, ultimately to rest their arguments."
>
> (Young 1971).

It appears logical that given concentration of research in molecular biology, biology will eventually be explained in terms of chemistry. If biology can be interpreted by chemical principles, it would be a short step to biology being explained in terms of physics. Thus chemistry, physics and biology will become a unified science. This seems to be a commonly held assumption.

The argument is faulty if it is taken further. Physics must have its own principles and laws. These are mathematical. The ultimate mature science, therefore, contrary to the popular assumption perpetuated in text-books, must be applied mathematics - not physics. Would a reputable mathematician claim that he is studying physics when he is solving mathematical problems? Moreover why ought one study physics, chemistry and molecular biology? Why not merely study mathematics? The advocates of molecular biology put their own field of study in a position which could be regarded as bogus. No molecular biologist would admit to this. Nor would a mathematician claim that he was studying molecular biology, when he is studying mathematics.

If biologists accept the assumption of an ultimately unified science they must therefore accept that current biology is temporary. Biological educators, in trying to keep up to date with the latest information and the enormous changes taking place, seem to assume that these changes are maturing stages toward an ultimately unified science.

Furthermore, some decision is required as to when the ultimate unified science is to be achieved. If this time is estimated to be in the near future, then priorities for biological education must be established now. If this likelihood is remote, then different priorities must be established for biological education. Yet current biological education, by its emphases, assumes that a unified science will occur in the very near future. That it may be impossible does not appear to be given consideration.

To conclude, the following three quotations are appropriate:

> "Excessive reverence to Newton and his mathematics led to too much respect for 'quantity' in science and a neglect of 'quality' to a narrow almost mechanical, conception of scientific method, and to the extreme reductionist dogma expressed by a physics professor who, within the last five years, said to a group of science teachers "Physics is the most fundamental of the sciences since ultimately it must be possible to explain all of the phenomena and properties of the material world in terms of the laws and concepts of physics."
>
> (Ramage 1967).

Not all physicists are aware of exclusively biological properties and principles. Simpson, on the other hand accepts the ultimate unification of science as a possibility, but he outlines an integrative trend which is the direct opposite of the current one:

> "In our days, Einstein and others have sought unification of scientific concepts in the form of concepts of increasing generality. The goal is a connected body of theory that might ultimately be completely general in a sense of applying to all material phenomena.
>
> The goal is certainly a worthy one, and the search for it has been fruitful. Nevertheless, the tendency is to think of it as <u>the</u> goal of science or <u>the</u> basis for unification of science has been unfortunate. It is essentially a search for a least common denominator in science. It necessarily and purposely omits much of the greatest part of science, hence can only falsify the nature of science and can hardly be the best bases for unifying the sciences. I suggest that both the characteristics of science as a whole and the unification of the various sciences can hardly be the best basis for unifying the sciences. I suggest that both the characterisation of science as a whole and the unification of the various sciences

can be most meaningfully sought in quite opposite direction, not through principles that apply to all phenomena but through phenomena to which all principles apply. Even in this necessarily summary discussion, I have, I believe, sufficiently indicated what those latter phenomena are: they are the phenomena of life.

Biology, then, is the science that stands at the center of all science. It is the science most directly aimed at science's major goal and most definitive goal. And it is here, in the field where all the principles of all the sciences are embodied, that science can truly become unified."

(Simpson 1963).

In conclusion, Ramage (1967) suggests that philosophy of science, especially philosophy of biology, has important contributions to make in biological education to elucidate exclusively biological concepts and theory:

"Much of the recent work on new schemes for school science education has been marred by excessive attention to means and too little to ends. Much consideration has been given to the mechanics of teaching and learning science, but far too little to philosophical whys and wherefores. For example, the disjointed list of alleged aims for one biology course makes no distinction between those aims which are scientific in general and therefore attainable through any branch of science, and those which are biological in particular and so require specifically a course in biology."

(Ramage 1967).

Essential Feature V - The Emphasis Upon Enquiry Processes.

This essential feature is generally not acknowledged by current text-book writers. An exception is the "Note To Students" in "Biological Science: Processes And Patterns", 1970. One has to look at laboratory guides instead, to note the emphasis on 'enquiry processes'.

> "It is hoped that the course will foster a critical approach to biology with emphasis on experiment, enquiry, and understanding, rather than on the accumulation of information."
>
> ("Biological Sciense: Processes And Patterns Of Life". Laboratory Guide. Department Of Education. Preface. 1970).
>
> "One of the principle aims of the Nuffield Biology Course has been to foster a critical approach to the subject with an emphasis on experimentation and enquiry rather than on mere factual assimilation ... In class practical work the accent is either in using information, techniques and concepts, or working them out. It is essentially an investigatory or problem-solving activity."
>
> (Nuffield Biology Teachers' Guide. I., Pages XII, and XIII).
>
> "The inclusion of a preamble setting out the aims and objectives of the course is probably the most novel feature of the prescription. It places great emphasis on THE DEVELOPMENT OF SKILLS AND ATTITUDES rather than the former stress on the acquisition of knowledge."
>
> (Form VII Teachers' Guide, University Bursary/ Scholarship. Department Of Education, N.Z. Page 1).

Despite the emphasis, there is still an increasing 'drift' from biology. A detailed account as to the nature of these 'enquiry processes' is necessary.

Commoner (1963) notes a 'knowledge explosion' in science. Biology has also been affected. (Most recent text-books are larger than traditional school texts.) Emphasis is now placed upon analytical detail, and complete specification.

The problem therefore, is how curriculum makers (and students) are to deal with this enormous quantity of biological knowledge. A student cannot absorb it all. There appear to be three alternative strategies. Firstly, curriculum makers could reduce the quantity of information needed to the most essential details. An attempt seems to have been made to do this, with an emphasis being placed upon 'general themes' (Glass 1965) or 'big general ideas' (Department of Education N.Z. 1970). De Beer (1969) also advocates this strategy. Yet this has failed. The quantity of information has shown no reduction at all. For example the following text-books serve to show how already very large text-books in biology become even thicker.

The text-book "Biology" by C.A. Villee was composed of six hundred and twenty-five pages in 1962. It was then in its fourth edition. In 1967 the fifth edition totalled seven hundred and thirty pages. In five years the text-book had increased by over one hundred pages. Secondly the text-book "The Science Of Biology" by Weisz in 1963 consisted of seven hundred and eighty-six pages. Yet in 1967 the text was not only larger in area, but its volume had increased to eight hundred and eighty-six pages - an increase of over one hundred pages in four years.

A second strategy - the one being proposed - would be to advocate theoretical biology. This could reduce the sheer quantity of fact to be learned up. It could also act as a back-bone for research. Biological curriculum makers have turned away from problems of subject-matter toward pedagogical aspects. They have relied upon the incorporation of 'enquiry processes' into biology as a way of adequately coping with the 'knowledge explosion'. Moreover, the rationale for enquiry processes may be distorted to a level where they are deified as being much more significant than the subject-matter:

> "Some of its proponents have elevated it (learning by discovery and inquiry techniques) into a panacea, making exaggerated claims for its uses and efficacy that go far beyond the evidence, as well as far beyond all reason. It purportedly can do things for which it was never intended, and is even ill adapted - and for reasons that border on mystical veneration of its alleged effects on the learning process, or on sheer sentimental fantasy about the nature of the child and of the educational process."
>
> (Ausubel 1961).

The detailed quantity of information presented in laboratory and teacher guides under 'aims and objectives' is sufficient to assume a certain degree of 'veneration' among biological curriculum makers of enquiry processes.

A number of different interpretations seem to be made as to the nature of enquiry processes. However, all appear to be based around the 'heuristics of discovery' promulgated by Bruner (1960, 1971).

> "Intellectual activity is anywhere the same, whether at the frontier of knowledge or in a third grade classroom. What a scientist does at his desk or in the laboratory, what a literary critic does on reading a poem are of the same order as what anybody else does when he is engaged in like activities - if he is to achieve understanding. The difference is in degree, not in kind. The schoolboy learning physics is a physicist, and it is easier for him to learn physics behaving like a physicist than doing something else."
>
> (Bruner 1960).

Bruner outlines the 'heuristics of discovery' in a simpler way when he says that they are "a style in problem solving or inquiry that serves for any kind of task one may encounter." (Bruner 1961).

This therefore relates closely to the development of attitudes and skills. Instead of rote memorisation of factual material in biology, the methods of attack (appropriate attitudes and skills) are developed for students. (See previous quotation Form VII Teachers' Guide). Current biology has therefore pressed for this third alternative. In doing this, it has allowed for a number of implications and consequences.

(a) The Subject Matter Content Is Of Little Account.

Ausubel is a strong critic of 'enquiry processes':

> "Much of this 'heuristics of discovery' orientation to the teaching of science is implied by the view that the principal objectives of science instruction are the acquisition of general inquiry skills, appropriate attitudes about science, and training in the operations of discovery. Implicit or explicit in this approach is the belief either that the particular choice of subject matter chosen to implement these goals is a matter of indifference (as long as it is suitable for the operations of inquiry) or that somehow, in the course of performing a series of unrelated experiments in depth, the learner acquires all of the really important subjects he needs to know.
>
> Thus Hibbs states: "It does not matter whether the student learns any particular set of facts, but it does matter whether he learns how much fun it is to learn - to observe and experiment, to question and analyse the world without any ready-made set of answers and without any premium on the accuracy of his factual results, at least in the field of science."
>
> And Suchman contends that " ... more basic than the attainment of concepts, is the ability to inquire and discover them autonomously ... The schools must have a new pedagogy with a new set of goals which subordinates their efforts to thinking. Instead of devoting their efforts to storing information and recalling it on demand, they would be developing the cognitive functions needed to seek out and organise information in a way that would be most productive of new concepts."

Finally Paul Hurd in this particular paper contends:

> "To state the goals of science education is to describe the cognitive skills expected in the student rather than the knowledge assumed essential to attaining these skills."
>
> All of this implies of course that the inquiry process per se in science education is more important than the acquisition of knowledge itself."

(Ausubel 1965).

If the attitudes and skills are made important, then the 'subject matter' areas could be played down. It need not matter which science is being studied. The attitudes and skills are appropriate to all science, indeed to all subject matters. This may seem to be a convincing argument for the ultimate unification of science. If the attitudes and skills necessary are all of the same sort, why should there be a number of sciences being studied at secondary schools? Surely one or two sciences would be sufficient. Are there no exclusively biological concepts and skills to be inculcated? (It will be contended later that through biological theory there are exclusively biological skills (creative observation), and theoretical questions of biology such as 'adaptation', 'function', and 'entelechy'.)

It is noted as well that in laboratory guides and curricula very little mention is made of 'biology'. Instead mention is always made of 'science' as though biology has no concepts and methods of its own. Moreover, it seems to indicate, erroneously, that there is indeed now a single unified science. The Laboratory Manual, "Biological Science Processes and Patterns" (1970), in its introduction, explicitly denies an exclusive subject area called biology when reference is repeatedly made to 'science' and 'scientists'. It would seem that 'biology' and 'biologists' are embarrassing labels. Biological curriculum makers are attempting to eradicate from courses a science which has its own unique subject matter and rationale. Downgrading of biological theory contributes to this situation. Biological theory, it seems, is not only an important aspect for students to comprehend. It is also crucial that biological curriculum makers have some familiarity with its significance. Moreover it will be contended later that knowledge of biological theory in learning, could, if applied to the pedagogy of biology, make new and most substantial contributions to the design of curricula not only for biology, but also for other subjects. Yet current biological education prefers to accept 'enquiry processes'. In doing so, it downgrades biology as an exclusive science.

Furthermore, and perhaps more importantly, the emphasis on pedagogy impedes the positive contributions biological science could make to education.

It seems that curriculum makers have decided that the 'knowledge explosion' is beyond any hope of control, and is hence ignored. It is assumed that new scientific knowledge builds on to older scientific knowledge in an additive fashion. Future information will be added to past information in an accelerating manner. This is recognised when statements such as this are noted: Science is

> "a progressive activity each generation building on the accumulated knowledge of the past."
>
> ("Biological Science: Processes and Patterns Of Life" 1970, <u>Laboratory Manual</u>, Page VII.)

According to this statement, the problem of the 'knowledge explosion' can only get worse, and this is the reason for attention being paid to 'enquiry processes'.

Ausubel (1965) makes obvious the importance of some knowledge of the history and philosophy of science in biology especially at more advanced levels. It is well established (Hanson 1961, 1972; Kuhn 1962, 1970; Toulmin 1962; Koestler 1964, 1969; De Beer 1969) that scientific knowledge is <u>not</u> cumulative in the way described. Moreover it is the dependence upon 'theory' which makes scientific knowledge not cumulative. Kuhn (1962) outlines this situation, when he shows, historically, that science (including biology) has been syncopated by a series of more violent revolutions, with much longer 'quiet' periods in between. These revolutions involve a 'paradigm change'. The meaning of 'paradigm' is complex, (Lakatos and Musgrave 1970) but it also involves <u>theory</u> change. Thus if 'paradigms' are changed, the new knowledge which accumulates as a result, is different from that of another, previous paradigm. For example if knowledge was cumulative, all students of biology would need to attempt to learn about all thinking in biology which has been recorded. Clearly they do not do this. Nor would it be possible. Curriculum makers are not aware of the nature, nor influence, history and philosophy has upon biology. Consequently they are apt to be making 'odd' statements as to the nature of biology:

> "The remedy (of the drift from science) clearly, is for everyone to come to a much better understanding of what the scientific activity is really like. This is desperately urgent with regard to those who <u>teach</u> science at whatever level. A great deal of scientific research can quite usefully be done by people lacking an understanding of the higher methodology - but such a lack in <u>teachers</u> of science generates in those taught the sort of fundamental misorientation the unhappy results of which are now coming to see. Since virtually

> everyone undergoes formal training of some sort or another at a tertiary level, the immediate need i. for changes in the education offered at that level.
>
> The prime requirement is for teaching in each of the sciences to give more cognisance to theoretical and methodological issues. Better understanding of epistemology is needed - and the better if it is instilled along with the inculcation of fact and technique peculiar to the science in question. But it must be instilled somehow. Many of our present troubles in science education have resulted from decades of neglect of the essentially philosophical issues which, whether we like them, or even recognise them or not, are there nevertheless. We shall get out of trouble only by recognising and coping with these issues."

(Stenhouse 1972).

Incorporation of 'theory' in biological curricula, presently neglected, would serve to develop understanding of the relationship between theory and fact. A new paradigm in biology, for example would likely make some present biological 'facts' irrelevant. Theory determines what is to count as fact. Theory deals with exclusion and not complete specification. Therefore a situation could be arrived at where subject matter content can be outlined in curricula through the 'lens' of biological theory. Not all of the biological 'knowledge explosion' will focus out when the lens of theory is applied. (See pages 143 - 146) for an explanation). Some would be excluded.

Stressing history and philosophy would also outline and emphasise the need to incorporate strictly biological concepts and methods into curricula. Moreover, the amount of subject matter would be able to be comfortably dealt with by students. Compared with the present text-books and laboratory courses, the content would be adequate as a basis for later research in biology.

There would also be no need to incorporate and rely upon encouraging definite 'attitudes' and 'skills'. These would be incorporated into a theoretical approach.

(b) Scientists And Students Are Carrying Out Essentially The Same Activities.

Bruner, (the quotation already outlined) emphasises this point. Students, it is maintained, can enact the roles of scientists at work. Texts and courses also follow this pattern:

> "However its full worth (the text-book) will become more apparent when you see it in relation to the field and laboratory investigations you will be engaged upon. In these investigations you are working as a scientist as you seek your own answers to the problem posed by living organisms."
>
> ("Biological Science: Processes And Patterns", Introduction. 1970.)

The introduction then goes on to develop the method of how scientists work. In doing this it leaves little doubt as to the nature of attitudes and skills which are to be developed. These relate to what is commonly acknowledged as 'the scientific method':

> "Initially you should try to identify the problem you are going to investigate. If often pays to write this out as a statement. You should then search the available literature to help build up your background information - it is here we hope, the text-book will be of assistance. This knowledge, together with your own observations of the organism or situation, should then be surveyed to see what information can be discarded as being irrelevant to the problem and what patterns or generalizations are apparent. Using your background of knowledge and understanding of biology in general you should now seek to explain why such a pattern or relationship might exist or appear to exist - in other words you are developing an idea, theory, or hypothesis ... Your next move is to suggest ways of testing your ideas. What experiments could you design to test your theory? Your responses to successes and failures will be a measure of your ability to overcome

obstacles and at the same time you will know the excitement of adventuring after truth."

("Biological Science: Processes And Patterns" Introduction 1970)

Moreover 'the scientific method' is regarded as being important enough to be included in examinations:

"During your school-work in senior biology you will have the opportunity to pursue a course of practical work in which you have applied the scientific method of investigation to a biological problem or hypothesis.

(a) State succinctly, but completely, what you understand by 'the scientific method' of investigation?"

(Entrance Scholarship Examination Question, 1973).

Current courses use 'the scientific method' as the 'enquiry process'. This situation can be taken to an extreme. It is implied that mere application of 'the scientific method' in biological (or any other) phenomena will reveal 'truth'.

Yet it is noted (Heslop-Harrison 1958; Medawar 1967) that there is no such thing as a single 'scientific method':

"What scientists do has never been the subject of a scientific, that is an ethological inquiry. It is no use looking to scientific 'papers', for they not merely conceal, but actively misrepresent the reasoning that goes into the work they describe. If scientific papers are to be accepted for publication they must be written in an inductive style."

(Medawar 1967).

"There is no such thing as The Scientific Method" - as the scientific method, that is the point: there is no one rounded art or system of rules which stands to its subject-matter as logical syntax stands towards any particular instance of reasoning by deduction". "An art of discovery is not possible" wrote a former Master of Trinity; " we can give no rules for the pursuit of truth which shall be universally and peremtorily applicable." To many philosophers of science, such an opinion must have seemed treasonable, and we can understand their unwillingness to accept a judgement which seems to put

> them out of business. The face-saving formula is that although there is indeed a Scientific Method, scientists observe its rules unconsciously and do not understand it in the sense of being able to put it into words."
>
> (Medawar 1967).

(Yet students are expected to do so 'succinctly' in examinations.)

Thus a situation arises where students are being asked to understand a method which is not fully accepted by scientists in their actual work. It is assumed by curriculum makers, that by using 'the scientific method' unembellished, students are acting as scientists act when they work. If Medawar's evidence is to be given credence, this is not so. Scientists when they work do not adhere strictly to the scientific method. The 'scientific method' is 'theory' - possibly the only major theory advocated by biological curriculum makers and even this is found to be based upon assumptions which contrast with evidence which can be obtained from the history and philosophy of science. This situation seems also to further serve as evidence for the need to incorporate 'theory', history and philosophy of science into biological curriculum formulation.

Students cannot be scientists merely by becoming familiar with and applying an officially outlined 'scientific method'. 'The scientific method' as outlined in the previous quotation serves as no more than a general guide, and must not be equated with the view that it is the sole method of science.

Ausubel attacks this assumption on pedagogical grounds:

> "The scientist is engaged in a full-time search for new general and applied principles in his field. The student on the other hand is primarily engaged in an effort to learn the same basic subject matter in this field which the scientist learned in his student days, and

also to learn something of the method and spirit of scientific enquiry. Thus, while it makes perfectly good sense for the scientist to work full-time formulating and testing new hypotheses it is quite indefensible ... for the student to do the same thing ... If he is ever to discover, he must first learn; and he cannot learn adequately by pretending he is a junior scientist: To acquire facility in problem solving and scientific method, it is also unnecessary for learners to rediscover every principle in the syallabus. Since problem-solving ability is itself transferable at least within a given subject-matter field, facility gained in independently formulating and applying one generalization is transferable to other problems in the same discipline. Furthermore over-emphasis on developing problem solving ability would ultimately defeat its own ends. Because of its time consuming aspects it would leave students with insufficient time in which to learn the content of the discipline; and hence despite their adeptness at problem solving they would be unable to solve simple problems involving the application of such content.

Under these circumstances, students would fail to acquire the minimal degree of subject matter sophistication in a given discipline that is necessary for abstract intellectual functioning in that discipline, much less make original research contributions to science."

(Ausubel 1965).

(c) Laboratory Experimentation Is The Place For Enquiry Processes.

It has been pointed out that present biology places great importance on 'practical' biology. The laboratory apparently is the place where the enquiry processes are put into practice - where students can act as scientists.

Laboratory guides, apparently, are written to inculcate 'the scientific method'. But even cursory investigation of laboratory guides does not reveal emphasis upon this supposed most important method. For example, "Biological Science: Processes And Patterns" Laboratory Manual, 1970, has but one exercise (Exercise 2:1) of about fifty exercises, specifically concerned with the method as previously outlined. The type of biology perpetuated by laboratory manuals is claimed to be scientific by the writers. These same writers maintain in prefaces and introductions, that 'the scientific method' is the only path to truth. Yet the actual laboratory exercises presented to the students are divorced from 'the scientific method'. Strict obedience to the steps of each laboratory exercise is necessary.

Moreover, this type of biology could be labelled 'obedience' biology. 'Obedience' biology is important in technical biology which relies upon past achievements. Little which is new will be derived from 'obedience' biology. Yet it is well documented (Koestler 1964; Stenhouse 1971) that important scientific discoveries have originated through disobeying generally accepted rules and theories. Biological science therefore has disobedience characteristics. Technical biology, by contrast, does not. Yet current biology advocates through laboratory guides the latter at the expense of the former. At introductory levels it would perhaps need to encourage both aspects. The perpetuation of 'obedience' biology in biological education will be discussed later under 'technicism' in biology.

Furthermore, laboratory exercises are apt to belabour the obvious, and to waste a great deal of valuable teacher and student time.

> "Yet science courses at all academic levels are traditionally organized so that students waste many valuable hours in the laboratory collecting and manipulating empirical data, which, at very best help them rediscover or exemplify principles that the instructor could present verbally and demonstrate visually in the matter of minutes. Hence, although laboratory work can easily be justified on the grounds of giving students some appreciation of the spirit and methods of scientific inquiry, and of promoting problem solving analytics, and generalising ability, it is a very time consuming and inefficient practice for routine purposes of teaching subject matter, or of illustrating principles, where didactic exposition or simple demonstration are perfectly adequate."

(Ausubel 1965).

Moreover it may hinder students in their appreciation and interest in biology:

> "The unsophisticated scientific mind is only confused by the natural complexities of raw unsystematised empirical data, and learns much more from schematic models and diagrams; and following laboratory manuals in cook-book fashion, without adequate knowledge of the relevant methodological and substantive principles involved, confers about as much genuine appreciation of scientific method, as putting on a white 'lab' coat and doing a T.V. commercial for "Roll-Aids"."

(Ausubel 1961).

Friedenberg (1961) also notes that teaching can portray unrealistic stereotyping of science and scientists. Laboratory work may become deadening and formal. Yet it has been introduced into courses apparently to reduce 'rote memorisation'. The type of laboratory investigation presented in current biology is likely to favour the very process they seek to prevent:

> "Problem solving can be just as deadening, just as formalistic, just as mechanical, just as passive, and just as rote as the worst form of verbal exposition."
>
> (Ausubel 1961).

(d) Emphasis Upon Enquiry Processes Is Implicitly Lamarckian.

Current biological curriculum formulators, in advocating enquiry processes, also interpret learning from a behaviouristic framework. (Mowrer 1960; Koestler 1964). This is Lamarckian in some of its formulations. It is therefore surprising to observe that reputable biologists (apparently New Zealand's leading biological educators) implicitly adopting and advocating Lamarckian theory, to inculcate anti-Lamarckian subject matter.

Criticism may be directed toward this claim by stating that behaviouristic principles are now 'dead issues'. It may be regarded as 'flogging a dead horse':

> "We are constantly assured that the crudely mechanistic nineteenth century conceptions in biology, medicine and psychology are dead, and yet one constantly comes up against them in the columns of text-books and technical journals and in lecture rooms. In all this, Behaviourist psychology occupies a strategic key position. This is the case, not only in the United States where the Watson-Hull-Skinner tradition is still an immensely powerful and keeps an invisible stranglehold (by negative reinforcements) on academic psychology. In England Behaviourism has entered into an alliance with logical positivism and linguistic philosophy."
>
> (Koestler 1967).

The introductions in two commonly used publications in Form 6 and Form 7 biology in New Zealand ("Biological Science: Processes and Patterns Of Life", Laboratory Manual, and Form VII Teachers' Guide, "University Bursary/Scholarship Biology", published by the Department of Education NZ) both maintain a decidedly behaviouristic frame of reference. Behaviourism, on the contrary, is not a dead issue in current biological education.

Extensive use of evidence from Piaget (1969) who received his early education in biology, will be used to show the Lamarckian characteristics of pedagogical emphases currently perpetuated in New Zealand biological education.

Biological educators, in neglecting theory and in emphasising these pedagogical aspects have, it appears, missed a golden opportunity. They seem to have forgotten that learning has essentially biological roots. They have preferred to not make learning a biological problem. It is probable that this is due to the present deriding of 'biological theory'. Theoretical biology, if explored, would probably have revealed to biological educators the contributions that biology could make to education. This major reorientation would have coincided with the renewed current interest in the biological nature of man, and how he behaves. (Tinbergen 1963, 1968; Hinde 1966; Lorenz 1966; Morris 1967, 1969; Fletcher 1968; Bronfenbrenner 1968; Bowlby 1971). Surprisingly, curriculum makers do not seem to be aware of the research findings, and the methods and rationale (theory) of ethology, as it relates to learning in man.

Few current biological educators would wish to be labelled Lamarckian. The manner of explanation, and the amount of attention devoted to Lamarckism in text-books is usually meagre, indicating that Lamarck's theory is not held in any regard.

We thus arrive at a paradoxical situation. Current biological educators maintain that curricula are novel and up to date with the latest biological ideas. They claim to have managed this with the 'subject-matter' side of biology. Yet, when they deal with pedagogical aspects, they implicitly adopt and maintain a position which was refuted in July, 1858, with the publication of the Darwinian theory. Furthermore, the situation is worsened because current biological education especially in prefaces and introductions of laboratory manuals, places a great deal of significance to the appropriate external milieu for learning. Introductions to courses - 'aims and objectives' - maintain that learning has occurred when the desired repsonses (aims) are seen to be acquired. Learning in this context is a set of responses which are previously determined by the appropriate external environmental conditions. These introductions imply this when they give specific details as to the exact types of desired attainable responses. A laboratory manual states:

> "Only by experience in the laboratory is it possible to see what science really is. No matter how much you learn about the facts of science, you will never quite understand what makes science the force it is in history, or scientists the kinds of people they are, until you have participated in such an experience."
>
> ("Biological Science: Processes And Patterns", Laboratory Manual, 1970 Pages VII - VIII).

Apparently, the aims which are given in detail, and subsumed under enquiry processes, can be 'stamped in' during lessons and laboratory sessions. This assumes that the students are organisms who are passive receivers of stimuli from the external environment. This particular assumption is behaviouristic. Copies of external reality are taken in. A stimulus is applied to engender an appropriate response. It is the stimulus (the external environment) which is important. It must have certain properties to elicit an appropriate response. Apparently the 'aims and objectives' supplied in these publications are sufficient and adequate responses. The behaviouristic approaches to education are outlined in many current educational texts, and in Hull (1943), Skinner (1957), Koestler (1964, 1967), and Fletcher (1968). The position which incorporates behaviourism as being the <u>only</u> means to learning is sometimes labelled 'learning theory' (Koestler 1964; Mowrer 1960).

By contrast the subject matter of ethology has shown that learning is an activity which has endogenous origins. (Thorpe 1963; Koestler 1964; Fletcher 1968). That is, an organism <u>reacts</u> to an environment. Organisms are not passive receivers of stimuli. Insight is involved. 'Learning theory' does not appear to accept endogenous origins. It prefers to stress the importance of the external conditions as a pre-requisite for learning.

<u>How Is The Situation Advocated By Biological Curriculum Makers Lamarckian?</u>

Piaget and Inhelder (Koestler 1969) have outlined this position as follows:

> "Empiricism has engendered many different ideas from the naive concepts of knowledge as a copy of reality, to the more refined forms of 'functional copy' (Hull's behaviourism) to logical positivism which aims at reducing knowledge exclusively to physical experience and to language. If we look for common factors in these diverse approaches we find a central idea. <u>The function of cognitive mechanisms is to submit to reality, copying its features as closely as possible, so that they may produce a reproduction which differs little from external reality</u>. This idea of empiricism implies that reality can be reduced to its observable features, and that knowledge must limit itself to transcribing these features."

Current biological curricula seem to assume that if the right external conditions are supplied, then what is learned will be an exact (and correct) copy of external reality. Piaget and Inhelder continue:

> " - such a concept meets with three fundamental difficulties. Biologists have shown that the relationship between an organism and its environment ... is one of constant interaction. The view that the organism submits passively to the influence of its environment has become untenable. How then can man as a 'knower' be simply a faithful recorder of outside events? In the second place among fields of human knowledge and endeavour, mathematics for one, clearly escapes from the constraints of outer reality. This discipline deals essentially with unobservable features, and with cognitive constructions in the literal sense of the word. Thirdly, man acts on, and modifies reality, he obtains by transforming his world, deeper understanding than reproductions or copies of reality could never provide ... "

> " ... the exact counterpart of behaviourist empiricism in biological theory is a doctrine long since abandoned by biology itself, not because it was wrong in what it maintained, but because it ignored all that has since proved essential to an understanding of the relations between the organism and its environment; we are referring to the Lamarckian theory of variation and evolution. Soon after Hume had sought the explanation of the phenomena of the mind, in the mechanisms of habit and association, Lamarck too, saw the key to the morphogenetical variations of the organism and of organ-formation in the habits adopted under the influence of the environment. Admittedly, he was also speaking of a factor of organization, but he thought of it as a capability of association, not of composition, and the essential aspect of the acquisitions was for him the way in which living beings received, in modifying their habits, the imprint of the external milieu." ...

> "But Lamarck's theory lacks the basic principles of an endogenous possibility of mutation and recombination, and above all those of an active capacity for self-regulation. When Waddington or Dobzansky today put forward the pheno-type as a 'response' of the genetic pool to environmental 'incitements' this response does not mean that the

organism has simply been marked by an external action, but that there has been interaction in the full sense of the term i.e. that as a result of a tension or imbalance provoked by environmental changes, the organism has invented an original solution by means of recombinations, resulting in a new equilibrium. Thus when we compare this concept of 'response' to that used so long by behaviourism in its famous stimulus-response schema (S-R) we are amazed to find that the behaviourist psychologists have retained a strictly Lamarckian outlook, as if they had ignored the contemporary biological revolution.

In the exclusively Lamarckian context of behaviourist theory, the response is simply a sort of 'functional copy' (Hull) of the stimuli in their particular succession. Consequently, the fundamental process of acquisition of knowledge is considered a learning process in the empiricist sense of obtaining information through observation of the environment. If this were true, mental development as a whole would then be thought of as the result of an uninterrupted series of bits of learning in the abovementioned sense. If, on the contrary, the basic point of giving certain responses i.e. the 'competence', learning would not be the same at different development levels, and would depend essentially upon the evolution of 'competence'. The true problem would then be to explain their development, and for this the concept of learning in the classical sense of the term would be inadequate. In our opinion, we cannot but follow the principles discovered by contemporary biology. This means a fundamental change in the psychological interpretation of mental development."

(Piaget and Inhelder in Koestler 1969).

Biological curricula seem to portray two assumptions which are important in this respect. The points subsumed under 'aims and objectives','recall', 'use of enquiry processes', 'use of practical techniques', 'interpreting data', all seem to be presented in a manner which is apparently obvious and 'pure', and can be immediately stamped into the cognitive apparatus. Secondly, the position which assumes 'pure' experience is well exemplified with laboratory exercises. The culmination of the exercises usually involves a simple observation of colour changes of obvious movements. (Observation has been cut down to a level where all who have basic sensibilities can observe.) Apparently this paring away of complexity allows for exact copies (colour changes, movement) to be taken in as stimuli which are completely 'unbiassed' and hence 'truthful'. Medawar (1967) notes that observation is not unbiassed. Tinbergen (1972) also notes this.

Yet curriculum makers accept the Lamarckian view that 'exact copies of reality' are taken as functional copies. That is, presentation of aims and objectives, 'obedience' biology and laboratory manuals advocate those aspects of external reality which can be simplified and then 'stamped into' the students, as though external realities can be internalised as copies.

Why do biology curriculum makers implicitly accept this Lamarckian position? Familiarity with biological theory, especially ethological theory, readily available to biologists, (some authors have already been outlined) has not been regarded as significant. This seems to be in keeping with a general downgrading of theory in biology. If the curriculum makers accepted theory, they would not have placed themselves in this embarrassing situation. Moreover, if they had acknowledged ethological theory, they would probably have been able to make major contributions to education as a whole, through giving learning a biological basis. Instead, they have accepted behaviouristic assumptions and applied these to biological education.

In conclusion, it is even more surprising to find biological educators accepting a Lamarckian position, by advocating certain aims and objectives, and then maintaining that the latter are a 'novel' feature of a new curriculum:

> "The inclusion of a preamble setting out aims and objectives of the course is probably the most <u>novel</u> feature of the prescription."
>
> (Form VII Teachers' Guide, 1971, Page 1.)

The preamble claimed to be novel, is advocating a position refuted in 1858.

Essential Feature VI - The Downgrading Of Botany In Biological Education.

In an article entitled 'Is Botany Dead?' (Nature Vol. 220, Page 521) the view was expressed that botany was a declining subject. The article, which elicited a great deal of later discussion about the state of botanical education and research, had an anonymous author, probably because of the controversial nature of the topic. Reputable botanists in the United Kingdom saw fit to reply to the claims made. (Brian 1968; Harper 1968; Whittingham 1968; Markham 1969).

Brian (1969) has attempted to draw threads of the discussion together: (Conclusions which were less related to botanical education have not been included).

> "(a) The numbers of students studying botany in universities at undergraduate and graduate levels are too few and perhaps of too low quality. Most science students and particularly most of the best ones being channelled into physical sciences.
>
> (b) There is an unsatisfied need for botanists with considerable physical knowledge to work on problems of physiology of whole plants and crops. Such work requires a degree of instrumental sophistication and progress is inevitably slow, taking years where more purely laboratory work takes weeks; ...
>
> (c) The tendency to bring university departments concerned with individual biological sciences together into biological schools, or in the newer universities to set up schools or departments of biology from the beginning, though educationally justifiable, could work to the disadvantage of the plant sciences.
>
> (d) A tendency to separate basic from applied botanical studies in the universities has helped to foster the idea that botanical studies have little relation to human needs.

(e) The small size of a university department is a serious disadvantage since the necessary stimulus to real intellectual interest in biology can only be achieved where there is a research group of some size ...

(g) The image of botany among the public and the profession, is so poor that many engaged in research on plant problems prefer to avoid any suggestion that they are botanists."

(Brian 1969).

There is no reason to believe that the situation is any different in New Zealand botanical research and education. The numbers of students studying botany at graduate and undergraduate levels is small. These numbers are reflected by the relatively small staffs in botany departments in Universities. (Perusal of current University Calendars confirms this for New Zealand.)

Secondly, Brian notes that at present molecular botany is receiving a fair amount of attention. This type of botany has stimulated interest at cellular and subcellular levels. But the physiology of the whole plant is being neglected.

"The impact of the theoretical approach of 'molecular biology' has immensely stimulated interest in biochemical processes at cellular and subcellular levels. These very successes have drawn many workers into the field, and they continue to attract the brighter students, with the consequence that plant physiology is becoming progressively more biochemical in its outlook and more concentrated upon events within the plant cell, so that the physiology of the whole plant is relatively neglected as Engledow has said. I do not want to hinder the development of cell biochemistry except insofar as 'mere fashion' is responsible; I do want to point out that an important aspect of plant physiology has been neglected, and should be given more financial support.

It is unfortunate that this particular aspect of plant physiology should be relatively unpopular, because physiological studies of the whole plant in relation to its physical, chemical and biological environment are essential if we are to be able to understand the relevance of our new knowledge of cell processes to the whole organism in its natural growing conditions. They are essential because it is at this level that new physiological knowledge can be applied in agricultural practice. Such application need not be direct: plant breeders are increasingly selecting for physiological characteristics, and those characteristics that determine crop plant performance can only be defined in terms of whole plant physiology; plant pathology is becoming more physiological, and comparative studies of healthy and diseased plants at the whole plant or crop level should be most rewarding."

(Brian 1969).

Zuck (1964) also puts the case strongly against the over-emphasis upon molecular botany:

"This is an age dominated by too much preoccupation with the physical sciences so far as thinking about and experimenting with plants is concerned. Although there is no American Lysenko, there is a kind of thinking being foisted on the plant sciences which tends to put non-adherents of this new orthodoxy as beyond the pale of serious scientific endeavour; whereas, in reality, the kind of blind zeal of the neorthodoxy only reveals profound ignorance of many of the well known facts of life. It is a dominance which is being encouraged by the channelling of large sums of money to those institutions with increasing numbers of these zealous adherents and apostles."

(Zuck 1964).

In reference to Brian's third point; perusal of present New Zealand University Calendars shows that first year courses in biology as opposed to botany and zoology are common. There also appears to be a tendency in New Zealand to separate 'basic' research from 'applied' botanical research. Finally in reference to the image of botany in New Zealand, it seems that it is regarded as a course for females. The image for botany therefore is probably very little different from that in the United Kingdom.

Some implications of the general downgrading of botany in biology can be noted for secondary education in New Zealand.

Firstly, teacher qualifications in botany. Osborne (1973) outlines the case for physics education in New Zealand. He notes:

> "A sustained shortage of physics teachers must eventually result in a low standard of physics achievement in schools, a lowering of the number of graduates produced and a further deterioration of teachers' qualifications."
>
> (Osborne 1973).

Osborne is in fact explaining an othogenic situation which becomes progressively worse, with each new generation of poorly qualified teachers detrimentally affecting the subject which they teach. The same pattern could be used for generally low esteem held for botany in New Zealand biological education. The very s 11 sizes of botany departments at University could be taken as an indication of a general lack of interest in the botanical aspects of secondary school biology.

Osborne in his comprehensive study also supplies data for first degree graduates from Secondary Teachers' College for the years 1967 to 1971. The graduates are called 'biology' graduates. But unlike most other sciences, a 'biology' graduate can hold any of a number of majors within the qualification. These are not noted by Osborne. (Nor are they expected to be in his particular study.) A biology graduate can hold any one of the following first degrees:

(a) A B.Sc. in zoology.

(b) A B.Sc. in botany.

(c) A B.Sc. in biochemistry.

(d) A B.Sc. in geology.

(e) A B.V.Sc.

(f) A B.Ag.Sc.

(g) A B.Hort Sc.

All of these above qualifications are accepted as being 'biological' in biological education.

This wide spectrum of a variety of basic and applied qualifications, if balanced, could be a noble characteristic for current secondary biological education. However this is probably not the case. It is anticipated that teachers holding qualifications in zoology are likely to predominate over all of the others. This is reflected through the p esence of large zoology Departments in Universities in New Zealand. This can lead to the development of courses and syllabuses highly orientated to the zoological side of biology. An imbalance it seems, is occurring. Botany is 'losing out' against zoology. Brian (1969) expresses his concern:

> "... the section of the public that we botanists most need to appeal to is the younger generation - school children and first year university students. Once we get real competition for entry to our honours courses, once we get a real demand from students for expansion of our laboratories, we shall know we are winning the battle.
>
> We have to decide whether we approach these young people as botanists or as a particular brand of biologist. I believe strongly in the unity of biology (Brian 1962). To my mind any move toward separation would prove fatal. Children at school must be taught biology, not botany or zoology; I am glad to say that this practice has become increasingly adopted. What we do need to do is to ensure that in school biology syllabuses, plants are given proper attention, not to be fair to botanists but because a biology course must contain a proper treatment, if it is to be a good biology course ... '

... there are forces that keep tertiary botany to small population sizes which are more irrational. I was once invited to help appoint a head of biology department at a large college of education. Before the interviews, I was told that they would not normally appoint a botanist, as he would be too narrow in knowledge and outlook, but a zoologist would be excellent. This kind of attitude in a college of education can lead to its appearance at school level. Indeed I suspect far more zoologists than botanists are employed as school biology teachers. And this can influence students coming to University, and even those appointing heads of university biology departments. It can lead to plant studies being neglected in such departments. We must fight such attitudes, again not mainly because they are unfair to botanists (though they are) but because they are bad for biology."

(Brian 1969)

Furthermore current text-book writers are usually zoologists (Weisz 1967; Keeton 1967; Berrill 1967). Syllabuses seem to be heavily orientated to zoology (see Form VII Teachers' Guide 1970). Hence, botany in biology courses is not given a great emphasis. Current introductory biology emphasises unification of botany with zoology but the process seems to have been an imbalanced one, and zoology has prevailed.

Moreover, botanical topics, if they are discussed, are usually at cellular and subcellular levels, dealing with detailed chemical mechanisms, for example 'the biochemistry of photosynthesis'. Little attempt is made to develop the ecology, and whole plant, or crop physiology. Yet it is in these areas that urgent attention must be given. Crop research involving 'whole plant physiology' for food production, and conservation are both problems which must be successfully dealt with in the very near future. Future food production is crucial.

Brian emphasises that in research:

"physiological studies of the whole plant in relation to its physical, chemical, and biological environment are essential if we are able to understand the relevance of our new knowledge of cell processes to the whole organism in its natural growing conditions. They are essential because it is at this level that new physiological knowledge can be applied in agricultural practice."

(Brian 1969).

What can biological education attempt to do to rectify the downward trend and generally low status of botany? One strategy being emphasised in this thesis, is to deal with the problem by upgrading theory in elementary biology. A plant interacts with its environment. It has morphological and more subtle physiological features which allow it to live in its environment. Once this is noted, then theory and theoretical phenomena such as 'adaptation' and 'survival value' are immediately important. Biological education could introduce theory in botany as well as for zoology. Darwin recognised this with his own plant studies. He based his observations and experiments around evolutionary theory:

"To him the Orchid work, - which on more than one occasion he referred to as the most interesting of his life - provided him with one of the finest of all test cases for the theory of adaptive evolution. He saw in it a clear demonstration that when an end as significant as he believed cross fertilisation to be was to be attained, the simple basic ground plan of the mono-cotledonous flower could become modified in the course of evolution to produce mechanisms transcending "in an incomparable manner the contrivances and adaptations which the most fertile imagination of man could invent". The motivation for these modifications was of course natural selection."

(Heslop-Harrison 1958).

Evolutionary theory is also inexorably intertwined with botany. Thus a general development of theory in biological education would probably serve to also prevent botany from being swamped by zoology. The importance of theory in botany is equally as important as for biology generally:

> "Arising from the evolutionary view was Darwin's constant attempt to weigh all his observations of structure and function in terms of phylogenetic relationships. This procedure carried to an illogical extreme in some biological fields, has lapsed, or been unconsciously rejected in others. It is possible for a systematist or morphologist who is blind entirely to the implications of evolution when dealing with lower levels of organic variation, to be dogmatic about supposed evolutionary arrangements of higher systematic categories and, on the other, for an analytically minded physiologist so to scorn phylogentical speculation which he regards as unfounded and incapable of rigorous test, that he rejects a mode of thought not necessarily without value in application to his own material. There is a lesson for both in the spirit - cautious yet enterprising, speculative yet reasoned - in which Darwin used the evolutionary hypothesis the most important generalization of biology, in his own botanical researches."

(Heslop-Harrison 1958).

Finally, it is popularly thought that botany is no more than a mere cataloguing and naming of species, yet Darwin himself did not accept botany in this way. In fact he could be regarded as the progenitor of plant physiology. Yet, at present a great deal of the meagre amount of botany in secondary school biological education seems to have forgotten its origins, when it attempts to be non theoretical:

> "The work of Darwin's later years has given him a position in botany which he never attained in zoology, that of a progenitor of a line of research of a purely physiological nature ... Amongst botanists, Darwin's later work on plant movements had a special impact on plant physiologists whose concern with his evolutionary

argument was slight indeed. Through a distinguished line of personalities, Darwin's work on plant movements may be linked with present-day activity in the field of tropic responses, one outcome of which has been the discovery of plant growth hormones ... Whilst historical connections like that just mentioned may be distinguished linking Darwin's experimental botanical research with that of today, it cannot be said that the Darwinian philosophy or mode of reasoning is particularly evident in modern plant physiology."

(Heslop-Harrison 1958).

Essential Feature VII - Educational Precociousness.

A current trend in biology seems to be to push highly sophisticated principles and techniques further and further down the educational levels. What was once taught to second year zoology students a few years ago, may now be found being taught to fourth form pupils as part of their science course. Indeed it seems that to attempt to inculcate complex principles to younger and younger students is an educational virtue, to be looked upon with favour in current education. De Beer (1969) attacks this notion on the grounds of biological principles. Firstly, he emphasises that this educational strategy engenders educational precociousness among students. These students lack an appreciation of a wide variety of subject areas. He contrasts this educational strategy with the biological principle important to human beings - 'delayed development'. Secondly, he implies the biological principle of the 'critical periods' hypothesis (Scott 1962; Bowlby 1971). (It seems that children are more sensitive to learning certain concepts and language at one stage and not at other stages of development.) Furthermore, if a child misses a critical period, it will be to his detriment:

> "The second great mistake was to go on the principle that as more and more is discovered, more and more must be taught. This inevitably leads to a premium on precociousness, for as economic reasons limit the time during which a student can be kept at university, time is borrowed, or rather mortgaged, at the other, earlier end of curriculum, and specialization is pressed back into the schools. Advanced subjects are introduced prematurely at the expense of more general subjects, and worse still, the competitive nature of examinations for scholarship confers an advantage on the precocious which is the exact opposite of one of the most important processes responsible for the

> evolution of man: delayed development ... Besides this, subjects introduced prematurely are only imperfectly appreciated, and at the expense of more basic subjects which are increasingly difficult to acquire at later ages. Mathematics and modern languages do not come so easily to students after they have spent so much precious young time with test-tubes and dissecting dishes."

(De Beer 1969).

Current biological educators, in neglecting two biological principles outlined above by De Beer, may be promoting a 'drift' from biology through encouraging educational precociousness. Moreover, the situation is made worse when this encouragement is given official favour. It would seem that if biological educators appealed to biological theory they may have a great deal to contribute to many areas in education:

> "With the progress of science during the last half-century, the situation has really become easier to cope with, without anyone's noticing it, not in spite of the progress, but because of it. Sir Peter Medawar has reminded us that whereas in the early decades of this century, the different branches of science were in chaos, the discoveries that have since been made throw light on general principles of increasing breadth which require for their teaching a few well selected examples, leaving the whole mass of unwieldy detail growing like a snowball to be acquired later, and to fall into place if necessary. In biology at any rate it is all so much more tidy that there is no justification for the precocity scramble ...
>
> The situation has also become easier because of the increasing realization of a great truth of which sight should never have been lost: the mental processes involved in observation, verification, and use of imagination in producing ideas are fundamentally the same in poets, essayists, artists, musicians, and scientists. This is why the notion of 'Two Cultures' is exaggerated."

(De Beer 1969).

Essential Feature VIII - The Emphasis Upon The 'Central Dogma' Of Molecular Biology.

" ... there have been only two great theories in the history of biology that went more than a single step beyond the immediate interpretation of experimental results; these were organic evolution, and the 'central dogma'."

(Stent 1968).

Stent (1968) assumes that both the 'central dogma' and the theory of evolution be given equal status. Current biology by contrast, seems to imply that the former prevails over the latter.

Some preliminary discussion seems necessary. Firstly, Stent seems to assume that the thing organic evolution is the same as the theory of evolution. The two are different. The theory of evolution is an abstraction - a scientific 'idea game' as outlined by Munson (1971). Organic evolution on the other hand is an accumulation of evidence which, when seen through the 'lens' of theory, comes into focus as 'fact'. Stent seems to assume that the theory is the same as the evidence for evolution:

"The fact that it is proper to speak of a 'theory' of evolution does not mean of course that the phenomena called 'evolutionary' have not occurred, and do not continue to occur quite independently of the theories advanced to explain them. Many instances of speciation, extinction, and population changes took place long before it was possible to offer anything like an adequate account of them. Moreover, evolutionary change is a process that has left an historical record, which is the task of evolutionary theory to interpret and explain. There is a sense, then in which the process of evolution is separate from the theory of evolution."

(Munson 1971).

Consideration seems also to be necessary not only in the historical aspects of science, but also the philosophical aspects. A theory is a logically consistent abstraction. It would appear that logic and theory are inexorably intertwined. Furthermore it would seem that discoveries have to be related in some way to theory for them to be counted as 'fact'. This relationship is formulated through logical steps. The process of the focussing of the lens of theory is determined by the general methodology of science (Rudner 1967). Thus it would appear that theory and methodology are both significant to biology.

Secondly, and similarly, a distinction must also be made between the central dogma as _an entity_, and the 'central dogma' as _dogma_. Crick coined the _term_ 'central dogma' in 1958. Since that time it has generally been uncritically accepted (Commoner 1965, is an exception). It seems therefore that _the thing_, the central dogma, has taken on the characteristics of _the term_ dogma:

> "Certainly there is good experimental evidence to support the notion that D.N.A. does influence the hereditary characteristics of living cells in which it occurs. But the question which relates to the basis of theoretical issue is whether D.N.A. represents a self contained code that _by itself_ determines whether the organism is a turtle or a tiger.
>
> Such a conclusion is not based upon an experimental fact, but on dogma. If you are shocked by my use of the word let me hasten to add that it is not own. The _term_ 'central dogma' is often used in current literature to _describe the principles_ which are _supposed_ to explain the governing role of D.N.A. in inhertance. It was introduced into the scientific literature - probably for the first time since the Middle Ages - by proponents of the D.N.A. code theory. You will find in the index of a report of a recent symposium on molecular genetics the entry "Dogma, The," followed by eleven page references. On page 107 one of the participants

makes the following remarkable statement:
"The reason we call this 'dogma' is that
it depends upon personal bias, not logic."
Shades of Galileo."

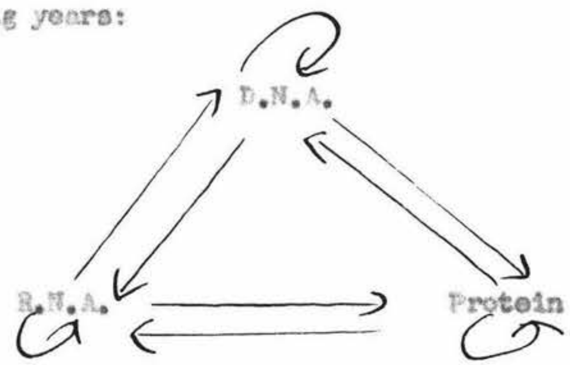
(Commoner 1963).

<u>What Is The 'Central Dogma'?</u>

The Teachers' Guide for Form Seven biology published by the New Zealand Department of Education 1971, outlines it as follows:

It is a set of transfer relationships between compounds, where D.N.A. is the determining template.

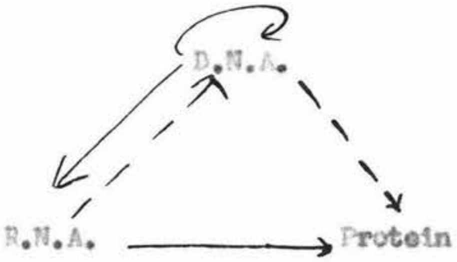
Crick (1970) outlines the thing 'central dogma' in a manner which shows how it has developed and been modified in the intervening years:



It consists of possible transfer relationships between the three families of polymers. Each arrow represents the directional flow of sequence information. We can ~~regard this diagram as 'the~~ central dogma' as established in 1958.

The above diagram represents all possibilities for directional flow of information. However, later it was found that some transfers seem to be impossible.

The 'central dogma' has been given a tentative format today, and is represented thus:



The solid arrows show general transfers. The dotted arrows show special transfers. The absent arrows are the undetected transfers specified by the 'central dogma'.

(After Crick 1970)

Crick explains the context of the formulation of the 'central dogma' in the following way:

> "The 'central dogma' was put forward at a period when much of what we know in molecular genetics was not established. All we had were certain fragmentary experimental results, and a boundless optimism that the concepts involved were rather simple and probably much the same in all living things. In such a situation, well constructed theories can play a useful part in stating problems clearly, and thus guiding experiment."
>
> (Crick 1970).

It can be noted that the 'central dogma' was no more than a tentative, but fairly concise and clear-cut model. This model could then determine possibilities for further research.

Further it is interesting to observe that the 'central dogma' as originally formulated in 1958 is a good example of what Scheffler (1960) calls a 'programmatic definition':

> "A programmatic definition is moral in purpose rather than communicatory and explanatory. It proposes that the thing defined should be treated in a certain way. Hence it embodies a programme or plan of action. To assign a certain term to a new thing may in context be a way of proposing that this new thing be treated in the same manner as the things to which the term has been referred hitherto. For example to define

> education as a 'profession' may be a way of advocating that educators be given more privileged treatment."
>
> (Kneller 1966).

The 'central dogma' does not communicate a great deal of information. It does embody a plan of action which seeks to elucidate possible transfer relationships. The plan of action is already determined. Analytical descriptive techniques are more or lesslegislated by the model as outlined.

However and more importantly, the 'central dogma' in being a programmatic definition has also a 'moral' purpose. It proposes that the thing the 'central dogma', must also be accepted as a 'dogma'. It has been allowed to take on the characteristics of the term 'dogma'. If biology is governed by a definition having 'dogma' characteristics, then a science is in danger of not being a scientific activity. Biology could be transformed into 'biologism'. (Frankl 1969).

Confirmation that the 'central dogma' is accepted as dogma has been noted by Commoner when he reports difficulty in getting material published which is highly critical of the term. (New Scientist, Vol. 50, No. 146, April 8, 1971. Page 103).

In biological education, it appears therefore that the 'central dogma' is accepted in both senses. Since 1958 a few ~~minor changes in the~~ 'central dogma' (as a thing) have occurred. The original model remains. Moreover, through popularisation, reminiscent of the 'smashing of atoms' attributed to Rutherford, the 'central dogma' is held to be the 'code, or language of life'. It has taken on the characteristics of a dogma, but students and educators seem to accept its authority.

The dogma promulgated by Crick as a working model, seems to be perpetuated by biological educators and commentators as an apparent 'fact'. For example, the following is a question given in an national examination in 1972:

> " 'The Central Dogma' of cell biology as it is called, is the statement of cause and effect that links D.N.A. to the finished protein molecule. A vast amount of scientific effort has been expended on discovering the steps that culminate in the synthesis of protein. Most of the experimental work has been carried out on bacteria and viruses. Describe the manner in which it is thought that protein is formed, and discuss whether this knowledge is important in understanding biological processes of, say, mammals."

(University Scholarship Question 1972).

The acceptence of the dogma as a thing, is attacked:

> "Since they (the reductivists) declare the processes of growth of heredity have been shown to be determined by a sequence of D.N.A. molecules, biology has already been reduced on principle to biochemistry; the completion of the job is routine. Granted however that D.N.A. has precisely the power they (the reductivists) claim for it, its operation demonstrates, on the contrary, that biology is not reducible to biochemistry (and ultimately to physics). What makes D.N.A. do its work is not its chemistry, but <u>the order of bases along the D.N.A. chain</u>. It is the order which functions asthe code to be read out by the developing organism. The laws of physics and chemistry hold, as reductivists rightly insist, universally; they are entirely unaffected by the particular linear sequence that characterises the triplet code. <u>Any</u> order is possible physicochemically; therefore physics and chemistry cannot specify <u>which</u> order will in fact succeed in functioning as a code. This argument which appears incontrovertible was stated by Michael Polanyi in "Science" 1968."

(Grene 1971).

The notion of <u>simplicity</u> advocated by the 'central dogma' seems too difficult to accept. Grene attacks the notion of simplicity on <u>logical</u> grounds. Commoner (1963) criticises the apparent simplicity on the grounds of '<u>information theory</u>'.

> "1. Organisms which must differ considerably in their genetic complexity often have similar D.N.A. contents, and there is no evidence that the discrepancy can be accounted for by differences in genetic redundancy or inertness of some chromosome sections. Conversely, organisms which are nearly identical in genetic complexity may differ considerably in cellular D.N.A. content. The available evidence does not support the idea of a one to one correspondence between genetic information and the information represented in the structure of D.N.A., or for that matter, any other molecular component of the cell.
>
> 2. No cytologist has discovered a ubiquitous structure, considerably larger than chromosomes, (the code library) which shows evidence of serving as a translator. While recent biochemical evidence suggests possible means whereby D.N.A.-borne information may be translated into generally effective protein specifity, there is still no sign of a device capable of translating the D.N.A. code into the numerous anatomical features (fingerprints for example) that are also inherited.
>
> Thus a strict analysis of the problem of inheritance in accordance with modern information theory leads to the remarkable result that the organism's specifity must be determined, at least in part, by agencies not in the initial germ cell, and certainly not in the D.N.A. alone. Elsasser points out this view, which can be derived from modern physical theory, is identical with a principle already well established in biology - epigenisis."

(Commoner 1961).

Recently, the working model has also come under attack: In an article entitled "Biology's Central Dogma Turned Topsy Turvy" the editors of the <u>New Scientist</u> (June 25, 1970) report ~~the following:~~

> "The central dogma, first formulated in the early 1950s and given that name by Francis Crick states that information in a living cell flows in one direction only: from D.N.A. to R.N.A. to protein. As the receptacle of the cells information, D.N.A. ensures its continuance by replicating itself at every cell division. In order to

express the information, it holds, the D.N.A. acts as a template for the synthesis of messenger R.N.A. which in turn directs the synthesis of the appropriate protein. The central dogma is thus expressed

D.N.A. → R.N.A. → Protein

It is no exaggeration to say that the central dogma has been the backbone of molecular biology. And although a few people - notably that arch sceptic Barry Commoner - have challenged its contention that protein cannot affect the information content of R.N.A., and R.N.A. that of D.N.A., very few people have taken the challenges seriously. ... in about 1965, a biochemist by the name of Dr. H.M. Temin (now at Wisconsin University) claimed to have discovered, within a cell invaded by an R.N.A. virus, a stretch of D.N.A. that matched the viral R.N.A. The implication is that the R.N.A. acts as a template for D.N.A. synthesis in direct contravention of the central dogma. His results were dismissed as cranky ... "

However, in 1970, at a Royal Society meeting, Professor Sol Spiegelman "blew up molecular biology's most cherished belief. In a few words and a rapid succession of slides Spiegelman reported experiments done a few days earlier in his laboratory ... which clearly demonstrated a violation of the central dogma."

(*New Scientist*, Editorial, June 25,1970).

Further evidence for doubting the purported simplicity of the 'central dogma' can be cited from the *New Scientist*, May 1970. In an article entitled "Doubts About How D.N.A. Is Copied", it states as follows:

"D.N.A. polymerase is the enzyme Arthur Kornberg used a couple of years ago to synthesise biologically active D.N.A. in the test-tube. He ~~believes his enzyme also replicates D.N.A. in~~ living cells. So until recently did most people. But now Kornberg's enzyme is the centre of growing doubts ... But then just before Christmas last year, something of a bombshell burst with the publication in "Nature" Volume 224 p 1164 of a paper by John Cairns and Paul de Lucia. After the laborious task of screening almost 3,500 mutants of *E. coli* the Cold Spring Harbour workers came up with one that possessed less than one per cent of the normal level of D.N.A. polymerase activity - yet could replicate perfectly well. This work represents a formidable argument against D.N.A. polymerase being the D.N.A. replicating enzyme and in favour of fulfilling a repairing role."

(Chedd 1970).

Crick maintains that the great strength of the 'central dogma' is its simplicity and its universiality. This contrasts with evolutionary theory which accepts the obvious complexity and diversity of living organisms. Stent (1968) seems to give equality to both evolutionary theory and the 'central dogma'.

But current biological education apparently adopts the view that the 'central dogma' prevails over organic evolution and evolutionary theory. If this situation is adopted, then the many centuries devoted to 'pre-dogma' biology are of little account, and can now be safely rejected in favour of new molecular biology. This would be a difficult position to maintain. Not all 'pre-dogma' theorising has been cast out in biology, in spite of the 'central dogma'.

Secondly, the 'central dogma' is simple and restrictive. It deals with three major types of compounds, and nine possible transfer relationships. On the surface, it would appear that just as Einstein's equation condensed a great deal of diverse information for physics, the 'central dogma' has similarly carried out this function for biology. However, though the 'central dogma' has apparently derived a universal pattern to organisms, not all organisms are exactly identical. This lack of uniformity has to be accounted for. The acceptable theory which accounts for this is evolutionary theory. Thus evolutionary theory is more comprehensive than the 'central dogma'. Moreover the elucidation of the 'central dogma' is carried on 'in vitrio'. 'Life' is not a necessary pre-requisite to this type of analysis. Extracts can be used. Evolutionary theory in contrast, pre-supposes and encompasses the living organisms in which the 'central dogma' is functioning (Commoner 1961). The 'central dogma' is an important minor aspect, embraced by evolutionary theory.

Thirdly, evolutionary theory accounts for the gross behaviour of living organisms. The 'central dogma' is not able to account for the variability of behaviour among animals. Evolutionary theory however does present a comprehensive explanation for this. Thus it can be concluded that the 'central dogma', although given great emphasis in current biological education, cannot be given equal status with the theory of evolution.

Essential Feature IX - The Downgrading Of Theory In New Biology.

Since World War II and since the publication of the 'central dogma' biological theory has received little recognition in research and in education. Evidence for this is not difficult to find as has already been shown (Tinbergen 1972). Text-books in biology are noted for their enormity and for descriptive detail. Laboratory guides are of a 'cook-book' nature with very little consideration being given to theoretical issues.

That theoretical issues are either derided or are given cursory treatment in the introductory chapters or the prefaces of texts can be noted from Table It seems that text writers and curriculum makers in biology treat theoretical issues as though they are embarrassed at having to mention them. It is assumed that these issues are barely within the realms of scientific biology.

It is also interesting to note that the major theory acceptable to traditional biologists - evolutionary theory - is currently presented, briefly, in the latter parts of text-books. It would appear that the text writers presuppose that few students or teachers bother to read prefaces or introductions. Similarly with the last chapters. The descriptive details presented earlier in the text-books seem to be held in significantly greater importance.

The Table on page 117 shows that comparatively minor attention is given to evolutionary theory in present text-books. Not only is evolutionary theory as the paradigm of biology (Kuhn 1962) given little regard, but other theoretical issues, for example 'systems theory', 'organisation', 'hierarchy', 'entelechy', and 'holism', are not held to be important. (See Koestler and Smythies 1969; Weiss 1970.) When 'theory' in biology is referred to, it is intended to incorporate any exclusively biological abstraction, and is not necessarily confined to evolutionary theory. Lamarckism for example would be eligible for discussion in biological education. It is contended that the present downgrading of theory in 'new' biology is perhaps the most significant feature wrong with current biological education.

The Emphasis Which Is Placed Upon Evolutionary Theory in Some Current Text-Books.

Title	Author	Publication Date	Percentage Of The Text-Book (Quantity Of Pages) Devoted To Evolutionary Theory
"Biological Science: Processes And Patterns"	Department Of Education N.Z.	1970	0.05 per cent
"Biological Science"	W. Keeton	1967	0.05 per cent
"Modern Biology"	J.H. Otto and A. Towle	1969	0.03 per cent
"Biology"	C.A. Villee	1967	0.05 per cent
"The Science Of Biology"	P.B. Weiss	1967	0.06 per cent
"Biology In Action"	N.J. Berrill	1966	0.05 per cent
"Biology" (Teachers' Guide)	Nuffield Foundation	1966 - 1967	0.001 per cent
"Basic Ideas In Biology"	E.A. Phillips	1971	0.02 per cent
"Principles Of Biology"	Whaley, Breland et. al.	1965	0.03 per cent
"General Biology"	J.W. Mavor and H.W. Manner	1967	0.10 per cent

Table 2

Questions commonly heard among members of the teaching profession are of the following sort; Why should theoretical biology be given a place of importance in education? Surely it is the job of biological education to deal with 'facts' and the practical realities of hard bench research, as opposed to dealing with vague theories. Surely it is better to get down to the realities of science at introductory levels with emphasis upon practical skills and techniques, in contrast to arm-chair theorising.

A. The Problem Of Quantification In New Biology.

> "The highly developed language of science makes the subject matter opaque to the uninitiated. Any form of mathematical treatment - and, after all, mathematics has been said to be the language of science - immediately diminishes the potential readership."
>
> (Smith 1968).

Current text-writers and curriculum formulators place a great deal of emphasis upon quantification in biological education. These educators seem to hold with the position outlined above by Smith (1968). The rationale of the traditional 'dogfish - earthworm' biology is inherently sloppy. Quantification, according to curriculum formulators and text writers 'hardens' biology and removes bias. Current biolgical education therefore stresses data, collection and collation. It would seem that quantification in some aspects of biology is most important. But to imply, as Smith does, that quantification is the key to improving biology is difficult to accept. Smith, and current biological educators seem to assume that quantified biology is a 'higher' biology than non quantitative biology:

> "To the modern positivists and biologists, "phenomena" are not what appear to the ordinary stargazer, let alone to the ordinary natural historian, bent curiously over leaf or chrysalis. For a philosopher like Duhem, it is the "phenomena" accessible to the ingenuity of the mathematical physicist that count, and these are, in general, data obtainable only in highly contrived experimental situations. This change, like so much in the scientific revolution, can be documented in the writings of Galileo, on the one hand in his dictum that "nature is written in the mathematical language", and on the other in his exclusion of colour, sound, tastes, and smell from natural realities ... 'Philosophy is written in this great book, the universe which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which

> it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single work of it; without these one wanders in a dark labyrinth."
>
> So authoritative is the place of mathematical physics in our conception of scientific knowledge, that we take this pronouncement as the enunciation, trail blazing in its time, of what is now a truism. Applied mathematics is the paradigm case of science, science is the paradigm case of knowledge; of course some d y all we know or can know will be statable in strict mathematical form."
>
> (Grene 1968).

A number of points require elaboration.

Galileo maintained that physics is accessible only to those who are able to comprehend the world in mathematical terms. Thus a physicist is required to move out of the world 'seen and heard' into a 'more reasoned' mathematical world. Moreover it is this reasoned world which is more real than the life world.

What Galileo attempted for physics in the seventeenth century, Smith, and others (Crick 1966), are attempting for molecular biology in the twentieth century. A remarkable parallel occurs when traditional biology is compared with current molecular biology. If the Smith quotation is accepted, it would seem that other implications must also follow;[1]

The first implication concerns the apparent exclusiveness of current biology. Galileo also emphasised the exclusiveness nature of physics.

> "The language of nature, Galileo tells us, is one we must learn. Certainly: all languages must be learned. But this is a language, he seems to be suggesting which by no means everybody learns. It is not like one's mother tongue, assimiliated in infancy by any normal child. ... The language of nature, then in some sense is a foreign language.

> And indeed, for most of us, the language of mathematics which is for Galileo, nature's language, has to be learned at school, not at home, it is a secondary and artifical acquisition."
>
> (Grene 1968).

With the current emphasis being placed upon mathematical pre-requisites for advancement in biology, new biological education seems to be adopting a position advocated by Galileo three or more centuries earlier. This in itself is significant, if the argument presented by Grene is taken further:

> "But how do we learn such a secondary, a foreign language? Either the alphabet is written like our own, and we have to learn the meanings of words; or there is a foreign element, a different kind of character, to be learned before we can get as far as trying to understand the words. The latter situation holds for nature as Galileo sees it: not even the letters of its language form part of our ordinary environment, for, he insists we have to learn them too. And again, this is, of course, true of the language of mathematics: we have to familiarise ourselves with its formalisms before we can make use of them in order to understand what they have to teach. To the ordinary person, then, the language of nature bears to the perceptible surface of the things around him a relation rather like that which, for a native English speaker, a page of Chinese or Arabic bears to a page of ordinary English prose. Until he is trained to do so, he cannot make out so much as its constituent elements let alone their meaning. In short, the universe that "lies open to our gaze" is, if Galileo is correct, a volume written in a secret code which only the trained cryptographer can interpret. The rest of us can only wander in a dark labyrinth."
>
> (Grene 1968).

Molecular biologists strikingly agree withthis outline presented by Grene. Firstly many present day biologists who are not mathematical, tread in 'in the dark labyrinth' along with the vast majority of people. Their activities cannot be classed as scientific, as they are confined to the life world. Yet they are still able to publish findings of their reseaches in reputable scientific journals. Indeed Tinbergen, Lorenz and Von Frisch have recently been awarded a Nobel prize for their work. (See "Science" Vol. 182, No. 4111, November 2, 1973. Pages 464 - 466 for a report.) Awards such as these are not presented in science to non-scientists. Nor do reputable scientific journals reject the non mathematical writings of Simpson, Weiss or J.Z. Young. Yet the quotation made by Smith (1968) implies that many biologists are not scientists. Secondly, all past non-mathematical biology over many centuries would be (according to Smith) of no account. This would appear to be an unfounded claim.

Thirdly, there is no room for amateur biologists if Smith's position is accepted. Yet amateur biologists have contributed and are still contributing to biology in New Zealand. Some present amateur biologists of note in New Zealand include Crookes (1963); Taylor (1970) and Child (1971).

Fourthly, according to Smith, biology should not be studied until the student is thoroughly competent in mathematics. This claim would appear to be absurd. Beggs (1954) and Comstock (1960) have published sufficiently to show that children are curious about living organisms at a very early age, quite previous to being able to comprehend complex mathematical concepts and formulations. Furthermore, interest in natural history is often noted in the early lives of some great scientists.

The fifth consequence relates to the proposed exclusive nature of biology. Mathematical ability is the key to entry. Mathematical ability therefore is apparently the best indicator of later scientific ability. This does not seem to follow:

> Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers and compulsive tidiers up; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists, and philosopher-scientists, and even a few mystics. What sort of mind can all these people be supposed to have in common?"

(Medawar 1967).

There is no one scientific type. Just as scientists differ in temperaments, they are also likely to differ widely in mathematical abilities. Historically, it would seem that the greatest mathematicians ought also to have been the greatest scientists. Yet this is not the case.

Furthmore, Smith implies that mathematical ability among biology students is a good predictor of later success in biological research. Yet Hudson (1968) cites evidence that the converse may be true. Students who do not favour the physical sciences or mathematics tend to have 'divergent' propensities. Hudson seems to think that the 'diverger' is possibly an innovator. Hence, in advocating mathematical pre-requisites and emphases, current biological educators (Smith included) may be discouraging the very individuals who ought to be retained for biological research. Already it has been noted that it is the ever increasing group of non mathematical arts-biology students in secondary schools who are likely to have the personality tendencies which Hudson (1966,1968) describes. Yet current biology seems to be accepting the 'reduction in readership' outlined by Smith (1968). The short term consequence of this strategy, should it continue, will be to increase the 'drift' from biology; the long term consequence will be a continued decline in fruitful valuable basic research. An example cited by Crowther (1971) emphasises this point:

> "Rutherford, who has just received the Nobel Prize for chemistry, sat in one his mathematical colleague, Professor Horace Lamb's class on mathematical statistics."

(Crowther 1971).

Rutherford was a great scientist, who despite having already won a Nobel Prize, did not consider himself highly competent at mathematics prior to receiving it.

Sixthly, quantification could be encouraged in biological education as a 'false guarantor of intellectual rigour' (Stenhouse 1972). That is, students having ability in quantitative biology, may have their chances of success accentuated to the detriment of non mathematical biology students. If this trend continues the 'drift' from biology will be further enhanced. Some students, otherwise very capable, will, through pressures placed upon them by quantification emphases, be prevented from advancing in biology.

Moreover, students in later years, on observing the pattern of selection at introductory levels among students who are ahead of them, will opt away from biology, thus compounding the 'drift'.

Following on from the 'exclusiveness' of molecular biology expressed by Smith. He appears to be advocating a closed science community. He seems to think that molecular biology ought to be populated with scientists of one type. If mathematics was used as the sole method of selection into molecular biology it is probable that the degree of variety explained by Medawar (1967) would be reduced. The germ of the development of an uncriticising community would seem immanent. This is a dangerous situation because of its uncriticising outlook.

Traditional biology, in emphasising that it is available to all individuals with normal sensibilities is more universal. There is little intention apart from the usual examinations, to greatly reduce the potential readership. The comparison between traditional biology and new biology parallels remarkably the Galilean explanation:

(a) Molecular biology belongs to the quantitative and reasoned world.
Traditional dog-fish/earthworm biology belongs to the 'life world'.

(b) The reasoned world is an exclusive world. It is not available to all.
Mathematical initiation is necessary before one can enter molecular biology.

(c) Observations based around touch, taste, and smell belong to the 'life world'. Traditional biology stresses this in combination with extensive theory. By contrast molecular biology reduces theory and relies upon pared away apparently 'pure' observations from experimental and quantitative procedures.

(d) Implied in current biological education is the idea that new or molecular is of a <u>higher</u> level than traditional 'dogfish-earthworm' biology.

It appears that if biology is quantitative, it can also be made 'non theoretical'. Observer bias and other subjective elements which could 'infect' biology are apparently removed when biology is made quantitative.

Despite this popular claim, difficulties arise. Firstly how does a biological experimenter categorise and operationalise elements? Does he cut up phenomena to be measured randomly? Even the 'non theoreticians' cannot but have some rationale (theory) which determines their categorising, and the processing of data. A common rule would be to operationalise categories in a manner which makes them susceptible to measurement. This in itself is a theoretical notion. The processing of data is also determined by theory - even among biologists who would claim to be non-theoreticians. If a non-theoretical biologist takes the non-theoretical position to a logical extreme, he would be required to admit that his activities and categorisations involved in dealing with data were merely random movements. Research, on the contrary, is not random.

Furthermore, how does the non theoretician interpret findings? Does he merely let the results 'speak for themselves'? Interpretation again presupposes a theoretical position. Koestler (1964) strongly criticises the 'non theoretical' position.

> "By stressing the importance of the <u>interpretation</u> (or reinterpretation) of facts, I may have given the impression of underestimating the importance of <u>collecting</u> facts, of having emphasised the value of theory-making at the expense of the empirical aspect of science - an unforgivable heresy in the eyes of Positivists, Behaviourists, and other theorists of the anti-theory school. Needless to say only a fool could belittle the importance of observation and experiment - or wish

to revert to Aristotelian physics which was was all speculation and no experiment. But the collecting of data is a discriminating activity, like the picking of flowers, and unlike the action of a lawn-mower; and the selection of flowers considered worth picking, as well as their arrangement into a bouquet are ultimately matters of personal taste. As T.H. Huxley has said in an oft quoted passage:

'Those who refuse to go beyond fact rarely get as far as fact: and anyone who has studied the history of science knows that almost every step therein has been made by ... the invention of a hypothesis which, though verifiable, often had little foundation to start with ...'. "

(Koestler 1964).

B. <u>Reductionism In Current Biology.</u>

From evidence (already outlined) it seems that analysis is a recent strategy which is reflected in biological research and biological education. The level below in the biological hierarchy, is always <u>more basic</u> than a higher level, and will ultimately end in chemistry and physics, if the former quotations of molecular biologists of the calibre of Crick, Reiner, Smith and Caspari are indications of trends. An analogy (developed by Stenhouse) can be used at this stage which may highlight faults in the position:

Buildings are composed of bricks. Bricks are more basic than buildings. Therefore properties of bricks should be studied before properties of buildings.

Alternatively:

Organisms are composed of cells. Cells are more basic than organisms. Therefore the properties of cells should be studied before the properties of organisms. The cells are composed of organelles. Thus organelles ought to be given priority for study. However, organelles are composed of molecules. Therefore molecules should be studied prior to organelles.

The analytical slide can continue to sub-atomic particles, because there is no logical rule at all which will stop it. Indeed, according to the analytical position, if a lower level is more fundamental than a higher level, there <u>must be no rule</u> applied at all at any level which prevents the analytical slide. Of course, the logical ultimate would be to study mathematical probabilities, and this surely would not be biology. This analytical slide has been labelled 'reductionism' (Koestler 1964, 1970) or 'reductivism' (Grene 1971). It is a key issue in current biological research and education.

There is also another important point which is at present creating discussion and controversy. Not only is reductionism weak from a logical point of view, it is also being criticised by chemists and physicists on theoretical grounds.

Molecular biologists (Reiner 1968; Smith 1968) assume that physics and chemistry have already eradicated theory from their disciplines. Yet it is on theoretical grounds that chemists and physicists are criticising the molecular biological non theoretical frame of reference. For example, to assume a 'billiard-ball' concept of atoms as 'new' biology does, is to accept 'bad' physics:

> "But unfortunately the ordinary man's physics is still that of one hundred or more years ago! And Von Weizsacker in the article just quoted says "the concept of the particle is itself just a description of a connection which exists between phenomena, and if I may jump from a very cautious and skilled language into strict metaphysical expression, I see no reason why what we call matter should not be spirit." If I put it in terms of traditional metaphysics matter is spirit as far as spirit is not known to be spirit.
>
> Also - if reductionism were right in the sense that the mental, spiritual, artistic, and ethical values which we experience really are in the electrons and other primary components of which the world is made, - then all one can say is that they don't appear to be there. It follows that a great and unjustified leap of faith is required, a leap without any scientific evidence to believe it. Thus reductionism requires at least a great faith, if not a much greater faith than the organismic and hierarchic approach combined with Weissacker's open-mindedness. By the first, we are required to believe what we can in no way detect. By the second, we are required to believe in a source of value added to or injected into, the natural process as complexity develops which we are totally unable to understand."

(Thorpe 1969).

Grene (1971) puts the 'leap of faith' necessary for a reductionist position in the following way:

> " - there are, and have been since Leucippus' time, a paradoxical pair of principles at work in the support of the reductivists ideal. On the one hand, the orthodox view of scientific inquiry is presented as phenomenalism: science is shorthand for observations; theoretical contructs are conventions, enabling us to get from one stand in observation to another. And on the other hand it is the smallest invisible parts of things that are alone allowed to count as 'real'. Only an atomistic metaphysic, it seems is no metaphysic, but a defense of phenomena against metaphysics. Thus when I tell my students, there are quail in my garden in the morning and robins in the afternoon, they say, nonsense, there is one gene pool in your garden in the morning and another in the afternoon. That's what you're really observing. I must admit that my eyes deceive me: the real phenomena are the invisible ones demanded by the most unifying and economical theory, the phenomena I see are only apparent and must be explained away."
>
> (Grene 1971).

Molecular biologists maintain that they do not hold with beliefs, metaphysics or theories. Yet to maintain a one-level atomistic view of the universe, cannot help but involve 'belief', 'metaphysics' or a 'leap of faith'. (Physicists seem to still be unsure of the nature of ultimate particles, and they recognise that such discussions must revolve around theories.) Molecular biologists, in advocating reductionism must admit that ultimately their position is in fact a metaphysical one. A comment made by Beckner seems apt:

> "Professor Woodger somewhere remarks that those who consider themselves above all metaphysical beliefs are merely up to their necks in them."
>
> (Beckner 1964).

Molecular biology advocates that physics is the model science to be accepted. Yet physics rests its arguments upon theory (Thorpe 1969). Ultimately molecular biology rests its case upon a metaphysical framework - a position it explicitly abhors. Yet physics has a very strong theoretical basis. It seems therefore that non theoretical molecular biology may be following a blind path and eventually be annihilated by the theory of physics.

Equally significantly evidence can be derived from notable physicists which weakens some current assumptions in molecular biology. These physicists do not seem to comprehend physics in the manner in which molecular biologists do.

> "Another notable defense of life as something unique and distinct from non-life comes from one of the great physicists of our time, Niels Bohr. Bohr has written several remarkable papers about the relation between biology and physics, which have for too long been neglected by biologists and biophysicists alike. One of Bohr's contributions to physics is the theory of complementarity, which holds for example, that the electron is characterised by both particulate and wave length properties which are nevertheless mutually contradictory (the more precisely the wavelength is defined, the less certain we become of the electron's position)."

(Commoner 1961).

Bohr thus did not maintain only a particulate theory of matter. Current biology does. Commoner goes on:

> "Bohr suggests that complementarity regulates the relationship between two coeval aspects of biological systems: the existence of life in the whole intact cell, and the separate physico-chemical events that occur within it, the more precisely we try to determine the internal events of a cell, the more likely we are to destroy its life. Bohr concludes: "On this view the very existence

of life, must, in biology, be considered
an elementary fact, just as in atomic physics
the existence of a quantum of action has to
be taken as a basic fact that cannot be
derived from ordinary mechanical physics."

(Commoner 1961).

Bohr, it seems, belonging to a science which molecular biology admires - is quite able to make a 'leap of faith'. He accepts 'life' in the same way as he accepts 'action'. Bohr accepts what current molecular biology ignores:

"Bohr's principle simply serves as warning that we cannot study the property of life without retaining it in our experiments ... It is pertinent here to show that the penetrating insight of modern physical theory reveals certain inconsistencies in the notion that life can be reduced to the chemistry of a certain substance.

I believe that what is common - and to some degree unused - in these physical and chemical views of life (those of Bohr, Hinshelwood and Elsasser) is that they are profound. They apply to modern physical and chemical theory to the problem of life with the standards of depth and rigour that are required in the treatment of purely physical and chemical problems."

(Commoner 1961).

Moreover, one does not need to go down to the level of sub-molecular, and sub-atomic physics to note the difficulties which arise in accepting reductionism. The molecular level seems to be adequate in showing weaknesses. Modern chemistry does not always agree with some of the principles adopted. It seems that reductionistic biology is willing to accept 'poor' organic chemistry as a basis for its work. The noted molecular biologist Kornberg states:

"Recently I had an after-dinner conversation with an eminent organic chemist, who also had a deep interest in biology. I told him how badly organic chemical advances were needed in the nucleic acid field. Compared to the chemistry of other natural products, the chemistry of nucleic acids is a poverty pocket. The enormous interest and effort now attached to biochemical and biological problems involving nucleic acids are severely limited in their progress because of the relatively feeble chemical foundations in this field. My friend said that the difficulty is simply that nucleic acid chemistry is not good organic chemistry. I would have agreed with him that at present it is difficult and even tedious chemistry. I would have further agreed that the conceptual chemical harvest for time invested is likely to be considerably less now than a comparable effort on steroids, antibiotics, or plant pigments. What, I fear, he really meant is that nucleic acid chemists do not usually measure melting points or make elemental infra-red and magnetic spin analyses. What is even worse, they have been known to use an enzyme in a synthesis or analysis of a product. It is also true that nucleic acid chemistry is not carried out in departments of chemistry. These are crimes not easily ignored by a highly developed establishment."

(Kornberg 1969).

This situation is worsened when chemistry is incorporated to biological text-books. Molecular biology accepts 'bad' chemistry and incorporates this into text-books, further aggravating the situation. This can be outlined through the use of the following example:

Banks (1970) uses the example of adenosine triphosphate (A.T.P.) to show misapplications of chemistry in biology:

"One result of the spectacular progress in biochemistry in the past decade is that biochemical topics have been introduced into school curricula in biology and chemistry. Regrettably, there is an important area of biochemistry which is discussed in a very misleading way, properties being attributed to certain small molecules which are unrecognised in the field of chemistry. A conflict between what is taught in chemistry and implied in biology, or biochemistry is highly undesirable, yet attempts to resolve the quite unnecessary confusion have been strongly opposed

> by biochemists. Standard text-books of biochemistry at all levels abound with discussions (of chemical reactions) which are incomprehensible to chemists. It is frequently implied that certain organic molecules which occur in living systems possess bonds which can store energy. In addition to such abuse of all concepts of molecular structure, ideas drawn allegedly from that notoriously difficult subject, chemical thermodynamics, are distorted beyond recognition.
>
> To confuse students in this way is inexcusable. The false arguments used in this area are supposed to direct attention to the importance of particular molecule 'in vivo', but in fact they disguise its true role, where this is known; and where it is unknown, prevent design of useful experiments."

(Banks 1970).

A number of points require elaboration. Banks is placing molecular biology and biochemistry under the same umbrella. She attacks the latter for presenting 'bad' chemistry because of 'simplistic' notions. That is, taking complex issues and presenting these issues <u>as though they are simple</u>. Further, and even more significantly, she maintains that this actually inhibits possible future research. Yet it is this 'poor' chemistry, made worse by simplistic text-book presentation, which students may be required to familiarise themselves with in current biological courses.

Banks then goes into the details of one example:

> "The particular compound A.T.P., is persistently regarded as the universal 'energy currency', 'in vivo' and, on this view areas of cellular activity in which A.T.P. is a key compound such as muscle contraction, active transport, oxidative and photo-phosphorylation are discussed in terms of 'bio-energetics'. The part played by A.T.P. in intermediary metabolism is described as a trapper of energy from oxidation and the provider of energy to drive the energetically unfavourable reactions of biosynthesis."

She then goes on to 'examine the origin of this curious view'. It is not intended to do this except to note that it is a good example of the strong faith which molecular biologists place upon doubtful chemical principles.

Finally, Grene (1971) also criticises the assumptions made that biology is encompassed by the laws of chemistry:

> "Since, they (the reductionists and molecular biologists) declare, the process of growth and heredity have been shown to be determined by a sequence of D.N.A. molecules, biology has already been reduced on principle, to biochemistry; the completion of the job is routine. Granted however that D.N.A. has precisely the power that they claim for it, its operation demonstrates, on the contrary, that biology is not reducible to biochemistry (and ultimately to physics). What makes D.N.A. do its work is not its chemistry, but the order of the bases along the D.N.A. chain. It is the order which functions as a code to be read out by the developing organism. The laws of physics and chemistry hold, as reductivists rightly insist, universally; they are entirely unaffected by the particular linnear sequence that characterizes the triplet code. Any order is possible physico-chemically; therefore physics and chemistry cannot specify which order will succeed in function as a code. This argument, which appears incontrovertible was stated by Michael Polanyi (in "Science" Vol. 1. 60, 1968). The orderly structure of a chemical molecule, Polanyi points out, is due to a maximum of stability corresponding to a minimum of potential energy. Such order wholly determined by the laws of physics and chemistry and the boundary conditions of the system, is incapable of functioning as a code. The particular sequence of bases on the D.N.A. spiral, however is not so determined. There is simply no question of energy here at all. One can say that, statistically all sequences are equiprobable; any one, accordingly is highly improbable, and the measure of this improbability is precisely the measure of the information it provides. Polanyi writes:
>
> "As the arrangement of a printed page is extraneous to the chemistry of the page, so is the base sequence in a D.N.A. molecule extraneous to the chemical forces at work in the D.N.A.

molecule. It is the physical indeterminancy that produces the improbability of occurrence of any particular sequence, and thereby enables it to have a meaning - a meaning that has a mathematically determinate information content equal to the numerical improbability of the arrangement.""

(Polanyi (1968) quoted by Grene 1971).

C. "Factualism" In New Biology.

The following quotation is one taken from a currently used text-book:

> "D.N.A. is unlike any other substance. Life is a unique condition because D.N.A. is a unique molecule ...
>
> ... As you continue your study of biology you will find that D.N.A. comes into discussion again and again. How do organisms grow? How do they reproduce? How does a species maintain its identity? Why do new organisms resemble their parents in some respects and differ in others? D.N.A. provides the answers to these questions. D.N.A. is the key to life."
>
> (Otto and Towle, 1969, p.48 - 50).

The above statement can be regarded as simplistic because it presents a complex issue as though it is actually simple (Stenhouse 1972). This notion seems to indicate that D.N.A. is the only aspect of biology worth studying. Yet the text from which the quotation comes does not devote all of its pages solely to D.N.A. It also implies that a great deal of biology not referring to D.N.A. is of no value. This would bring a great deal of biology into disrepute. If agreement with the quotation is considered, most of the text written by these authors, not related directly to D.N.A., must be irrelevant. They would therefore be guilty of incorporating useless information.

Take for example the obvious biological principle of differentiation. Many organisms differentiate from a single cell (zygote) into a multicellular organism with many different and varied cells with many varied functions. Yet it is assumed that all living cells have the same identical D.N.A. contents. D.N.A. reputedly determines cell structure. Yet cells are obviously widely varied in structure and function. The information content of D.N.A. has yet to account for this:

"Cells should contain a device for translating the code library contained in the D.N.A. into the biological characters which it determines: computer science experience indicates that the translation device ought to be considerably more massive than the library.

The available facts suggest that living things do not meet these requirements:

(1) Organisms which must differ considerably in their genetic complexity often have similar cellular D.N.A. contents, and there is no evidence that the discrepancy can be accounted for by differences in genetic redundancy or in the inertness of some chromosome sections. Conversely, organisms which are nearly identical in genetic complexity may differ considerably in cellular D.N.A. content. The available evidence does not support the idea of a one-to-one correspondence between genetic information, and the information represented by the structure of D.N.A. or for that matter any other molecular component of the cell.

(2) No cytologist has discovered a ubiquitous structure, considerably larger than the chromosomes (the code library) which shows evidence for serving as a translator. While recent biochemical evidence suggests possible means whereby D.N.A.-borne information may be translated into genetically effective protein specifity, there is still no sign of a device capable of translating a D.N.A. into numerous anatomical features (finger-prints for example) that are also inherited.

Thus in strict analysis of the problem of inheritance in accordance with modern information theory leads to the remarkable result that the organisms specifity must be determined, at least in part, by agencies not present in the initial germ cell and certainly not in the D.N.A. alone. Elsasser (1958, 1961) points out this view, which can be derived directly from modern physical theory, is identical with a principle already well established in biology - epigenisis. This view holds that the fertilised egg begins with a limited amount of specifdty, which develops into more detail in progressive superimposed stages. Strong

> evidence from embryology supports this conclusion, and recently some investigators have suggested that certain specific types of inheritance, especially in protozoa, are epigenetic in character.
>
> These reults have an important bearing on the customary ideas about D.N.A., for they call into question the basic assumption that D.N.A. (or for that matter any other single component of a germ cell) can possibly serve, by itself, as the final arbiter of biological specifity."

(Commoner 1961).

It can be seen therefore that the quotation from the text-book above presents features as 'fact' when they are provisional and even controversial. The authors make simplistic apparently authoritative statements. This is a case where 'pseudofact' masquerades as fact for the purposes of clear exposition. A key issue of the 'new' biology is therefore 'factualism'. That D.N.A. is actually the key of life is based upon controversial evidence. Also this text demands of the student that he agree with what is said. Another issue therefore could be labelled authoritarianism encouraging an appeal to the authority of pseudofact in biological education.

'Factualism' arises when tentative or doubtful concepts and findings are treated for the purposes of exposition as though they were fact. Moreover, explaining what are really complex issues in ways which seem to reveal to students that they are simple is to be guilty of promulgating 'simplistic' notions, which are also 'factualistic' because they misrepresent the actual complexity of biological concepts and processes. The A.T.P. controversy (Banks 1970), seems to be a good example of 'factualism' by promoting 'simplistic' notions. Text writers and curricu~~l~~makers seem to be more concerned with clarity of explanation than with actual complexity. Hence they both can promote 'factualism' as well as 'simplisism'. For example the Seventh Form Teachers' Guide (Page 40) for University Bursary and Scholarship Biology has an outline of the 'family tree' of Man as though the evolution of man has been finalised as fact. Biological theory relating to Man's evolution notes that there is probably a number of alternatives as to the origin of Man. For example, the 'non-anthropoid ape theory' is not given any consideration at all (Straus 1949). Thus it must be assumed that the outline is not only 'simplistic' but also 'factualistic'.

D. "Technicism" In "New" Biology.

Biological curricula in New Zealand emphasise technical aspects. Current courses and curricula claim to place great emphasis upon 'skills'. One preamble is quite explicit when it is stated:

> "The intention was, rather, to keep the volume of factual and theoretical material to a minimum."
>
> (Form VII Teachers' Guide Biology", Curriculum Development Unit. 1970. Page 2.)

Moreover this same preamble states that emphasis ought to be placed upon 'applied' biology.

> "If possible students should have opportunity to meet practising biologists in maltworks, medical laboratories, sewage treatment plants, fisheries, landscape design, farm management etc. Discussion with these people could be followed up with project and related experimental work."
>
> (Form VII Teachers' Guide. Page 2.)

Two major points arise. Firstly, theory is held to be not important. Secondly, 'applied' biology rather than 'pure' biology is the important part of the course.

The 'applied biology' - 'pure biology' distinction is a difficult one. However for the purposes of this discussion 'applied' biology can be regarded as biological work carried out because of its economic advantage to the nation. Thus 'pure' biology could later become transformed into applied biology. Economic advantage, and vocational education are both emphasised in New Zealand. Biological education is not immune to the 'vocational' stress. A large number of various skilled activities is involved in 'applied' biological fields. Technical manpower is required for the many specialised tasks involved especially in a nation which bases its economy upon primary industry.

Polytechnical schools have increased in size and number. New Zealand Certificates in Science can be obtained in biology. Schools of food technology and biotechnology have been developed. As a consequence, there seems to be a 'drive to status' from technical biology. Technical biology seems to desire equivalent status with biological science, in spite of the fact that technical biology, (including technology) does not necessarily have the innovative characteristics of 'pure' biological science. But technical biology is not necessarily the same as biological science. It is necessary to distinguish between technical biology and biological science.

Firstly, technical biology deals with discovered phenomena. Seldom are significant discoveries made in strictly technical fields. (They could be, but the main function of technology is to use what has already been discovered).

Secondly, technical biology deals with specific skills. These skills may involve a high degree of manipulative dexterity. With the proliferation of highly sophisticated and expensive physico-biological extensions for observing phenomena, well trained technical personnel are most necessary. Poorly acquired skills, or mistakes cannot be afforded with highly expensive equipment. Thus, the skills necessary for one particular applied research centre may not be the same as those for other research centres. No variation in skill or procedure is allowable in technical biology.

Thirdly, technical biology is 'rule bound'. The varying of established procedures or skills is usually not allowed. Applied research centres cannot afford to have technicians 'experimenting' with intricate equipment.

Fourthly, the skills required are often determined by the technical hardware being used. These determining factors need not necessarily be biological.

Biological science on the other hand differs.

Special manipulative skill may not be as necessary. Nor need there be strict adherence to rules. Indeed initial 'negation' of accepted rules may be an important feature for biological science. Instead of giving import to 'obedience biology' as in the technical fields, 'disobedience' biology may indeed be a desirable pre-requisite to innovation. (Stenhouse 1971). The initial negation phase at first begins at abstract theoretical levels:

> "The established paradigm in such a case, must be dethroned before the new facts can come to notice. In terms of logic, then, this means that the previous paradigm must - provisionally at least - be negated or held in abeyance ...
>
> The logical structure of the situation may be illustrated by reference to the popular (though quite erroneous) version of the discovery of America by Columbus. According to this story, Columbus was a brave pioneer who sailed westward across the Atlantic 'into the unkown'! The point which must be kept in mind is that so far as Columbus' contemporaries were concerned he was not sailing 'into the unkown'. He was sailing into the known. They knew very well what would happen to him: he would sail on until he reached the edge of the world, and then he and his ships would fall over the edge and be destroyed!
>
> In short Columbus had to create an unknown before he could sail it on a voyage of discovery. To do so he had to negate the currently accepted 'known'."

(Stenhouse 1971).

Technical biology (like the contemporaries of Columbus) deals with the already established knowns. Columbus could be regarded as taking on the activity of an innovative scientist - he created in his mind an unknown by disobeying or negating currently established and accepted patterns. An activity of biology as a science therefore is to hold in abeyance, or to negate currently accepted views, to attempt to create an unknown, and then to explore the ramifications of this unknown. If logic is also involved, then theoretical and philosophical notions are crucial to the process. Biological science, as opposed to technical biology has therefore important theoretical aspects (but current biology does not incorporate these). Initial impetus in the 'breaking of new ground' in biological science is obtained firstly at a theoretical level. This may involve breaking away from conformist thinking in biology. For example 'systems theory' in biology was established as a break from orthodox biological theory. (Von Bertalanffy 1969).

Technical biology, on the other hand, may refine these procedures but brand new procedures are not usually established in this way:

Hanson puts the position succinctly:

> "Thus the major function of the scientific enterprise - to wit, the attainment of theoretical understanding of knowledge - should be hampered as little as possible by laboratory 'busy work'. Refinements in conduitry and circuitry, in beam-focusing, in spectrometry, thermometry, and hydrometry - these may lead to more decimal places as one reports the results of measurements, but they rarely determine a new form for an equation or a new kind of inference concerning old subject matter."

(Hanson 1971)

Another interpretation can be made. A spectrum could be imagined with 'raw sense experience', that is the usual sensory avilities at one end, and theory at the other end. As one moves from 'raw sense experience', theory becomes increasingly important. Technical biology tends to be nearer the 'raw sense experience' end of the spectrum; biological science nearer the theory end.

Hanson also emphasises this distinction when he states:

> "Brainless, photosensitive computers - infants and squirrels too - do not make scientific observations however remarkable their signal reception and storage may be ... That the motion of Mars is retrograde, that a fluid's flow is laminar, that a plane's wing-skin friction increases rapidly with descent, that there is a calcium deficiency in Connecticut soil, that the North American watertable has dropped - these all concern observations which by far exceed the order of sophistication possible through raw sense experience. Nor are these cases of simply requiring physico-biological 'extensions' to the senses we already have; for telescopes, microscopes, heat sensors, et cetera, are not sufficient to determine that Mar's motion is retrograde, that blood poisoning is setting in, that volcanic activity is immenent. Being able to make sense of the sensors requires knowledge and theory - not simply more sense signals. (Understanding the significance of the signal flags fluttering from the bridge of the 'Queen Elizabeth' does not usually require still more flags to be flown!)."
>
> (Hanson 1971).

'Raw sense experience' is obviously necessary. But to connect, for example, symptoms of calcium deficiency with the cause, theory is needed. That is the theory or science end of the spectrum is needed. Technical biology could be used to measure calcium amounts in soil and drinking water by testing techniques. Through 'raw sense experience', high or low levels of calcium could be observed. But no amount of repetitive testing for calcium in soil and soil water, will develop a general theory for 'mineral deficiency' involving all possible elements. Doing the same thing, if possible, in exactly the same way, bound by the limitations of the technique being used, will never by itself discover anything new about calcium-lack in soil. The only way in which this can occur is for a theory to be first worked out, and then technically tried. The innovative discoveries belong to the theory end of the spectrum. Theory, and hence biological science, is prior to technical biology:

> "The infant and the layman see: they are not blind. But they cannot see what the physicist sees; they are blind to what he sees."
>
> (Hanson 1958).

It must be emphasised that technical biology relies upon 'pure' biology for its sustenance and not vice versa. Should 'pure' biology be downgraded, at even introductory levels of biological education, then eventually technical biology will 'dry up'. This seems to be occurring. An article entitled "Agriculture: Critics Find Basic Research Stunted And Wilting" (Science Vol. 180, No. 4084, April 27, 1973 Page 390) has already outlined this problem for the United States of America. The United Kingdom also seems to be affected:

> "My thesis may be simply stated. It is that in Britain we are spending a great deal of money on research, that we have every reason to be disappointed by the productivity of that research, and that most attempts to improve the situation have made it worse."
>
> (Mellanby 1973).

A contributing factor to this decline may be the current deriding of theory at all levels of biological education.

'Technicism' in biological education can now be clarified. 'Technicism' involves an implicit or explicit assumption that the only biology which is important is technical biology. Thus biological education stresses the 'raw sense experience' of the spectrum. Current biology deals with past achievements, and downgrades theory. This encourages a 'backward stance' to biology. An unstated assumption seems to have been made by biological educators that all the major necessary discoveries have been made, and are there to be learned by students. This situation is discussed by Koestler (1964):

> " 'The particular phenomena of the arts and sciences are really but a handful' wrote Frances Bacon, 'the invention of all causes and all sciences would be a labour of but a few years.' "
>
> (Koestler 1964).

Current biological education, in being 'technicist' seems to also adopt this position.

Stress is also placed upon 'skill' and 'technique' in practical biology. Concomitant with this, is the assumption that biological education must out of necessity use expensive complex equipment. Technique centred specialisms and research teams are commonly noticed in present biological research.

Moreover, emphasis is placed upon the authority of 'fact' already discussed under 'factualism'. Students must accept past discoveries as read.

Negating tendencies are not tolerated at introductory levels:

> "It seems often tacitly assumed, however, that the casual factors of an individual's cognitive style and personality can operate in a neat temporal succession, the nonconformity of a discovery and innovative phase in adulthood being preceded by a docile acceptive phase in the teens and twenties."
>
> (Stenhouse 1971).

Students are not likely to be technical at introductory levels and then suddenly innovative at later levels. Innovation is most likely to arise in certain cognitive styles; for example in 'divergers' (Hudson 1966, 1968) and in 'negaters' (Stenhouse 1971).

The vocational emphasis in biological education previously mentioned, does not enhance theory nor encourage students who are theoretically orientated. This may create long term detrimental effects to biological research. 'Basic' research will dry up through being 'technicist'.

> "Technological advance must ultimately become trivial unless it is drawing upon substantial and continuing innovation at the basic or pure level."
>
> (Stenhouse 1968).

A final feature seemsto be this. Technical biologists are proficient only at the skills (which may be very complex) for which they are trained. They are not likely to go outside their sphere of training for a future vocation. Once trained for a job, a technical biologist becomes confined. Yet with certain future changes in techniques, and research equipment, the possibility of technical biologists becoming redundant is real. It is likely to be more real should 'technicist' biology be further emphasised:

> "It is possible that many biological graduates will have to accept posts in which their specialised knowledge of biology is not used as such. For appreciable numbers of university and further education students, the Working Group suggests that a general scientific education would be more appropriate than a conventional vocationally orientated course."
>
> ("Summary Of Report On Biological Manpower", Biologist, Vol. 18, No. 4, November 1971. Page 176).

'Technicist' biology deals with specifics, but it does not attempt to tie these specifics into one overall theory. The quotation above advocates a <u>general</u> science education in the hope that adaptability will be attained. The contention of this thesis differs. It is possible that a general course will consist of a different range of specifics added together to develop a science curriculum overloaded with facts and experiments. What seems necessary is a re-assessment of the nature and purpose of theory in science in general, and biology in particular. It would seem that if introductory biology attempts to develop theory, two consequences may follow. Firstly, 'thinking' and 'adaptable' technicians will enter technical and applied biological fields. These adaptable technical biologists may themselves show innovative tendencies. Their retraining, should it prove necessary, would not be a prolonged process. Secondly, the trained technician may not of necessity need to be confined in the job into which he has been trained. He may find that his technical skills are of a decided advantage in other seemingly remote fields. This latter situation is not a reality in current 'technicist' biology. Biological scientists, if they study zoology, botany or molecular biology seem to be destined to remain within the field in which they have been educated. If biological education was less technical and more theoretically orientated, a situation outlined in a recent "<u>New Scientist</u>" may become more common:

> "The idea that a higher education in science is vocational, but the study of arts is not, is bred into the science student - probably implicitly rather than explicitly - by parents and school teachers. Later, the belief is perpetuated and

strengthened by university lecturers and careers boards. The view of a university education as anything other than a straight forward meal-ticket for the scientifically oriented is a new one - not necessarily new in concept, but new in that it must now be accepted as a coming to terms with reality.

As the job market stiffens, the graduate will have to do more than wave his diploma like a magic wand: he must use his initiative in assessing what he really wants to do. And just as many arts graduates have found their way into science-based industry, perhaps the scientist should now assert the usefulness of his education as a training for life rather than just a training for a job in science ... Given a relatively free job market in which scientists are widely accepted in non-scientifc jobs, shortages and surfeits of scientists in scientific occupations would be evened out by economic motivated mobility between sectors according to changes in demand patterns. But how does a scientist get a job outside science: what does he do? We talked to six scientifically trained people, who like ourselves, do not practice the subjects they studied at university, but bring a scientific background to a non-scientific area.

In the end, science is a way of looking at the world: who can say of any job that it will not benefit from being occupied by someone who looks at it from a scientific way?"

("New Scientist" Vol. 50, No. 752, May 20 1971. Page 456).

Biological 'ways of looking at the world' are not likely to accrue if biologists are educated in specifics. 'Ways of looking at the world' are implicitly theoretical. It is therefore possible for biology to retain its vocational orientation while also incorporating theory into curricula and courses.

The New Scientist interviewers then go on to outline the careers of scientists working outside of science. These are as follows:

(a) A physicist who works as a librarian.

(b) A botanist with an honours degree who is a social worker. She comments as follows:

> "I have a vast number of cases to deal with, each with different priorities and urgencies, and with different time scales. You need an organised mind and a carefully structured approach - as well as compassion - to be able to cope with it all. My scientific training definitely helps me."
>
> (New Scientist Vol. 50, No. 752, Page 455).

(c) A mathematics graduate who works in science administration.

(d) A mathematician who is an editor and publisher.

(e) A biochemist who works as an economist.

(f) A chemist who works as an economist.

If biological education becomes less 'technicist' it may be that more biologists may become involved in careers outside biology, to the advantage of biology and the occupation chosen. Theory could, if developed, actually encourage biology graduates to seek employment outside biology.

E. "Experiment" In "New" Biology.

Present biology rates 'experiment' as paramount. It seems to be held that 'experiment' is a feature of 'mature' sciences such as physics and chemistry. Biology thus is maturing if it inculcates 'experiment' into its subject matter. What Thornton (1969) claims for science seems also apt for current biological education:

> "The Committee suggested in several places that many able students are deterred by the rigour of school science especially when that rigour degenerates into a grammarian's formalism when it is bolstered by an inordinate bulk experimental work and when it is overlain with vast bodies of factual information."

(Thornton 1969).

Biological education mimicks biological research. Reasons for accepting this view appear to be as follows:

(a) 'Experiment As An Integral Part Of Scientific Method'.

Firstly, 'experiment' forms an important and integral part of 'the scientific method'. This method is promoted in many text-books. It seems that it is the only way in which hypotheses can be refuted or confirmed. (See Weisz 1967). Secondly, the findings confirmed by 'experiment' are thought to be more real than findings derived from 'mere' observation. Experimental operations are apparently meant to ascertain the reality of any given situation 'truthfully' and 'objectively'. Thirdly, most text-books promote 'experiment'.

> "A hypothesis must be subject to some sort of experimental test - it must make a prediction which can be verified in some way - or it is mere speculation."

(Villee 1967).

> "Experimentation can provide the necessary evidence, and whosoever then experiments after guessing at answers becomes truly 'scientific' in his approach, be he professional scientist or not."
>
> (Weiss 1967).

> "The scientist must set up an experiment in which the hypothesis will either be supported or contradicted. While it is often difficult to do, all factors except the one to be tested, must be removed or accounted for. We refer to this one factor as the single variable or experimental factor."
>
> (Otto and Towle 1969).

It seems however that not all biology has been made experimental or indeed can be made experimental:

> "It may sound derogatory to the biological, and much more to the social sciences, to say that they are descriptive. Yet it is true - in part because of the historical development of the sciences which has seen the biological sciences pass from the descriptive to the experimental stage of methodology more recently than did the physical sciences."
>
> (Glass 1965).

This statement was made by Glass when he was chairman of the Biological Sciences Curriculum Study (B.S.C.S.). The emphases of this curriculum are reflected in New Zealand curricula in biology. Glass distinguishes between descriptive biology and experimental biology. He also implicitly maintains that the latter is desired. Text authors, it has been seen, emphasise experimental aspects of biology. Both Glass and text writers imply that biology already has become experimental, and that there is no longer any necessity for description or observation. It would seem that this is a situation where a prescription is masquerading as description. (Stenhouse 1972). To say that biology is experimental is to describe a situation. However to maintain that it is desirable for biology to be experimental is to prescribe. Thus the latter statement is arguable. Text writers and biological educators often, for reasons of expediency and clarification, make apparently descriptive statements to act as cloaks for prescriptions. They are maintaining that experiment is important for biology. The difference arises when such statements are put into prescription form - experiment ought to be important in biology. This latter statement is more open to argument. Text writers and curriculum makers do not seem to want argument. To present a prescription as a description is to give the prescription a degree of 'factuality', and few people, students, or teachers implementing curricula, dare to argue with 'facts' (Stenhouse 1972).

Both sentences (previously quoted by Glass) on the surface at least, look factual, descriptive, and unarguable. Yet closer investigation reveals a marked contrast between the two. In one sentence he says that biology is descriptive. In the next he says that it is experimental. Prescription can be readily unearthed. The position he occupies seems to be this. Biology, probably most aspects of it, is descriptive. Experiment is a feature of the advanced sciences. Therefore biology ought to become an experimental science. He seems to maintain that biology is a poor relation to the other sciences because it is descriptive, and that ought to move toward 'experiment'. If he had explicitly stated that biology ought to be experimental, he would find that his position would be open to dispute. A prescription appears convincing, if it is presented in 'factual' and descriptive format. The unearthing of prescriptions which are given descriptive cloaks seems to be a most important exercise in curriculum evaluation. The detail devoted to experimentation in some texts (Otto and Towle 1969; Weiss 1967; New Zealand Department of Education 1969) seems to indicate that 'experiment' <u>is actually</u> the most important aspect of biology:

> "It is hoped that the course will foster a critical approach to biology with the emphasis on <u>experiment</u>, enquiry and understanding rather than the accumulation of information ... It (the laboratory) is a place where accurate observation is of first importance, where precise measurement aids observation, and where controlled conditions make it possible to conduct experiments from which clear conclusions can be drawn by logical thinking. <u>Only by experience in the laboratory is it possible to see what science really is</u>."
>
> ("Biological Science: Processes and Patterns of Life". 1970. Pages VI and VII).

If evidence can be obtained to show that the above is not the case, then it must be accepted that descriptive statements, often made in texts, are really prescriptions.

Before this can be carried out however, some brief investigation seems to be necessary to highlight some meanings of 'experiment' within the context of biological education. This is necessary, as a decision has to be made upon some of the characteristics of an 'experiment' in biological education.

Firstly, 'experiment' may be loosely interpreted to mean 'any practical exercise' at all which involves laboratory equipment. This, despite the point that many of the practical exercises do not have the classical characteristics of experiments as defined in the text-book prefaces and introductions.

A second interpretation of 'experiment' is the one which is usually outlined in most texts. It involves the simplification of phenomena to a single experimental variable which can be used against a 'control experiment' to test an hypothesis. The 'principle of parsimony' is applied where complex reality is pared down to its barest essentials. This can be labelled the 'classic' meaning of 'experiment', outlined for example in Otto and Towle (1969) and in Villee (1967). This particular interpretation is usually the one incorporated into discussion of 'the scientific method'.

Thirdly, in the educational context, 'experiment' may mean 'doing original practical work'. This could involve applying the classical experimental procedure, or any other procedure, to an aspect of biology not previously accomplished by biological research. In this case the student would be acting as a mature biological researcher. The situation where the student is an actual scientist has been outlined (Ausubel 1965).

Fourthly, a 'field exercise' may be labelled 'experimental'. Usually the exercise involves data collection, and empirical procedures.

These are but four interpretations being given to 'experiment' in present biological education.

(b) 'Experiment' Helps Students Acquire Practical Skills.

Being acquainted with biological apparatus is important for all biology students. Skill in the use of everyday basic techniques must be incorporated into courses and curricula. But once a skill has been developed to an acceptable degree, there seems little need to continue with repetition of the same skill, especially when time is at a premium. Yet many practical exercises belabour the obvious and involve repetitive use of the same skill for a number of exercises. This claim can be justified, because many of the exercises involve a biological principle, very obvious to students, which could be presented to them formally. There seems little need to impede the comprehension of a simple principle by having to spend a great deal of time upon strict obedience to a set of instructions in a practical manual using already well accomplished laboratory skills.

(c) 'Experiment' And Current Laboratory Manuals.

Four meanings of 'experiment' have been outlined. How do these meanings apply to current commonly used laboratory manuals? As an exercise, one laboratory manual was analysed according to the four meanings. A preamble in this laboratory manual demarcated two general types of experiments.

> "The purpose of the practical course, then, is to provide some direction to your experiences in biological science. The exercises are of various kinds; different ones stress different aspects of science. Some are designed to acquaint you with biological thinking, some to acquaint you with biological apparatus. Some involve observing and measuring; some make use of observations and measurements made by others. A number of exercises are real experiments."
>
> ("Biological Science: Processes and Patterns" Laboratory Manual 1970 Page VIII).

It appears that the author refers to two sorts of practical exercises. On the one hand there are 'real experiments' and on the other hand there are 'others'. It could be assumed that the 'real' experiments come under the heading of either the 'classical experiment' or of the original 'student working as a scientist' meaning, or field-work, or experiments involving all three meanings together.

If the 'classical experiment' meaning is accepted as describing 'real experiments' in this particular laboratory manual, only one (Exercise 2:1) could be accepted as being an experiment. If a 'real experiment' is one which allows for original scientific research, not one exercise is specifically designed for this. Thirdly, if being 'real' involves field work, then three exercises specifically involve field work. If 'real experiment' means any one, or indeed all of these meanings together, then by far the greatest number belong to the group entitled 'others'. (Approximately fifty exercises are outlined altogether in this commonly used sixth form laboratory manual.)

What characteristics do these 'others' have in common? They all seem to involve a step-by-step obedience to a list of instructions to derive a result, usually an observation of a colour change in a test-tube, or a reading. The key to their commonality is the 'cook-book' nature of the procedure, and the simple observation required at the end. In essence the practical exercises are technically orientated.

Thus there seems to be a situation of contrasts, beginning with an apparent descriptive statement where it was noted that current biology is experimental, and that this characteristic is reflected in biological education. In fact evidence has been really obtained to show that biological education is not experimental at all, even when generous interpretations and meanings are given to the term 'experiment'. Thus it can be said that behind apparent descriptive statements relating to experiment in biology are prescriptive assumptions. What the curriculum makers and text-writers are saying is that biology ought to be experimental.

This contrast is further exemplified when the 'classical' meaning of 'experiment' is outlined in many text-books, usually in prefaces and introductions. (See "Biological Science: Processes and Patterns" in its introduction, and also Villee 1967; Keeton 1967; Weisz 1967). But once this outline of 'experiment' has been made, no further reference to it is made in the main body of the text, nor is any mention made in laboratory guides.

Moreover, if the 'classical' meaning of 'experiment' is accepted, then very little of the main body of these texts could be regarded as the 'truth' because a great deal of what is presented has not been derived using the 'classical' experimental method. Much present (and past) biology would be given little significance if the introductions and prefaces of texts were fully accepted.

Nor does current biological research use the classical experimental method. A great deal of present biological research is 'descriptive-analytical', where parts are broken to smaller parts, and the smaller parts are merely described. Classical experiments with 'controls' and few 'variables' are not necessary for this work. Yet despite this, current biological educators perpetuate 'the experiment' as the key to all biological research as though it actually were so.

(d) The Observation Phase Is Condensed.

Another important feature apparently a product of practical exercises, is 'observing and measuring'. Measuring has already been referred to in 'quantification'. Observation will be given attention at this stage. Current biology attaches importance to observation but only in so far as it is related to practical work. Any other form of observation is 'mere speculation' (See Villee 1967; Weisz 1967). Observation it seems, is applicable only at the concluding stages of an experimental investigation. All observations prior to experiment are according to current biological educators, 'unscientific'.

Within the context of biological education, the observations necessary at the culmination of a practical exercise, are clear, concise and obvious to any observer with normal sensibilities. Most observations involve an obvious colour change, a reading, a statistic, a drawing, or some gross movement. Complex or hazy observations are seldom allowed. The observation has to be obvious. This is in keeping with the Lamarckian position outlined previously by Piaget and Inhelder (1969). (External pictures are apparently being taken into the brain as copies of external reality.)

Even when observations are supposedly clear, concise, and definite, difficulties arise. For example when students make a biological drawing of the same leaf, not all drawings will look the same even though they really try to draw exactly what they see. Biological sketchers cannot draw as though they were taking photographs of an identical leaf. Yet it is assumed that the steps of a practical exercise or experiment, if strictly adhered to, culminate in a 'correct' observation obvious and identical to all.

Observation apparently is a necessary part of a practical exercise. But the exercise is designed to maximise and make observation obvious and definite. It is definite, and there is little need, for further interpretive discussion.

To conclude, the following quotation highlights the present situation in biology, and also emphasises the need for upgrading observation:

> "It cannot be stressed too much in this age of respect for - one might almost say adoration for - the experiment, that critical, precise, and systematic observation is a valuable and indispensable scientific procedure, which we cannot afford to neglect. Particularly in our young science we need good observers and the sense of hurry, the urge towards spectacular 'breakthroughs' must not be allowed to be a kind of contempt for non-experimental observation, which admittedly is a slow procedure but which, by trial and error processes has to provide us with our hunches."

(Tinbergen 1964).

Some Remedies For The 'New' Biology.

(1) A Need To Emphasise Theory In Biology.

(2) The Upgrading Of The Observational Phase.

(3) The Incorporation Of The Rationale Of Natural History Into Current Biological Education.

(1) A Need To Emphasise Theory In Biology.

Theory has declined in biological education. This thesis advocates its incorporation. Therefore a strong case must be made.

Firstly, some introductory comments as to the popular meanings of theory. Secondly, a brief (and by no means exhaustive) account will be made of theory within the [illegible] of the history and philosophy of science. Thirdly, some comments by reputable biologists will be presented, who note the importance of theory in biology. Fourthly, consideration will be given to some consequences for biological education, should theory be adopted.

Before detailed discussion, it has been the contention throughout this thesis, that the lack of theory in biological education is creating a 'drift' of potentially good biologists away from the subject. A return to an emphasis upon theory would possibly promote the attractiveness of biology to students at elementary levels.

(a) Some Possible Meanings of Theory in Biology.

One popular meaning of theory is that it is the 'gas' or abstract talk. Research biologists may talk about 'vitalism', 'teleonomy', 'entelechy', 'paedogenisis', 'function', 'reductionism', and 'organicism', but this type of discussion apparently is far removed from the realities of experimental research. Discussion relating to these topics is therefore more than likely to be confined to popular publications and encyclopedias, and generally will not be found in many texts.

Secondly, theory may be taken to mean discussion about issues at present refractory to experiment. It may be that these issues will never be experimentally disproved or proved. Thus 'theory' in this context may be of little value for the working biological scientist.

Thirdly, theory may be interpreted as a contrast with fact. Often some aspects of biology may be characterised as being 'merely a theory'. Sometimes it is held that 'theories' can hold up the path of research in a particular area of biology. A research scientist could be 'tainted' by theory as he works. For example the following quotation explains this idea clearly when referring to observation:

> "The difficulty of observation lies largely in unsuspected bias. People forever see what they want to see, or what they ought to see. It is extremely hard to rid oneself of such unconscious prejudice, and to see what actually is there, no more and no less. Past experience, 'common knowledge', and often teachers, can be subtle obstacles to correct observation, and even experienced scientists may not always avoid them."

(Weiss 1967).

Presuppositions, or unconsciously held assumptions may apparently prevent a scientist from getting at the facts. Thus this interpretation of theory can be interpreted as being antagonistic to 'fact'. Theories could therefore be added to the list of obstacles to observation outlined above.

Fourthly, theory may be equated with a metaphysic in a strict religious sense. Crick (1966) maintains this interpretation when he says:

> "I have a strong suspicion that it is the Christians and The Catholics in particular who write as vitalists, and it is the agnostics and atheists who write as anti-vitalists."

(Crick 1966).

Fifthly, theory may be taken to mean that which opposes the practical. Current curriculum makers imply this when they make statements of the following sort:

> "The intention was rather to keep the volume of factual and theoretical material to a minimum ... Throughout the course, great emphasis is placed on practical work and on the development of associated skills."
>
> (Senior Biology Revision Project. Curriculum Development Unit Department of Education 1970).

All contexts for the meaning of theory emphasise it in a less favourable light. Those meanings and contexts have percolated into current biological education. Theory in biological education is treated usually by default in curricula and text-books, by not being mentioned at all.

(b) Characteristics Of Theory In Science Generally.

It must be emphasised that it is not intended to give an in depth and detailed philosophical account of theory in science. Instead a few characteristics of theory will be outlined.

In the first place, a theory is an abstraction. By abstraction it is meant that theory need not be derived only from experiments. If one deals with abstractions one also deals with logic, and therefore theorising involves philosophy. Rudner (1967) emphasises the 'abstract' and philosophical nature of theory when he states:

> "Now in general the context of validation is the context of our concern when, regardless of how we come to discover or entertain a scientific hypothesis or theory, we raise questions about accepting or rejecting it ... How Harvey came to think of an hypothesis of the circulation of the blood is a substantive question of the history of science. What could be meant by the claim that this hypothesis has been sufficiently confirmed by the evidence amassed for it is obviously a quite different question and one belonging to the philosophy of science."

(Rudner 1967).

Moreover there is plenty of evidence to show that theoretical discussion is an abstract non experimental exercise. The following brief selection of titles and authors is supplied as evidence for this:

"Popper's Falsifiability, And Darwin's Natural Selection", Lee. (1969).

"The Bases Of Conflict In Biological Explanation", Lewontin. (1969).

"Mechanism, Methodology, And Biological Theory", Ackerman. (1969).

"On Semantic Pitfalls Of Biological Adaptation", Ghiselin. (1966).

"Are There Laws In Biology?", Ruse. (1970).

"Biology And The Unity Of Science", Shapere. (1969)

"Urge And Molecular Biology", Mora. (1963)

"Reducibility: Another Side Issue?", Grene. (1971).

"Fitness And Some Explanatory Patterns In Biology", Manier. (1969).

"Footnotes On the Philosopphy Of Biology", Mayr. (1969).

Most of the above authors (Mora, Mayr excepted) are not famous experimental scientists. They are writers who deal with philosophical and theoretical issues in biology. It would therefore seem, so far as present evidence goes, that it is not necessary for reputable biological researchers to also be good theoreticians.

Secondly, an analogy may be used to explain what is meant by theory in science and in particular biology. This analogy is supplied in the knowledge that it probably suffers from inbuilt limitations of the use of analogies. However, it may serve to simply outline some characteristics. A theory can be regarded as an optical lens. There are as many sorts of lenses as there are theories. If objects are viewed through one lens, the objects that do come into view can be given the status of 'facthood' according to this theory. Another lens (theory) which, when applied to the same phenomena may bring into focus other objects different from the first case, which could be accorded 'facthood'. This latter lens may blur the well demarcated objects of the first lens. Therefore some objects, observable through one theoretical lens, may not be observable through another.

A proviso must be incorporated at this stage. It will be noted that the term 'facthood' has been used. This is so, because it is logically not possible to observe facts:

> "We observe objects, processes and events. But facts must be a different kind of denotatum, logically different. We do not

observe facts (what would they look like?). Facts are not objects, or collections of objects, or constellations of objects. Facts are to the effect that e.g. a bee while supping a flower's nectar gathers pollen on its limbs, later deposits it on other plants thereby fertilising them. A statement to that effect would be true, or false, in virtue of facts of this type - and not because of the simple existence of bees and flowers, and certainly not because such facts are bees and flowers or the geometrical interrelationships, or true statements about them. Facts are what true statements state3.

(Hanson 1972).

Hanson further amplifies the distinction between 'fact' and 'facthood':

"Noting the conceptual intimacy which obtains between 'the facts' and statements about the facts, however, suggests to other philosophers that there can be nothing logically less complicated about facts than about the statements themselves. Since statements are conceptually more intricate than names, so also facts must be conceptually more intricate than objects; more intricate than object clusters too. The theory-laden character of 'the facts' soon comes to impress such thinkers even more forcibly than is the case with observation. For whatever is 'out there' that makes us say (truly) that the space immediately adjacent to our sun is non Euclidian, or that the symmetry properties obtaining within our universe indicate the existence of an anti particle corresponding to each kind of familiar particle now known - these 'whatevers' must count as facts. Such 'whatevers' are accorded 'facthood' because they 'anchor' the least vulnerable statements within exant theoretical physics. The philosophical tendency here, then, will be to construe 'the facts' as those objective organisations of the objects events and states of affairs within a scientific subject matter which render true the theories we hold. The view thus arises that 'the facts' are those conditions a subject matter meets such that a given theory might be applied to it - the boundary conditions.

In that sense, 'the facts' are 'theoretically determined' somewhat as the rules of chess determine what layout the chessboard must have at the onset, and what moves will be permissible therefrom so that the subsequent interchange could be describable as chess. Thus in a Wittgensteinian view : ... 'the fact that it can be described by Newtonian mechanics asserts nothing about the world; but this asserts something, namely, that it can be described in that particular way in which as a matter of fact it is described'.("Tractatus Logico Philosophicus" London 1927 p 342).

Possible science is thus a potential infinitude of possible theories - scientific idea games ...

... so taking 'cognisance of the facts' is much more than simulating and emulating a hypersensitive data receptor. On the other hand it also seems to be more than just the clamping of a scientific theory's rules and definitions upon the world, thereby selecting of study only those subject matters which are co-operative with the exant theories. Rather the facts emerge as the world's possibilities for being described in some available language - which possibilities will be every bit as 'theory laden' as the descriptions themselves are disclosed to be. (Could $E=Mc^2$ have expressed as a fact one million years ago? For whom?). And this will be so whether these descriptions concern only simple colour registrations as in titrations, or intricate simple number assignments, as in most standard cases of measurement."

(Hanson 1972).

Phenomena are accorded 'facthood' only when they meet the conditions of a theory. If the phenomena do not meet the conditions of theory then it is difficult to see how such phenomena can be accorded 'facthood'. Facts therefore, are, to use Hanson's term 'theory-laden'.

Moreover, Hanson recognises the whole spectrum of theory from the 'Old Wives' Tale' at the one extreme, to more or less permanent and stable theories at the other extreme. These permanent theories have been expressed as 'facts'.

Hanson does not discount the more 'de-facto' theories. A current 'old Wives' Tale' may, with time, bring into focus more and more clearly, sufficient phenomena to attain the status of reputable theory. Alternatively, what we hold to be respectable theories at present, may be treated with indifference, or even laughed at a hundred years from now. (An example which immediately comes to mind is the change in theory relating to the post 'heart attack' care of patients. Physical exercise is now, but was not previously, an important aspect in the rehabilitation of coronary patients.)

(c) Some Comments About The Importance Of Theory In Biology.

The following is a quotation which may serve to exemplify some of the characteristics of the way the term theory is used in current biology: It has already been used but is also important in this context:

> "There have only been two great theories in the history of biology that went more than a single step beyond immediate interpretation of experimental results; these were organic evolution and the central dogma."
>
> (Stent 1968).

Stent is implying that theoretical aspects in biology are important. He implies that in some way they determine experiment, but he goes no further. Stent is a respected molecular biologist, and is a friend of Crick (See "Of Molecules And Men " 1967 p 25). Most molecular biologists would prefer to be regarded as non-theoretical biologists.

> "A good deal of theoretical biology is misunderstood by molecular biologists who by and large call themselves 'non-theoretical biologists', and think of themselves as the archetype of the experimental biologist, because they are concerned, not with exclusion, but with complete specification."
>
> (Lewontin 1969).

Stent, in having sympathy with theory, seems to be an exception rather than a rule among contemporary molecular biologists. Crick does not appear to advocate purely biological theory when he states:

> "So far, everything we have found can be explained without effort in terms of the standard bonds of chemistry."

Furthermore, Reiner (1968) does not hold that biological theory is important when he states:

"Scientific biology has aims and tactics essentially similar to those of physics and chemistry."

The reputable current molecular biologists downgrade theoretical aspects of biology.

Commoner, a current commentator and scientist, also notes the decline and ultimate exclusion of theory from biology when he states:

"Perhaps the oldest - and most profound - theoretical problem in biology is what might be called the nature of the living state. By this I mean the effort to explain the curious paradox that a living organism, despite its unique capabilities for growth, self duplication, and inheritance is nevertheless a mixture of substances which are separately no more possessed of life than the more prosaic molecules that never occur in cells.

... Now the debate appears to be over. There is, we are told, a constituent which is indeed 'a living molecule' - D.N.A. which has within itself the basic property of life, self duplication, and which guides the behaviour of all other components of the cell."

(Commoner 1963).

Commoner in this case is referring to a great theoretical issue in biology notably the difference between living things and non living substances. Current biological education agrees with the point that this debate is over. Apparently modern biology has replaced theory with well established fact. It seems that new biology is now successfully eroding old theoretical issues and replacing these with experimental findings.

Weiss (1970) notes the decline in theory:

"True, some 'great questions' are still familiar through the currency of their names; but like the names on tombstones, those are just symbolic mementoe no longer denoting the essence of their defunct carriers. The problem of 'organism' and 'organisation' is a good example; Other questions have simply assumed a verbal guise - perhaps more adequately phrased, though not necessarily nearer to solution. Such a one is the origin of life. Still others such as the mind-body dualism have been relegated to the attic of philosophy as being beyond the ken of science. Yet, on the whole, if anyone wants to find the 'great problems' of biology explicitly treated in current literature, he must turn to encyclopedias or the writings of historians, 'generalists' or 'publicists' - and writers of science fiction - rather than to the literature reporting or summarising bench research."

(Weiss 1970).

Weiss regards the great theoretical questions of biology as beacons or guides for research. Currently, he maintains this use is not being made of the theoretical 'great problems' in biology. He further explains the position by stating:

"Really nothing more drastic is called for than to bring back into full view as research targets the faded age-old unresolved 'great questions' stripped of the obscurant verbiage which has enveloped them. Peel out their essential naked kernels of clearly and objectively circumscribed phenomena and properties. Let imaginative researchers draw a bead on them, and find out whether the unveiled problems yield to explanation in terms of what we know (they probably will not) or whether we must expand the frame of our concepts in order to encompass and accommodate them.

There are many curious and resourceful students in my acquaintance alone who are bored and dismayed by their enforced engagement on rote mopping up operations in the quest for knowledge in sectors where the front has already become stagnant. I have no doubt that they, and many like them, would welcome the challenge if only the goal were presented to them concretely and realistically, and the feasibility of an approach to it plausibly demonstrated. My faith in this segment of the new generation - not necessarily large in numbers, but imbued with the vision, courage, steadfastness and versatility of pioneer explorers - prompts my prediction that on the whole the downward tide of research trends from quality to quantity will be stemmed and reversed."

(Weiss 1970).

At present the general viewpoint seems to be that as the facts come in from research the theories (the great questions outlined by Weiss) get thrown out. Crick (1966) agrees with this viewpoint, when he refers to a great controversial question in biology, notably 'vitalism'. (Vitalism is a theoretical position which postulates a 'life force', which appears to be refractory to experimental procedures.) Crick (1966) states:

> "When facts come in the door, vitalism flies out the window."

There seem to be two competing positions:

One, the current one which derides theoretical issues: the other advocated by Weiss and a minority of biologists which maintains a need for a return to theoretical issues.

Furthermore, there seem to be two reasons for theory and theoretical issues to decline in biological education. Firstly, there is the assumption that current biology is a non-theoretical enterprise anyway. Secondly there is the claim being made by biologists that scientific 'factual' discoveries have demolished many or most of the formerly held speculative theories and theoretical issues. Both of these reasons are common to the area of molecular biology. Weiss, a biologist of great traditional standing, strongly disagrees with the above two notions, claiming that 'a downward tide of research trends' will continue. This thesis maintains a position similar to that held by Weiss.

A. **Possible Theoretical Aspects Which Could Be Incorporated Into Biological Education.**

In stressing theory in biological education, it is not the intention to devote all emphasis to a particular theory. Nor is it intended to make all biology theoretical. On the contrary it is contended that theory should be given an important place in biological education. For example, questions of the following types could be used in theoretical discussion: Are humans solely at the mercy of their genes? Does ontogeny always reflect phylogeny? Does present biology account for vitalism? Is vitalism important anymore?

The "Four Pillars Of Unwisdom" outlined by Koestler (1969) could, for example, form a good basis for discussion:

> "(1) That biological evolution is the result of nothing but random mutations preserved by natural selection.
>
> (2) That mental evolution is the result of nothing but random tries preserved by reinforcements.
>
> (3) That all organisms including Man are nothing but passive automata, controlled by the environment, whose sole purpose in life is the reduction of tensions by adaptive responses.
>
> (4) That the only scientific method worth that name is quantitative measurement, and, consequently, that complex phenomena must be reduced to simple elements accessible to such specific characteristics of a complex phenomenon for instance Man, may be lost in the process."

(Koestler 1969).

(Also noted in a Review in New Scientist Vol. 43 No. 618, September 25, 1969, Page 635 by Thorpe).

These points provide good catalysts for wide theoretical discussion of important biological issues. Lamarckian theory, currently neglected, in most biological text-books could also form a basis for discussion. If current texts are an indication Lamarckian theory is a thoroughly bad theory. Yet this implication can be tempered by an opinion presented by Hardy (1965):

> "I am now going to say a good deal about <u>change of habit or behaviour</u>. Change of habit as a factor in evolution was of course the great contribution made to biological theory by Lamarck; a contribution which, as we have seen, has been largely rejected or neglected. In stressing this factor Lamarck was, I believe, absolutely right. In saying this I must explain that I am not a Lamarckian in the generally accepted sense of the term; I do <u>not</u> believe that change of habitat can influence evolution through a supposed inheritance of changes in bodily structure brought about <u>directly</u> by a greater use of some organs and a lesser use of others. I certainly feel, however, that Lamarck deserves much more credit than he gets at present, for discerning the great importance of the behavioural side in the working of animal evolution. I have little doubt that he will get this credit in time."
>
> (Hardy 1965).

B. <u>The 'Knowledge Explosion' In Biological Education.</u>

Current text-books are noted for their enormous sizes. It would appear that this is a necessary corollary which comes with the 'knowledge explosion'. The text-books are continuing to get thicker. If this additive process continues it seems probable that an 'information crisis' is occurring in biological education. Research is continuing at a fast rate. The findings derived from research are published in research journals. Text-writers and curriculum makers glean from these journals, information to be incorporated into text-books. The problem of the 'information crisis' is continuing to increase:

"Twenty five years ago, a practicing scientist could keep up with the literature by spending part of every week in the library reading room, glancing at a few dozen journals, noting the existence of perhaps that number of articles. By fifteen years ago, the number of relevent articles had become so large that scientists began to rely increasingly on abstracts. And nowadays, even abstracts have become too numerous to read. One of the most revealing developments in the literature of science, has been the publication of a new type of periodical which simply lists new articles appearing in several hundred scientific journals by title - about 2,000 of them weekly."

(Commoner 1963).

Text-books add information in later editions. Seldom does new information replace the old. De Beer (1969) notes that it is mistake to accept this notion of the additive features of scientific knowledge.

"As more and more is discovered, more and more must be taught."

Current biological education accepts this additive process. 'Keeping current' is an important aspect of biological education.

C. <u>'Being Current' In Biological Education.</u>

"The greatest overall threat to a science education that aims to remain viable and useful for a long time is that it will succumb to the temptation of <u>being current</u>. With a great burst of scientific discovery having taken place in the last quarter of a century just behind us; with half the scientific literature being written in the last dozen years; with half the Ph.D's being awarded in the United States in the last nine years, the urge to be current, to be modern is unavoidable. In proper measure, it is essential for the orientation and motivation of the student and for the establishment of the bench marks by which future development is measured. <u>In excess,</u>

<u>the student drowns in a world of facts and concepts for which he is unable to recognise precedents and from which he is unable to project the future.</u>"

(Doty and Zinberg 1968).

The revised editions of texts, the need for updating curricula, indicate that writers of curricula and texts are most concerned about keeping up to date with information. Since science is advancing at an apparently rapid rate, the problem is very significant. Earlier information gleaned by text-writers from journals, may, within one year become obsolete. Yet text-writers prefer to <u>add</u> to texts, rather than discard older, possibly doubtful information from texts. The sheer quantity of often doubtful information to be gone through by students, may be insurmountable. If excesses are allowed, then the drift from biology is compounded. It would appear that many texts are out of date by the time they get printed.

This problem is made worse when details or descriptive specifics, rather than general principles, are emphasised. Generally, it is with the specifics where the changes occur. For example some photosynthetic substrates accepted as 'fact' in texts may, right now, be no longer acceptable in plant physiology. The present importance attached to 'being current' in biological writings creates problems for biological education, where students may be learning descriptive details no longer accepted in biological research. The incorporation of 'theory' into biological education could reduce this need to be current. Theories are more resilient than specifics.

D. **'Factualism' In Biological Education.**

> "It saves trouble if theories and hypotheses are presented as facts. Nobody is then tempted to argue against them. The time and temper of the teacher is saved. The fact that under this sort of regime, education has degenerated into mis-education is either not noticed or else is 'explained away' by some facile rationalisation."
>
> (Stenhouse 1971).

The acceptance of tentative findings as though they are facts is termed 'factualism'. 'Factualism' has already been outlined, but its relation to theory has not yet been discussed.

'Factualism' can originate from three sources. Firstly, there is the treatment of probable tentative findings in science as fact. Secondly, 'simplistic' notions may be developed then treated as factual. If some biological phenomenon is simple - it can be described as simple. Yet there are instances in biology where complex phenomena are treated as though they are simple. These kinds of instances are 'simplistic'. Text-books, for example, treat the theory of Lamarck 'simplistically' rather than simply. A simplistic notion allegedly simplifying a complex issue for ease in explanation or exposition is thus also 'factualistic'. Sometimes these 'simplistic' notions are taken further. They are prescriptions harbouring under an aura of description. Statements which incorporate 'it would appear' and 'maybe' are often not used in most stanard texts. It may lead students to doubt what is written. Thus most texts explain tentative and provisional findings in definite 'it is' factual terms. (Stenhouse 1972).

Thus, in not wanting readers to doubt or argue about what is presented, text writers and curriculum formulators emphasise description and descriptive elements in biology. They emphasise description even to the point of surreptitiously or knowingly substituting provisional aspects, as being descriptive elements. If this is done, explanation is made easy. A 'perhaps' statement is written into a text or curriculum as an 'it is' statement. The student can then learn it as a fact. The transformation of prescriptions is another source of the general condition of 'factualism' currently being emphasised in biological education.

> "If a prescription is put forward openly, people may disagree with it. There is a healthy streak of 'contrariness' in most us. If it is put forward as though it were a descriptive statement of fact, however, most of the 'contra' reaction is inhibited. Nobody wants to look as though he is arguing against the facts."
>
> (Stenhouse 1972).

Theory and theoretical issues in biology would promote 'contra' viewpoints. The provisionality of aspects of biology would be highlighted. Present text-books and curricula do not allow for this. Reasons for this are difficult to elaborate.

One reason is that of expediency. Description (and that which masquerades as description) is easier to present in a text or curriculum than to have a long complicated type of discussion with many provisos about theoretical issues. It is also more expedient for a teacher to teach 'facts' with crammed class programmes. Preparation needed for theoretical lessons and discussions would take longer and be more intricate, than the preparation necessary to present facts by didactic exposition, practical work or demonstration.

A second reason is the viewpoint which advocates the 'non theoretical' nature of biology. By being 'non theoretical' biological educators claim to have no need to concern themselves about theoretical issues; or issues which appear to be open to doubt.

A third reason is that biology, if it is to 'advance' must take on the characteristics of the more 'mature' sciences, for example, chemistry and physics. Biological educators seem to assume that physics is a descriptive and non theoretical science. Yet few physicists would hold with this assumption. This has already been discussed in detail. (For example Heisenberg 1958; Bohr 1932; Delbruck 1949).

E. <u>'Reductionism' In Biological Education</u>.

Analysis creates an enormous increase in the labelling and description of new substances and compounds in biology. Previously, for example, the details of respiration could be described in a few lines. Today the detailed features of respiration may require pages as a result of the emphasis upon analysés of metabolic pathways. Moreover students are required to learn the sequences of glycolysis, Kreb's cycle and terminal oxidation.

Ultimately the amount of descriptive data will be indigestible for students. Some form of exclusion seems necessary. The incorporation of theory may serve to bring about legitimate exclusion.

Some Advantages For Biological Education Should Theory Be Incorporated.

A. 'Fact' Would Be Reduced.

The 'knowledge explosion' can be averted in biological education.

Surely facts form the basis of all science. How can facts be reduced? Biology aims to reveal the truth. Factual information surely is most important in biology.

No one can deny that facts are important in biology. Biological educators, despite claims that they are stressing principles and processes, deal mainly with facts. The principles and the processes, in themselves, take on factual cloaks, and are inundated with descriptive details. The problem, however, is not so much to do with fact but with 'factualism'; and the distinction between the two has already been discussed.

Alternatively, biological educators claim that the problem of the 'information explosion' can be reduced, if the method of deriving the facts is known. This method is popularly known as 'the scientific method'. These two features, the fact side of biology, and the understanding of the procedures of biology have formed the bases of curricula since the eighteen-forties. (Layton 1972).

Much has been written (Medawar 1968, 1969) on the 'simplistic' notion involved in accepting the 'scientific method' as a single all-encompassing method for deriving the 'truth'. This method is given great import by text-writers. Most give a great deal of detail to it in early chapters:

"You will often find a fairly precise pattern of investigation will give the most rewarding results.

Initially you should try to identify the problem you are going to investigate. It often pays to write it out as a statement. You should then search the available literature to help build your background information - it is here we hope the text-book will be of assistance. This knowledge, together with your own observations of the organism or situation, should then be surveyed to see what information can be discarded as being irrelevant to the problem and what patterns or generalisations are apparent. Using your background of knowledge and understanding of biology in general you should now seek to explain why such a pattern or relationship might exist or appear to exist - in other words you are developing an idea, theory, or hypothesis. You or your class may even have several different ideas. Your next move is to suggest ways of testing your ideas. What experiments could you design to test your theory? Your responses to successes and failures will be a measure of your ability to overcome obstacles, and at the same time, you will know the excitement of adventuring after truth. You will come to realise with humility, that ideas can stand only as long as they remain consistent with the observed facts."

(Knox 1969).

"The bases of the scientific method and the ultimate sources of all the facts of science are careful close observations and experiments, free of bias, with suitable controls made as quantitatively as possible. The observations and experiments may then be analysed or separated into their constituent parts so that some sort of order can be brought into the observed phenomena."

(Villee 1967).

"The scientific method is a logical and orderly procedure of investigation. Actually it is nothing more than the systematic use of common sense. It is this particular method of scientific inquiry that distinguishes scientific study from curious dabbling and hit or miss efforts to solve a problem."

(Otto and Towle 1969).

The above text-book writers maintain a generally non theoretical position. They seem, however, to accept one important theory. This theory is the scientific method. It is given such support by these writers as to count as fact. But it has been noted previously that scientists do not necessarily apply 'the scientific method' in their research. (Medawar 1967; Pantin 1968). The method cannot therefore be regarded as a fact.

Instead it is 'factualistic'. Text writers, however, persist in incorporating this method into texts, and presenting it as though it were factual.

Alternatively, texts assume that 'the scientific method' is universal to all sciences. This would mean that a physicist could become a biologist, a biologist could become a chemist - indeed all combinations would be possible. Some physicists and chemists later become biologists, but not often. If 'the scientific method' was as universal as implied by text writers, more inter-disciplinary movements would be noticed. But they are not.

Moreover, if the method was so significant, it would mean that anyone who wished to learn the method could become a scientist. Clearly this is not so. Being familiar with the method does not make a great scientist. Indeed the converse may be true. It is the individuals who break from accepted methods and 'norms' who may become the great scientists. (Kuhn 1962; Koestler 1964; Stenhouse 1971).

Why Is 'The Scientific Method' Perpetuated?

The 'information explosion' is probably a major reason. It seems that 'the scientific method' acts as an apparent organising core and unifying concept for all science. There might be enormous informational content, but there is still the method which holds all science together. This seems to be a basic assumpti n held by current biological educators.

There is also another reason. Text writers and curriculum makers get the information for courses and texts from research journals. Because of the great proliferation of details in research journals, text writers are likely to consult either the abstracts or r eviews of reasearch. If they do this the risk of gleaning'mis-information' is greater, because the context of the deriving of the research findings is not known. The purpose of abstracts and reviews is to assist fellow researchers rather than text writers. Text-books are large. Not all of a text-book will be within the writer's own area of interest. The likelihood of mistakes is therefore further increased. Also, some research findings are at best tentative. Text writers and curriculum makers transform these to 'facts'. A particular research publication may also be but a minor part of a general long term research programme. Once a fact is incorporated into the main body of a text, it is seldom culled out in the light of immediate later research, even though this later finding may repudiate what is written in the text-book.

Furthermore, the way in which research is written up in a research journal is usually in accord with 'the scientific method'. But this may not be the <u>actual</u> sequence which the researcher carried out when he researched. Text writers and curriculum makers seem to assume, wrongly, that the research journal reflects the actual sequence of events of the laboratory or research activity. They assume that the steps outlined in the research papers <u>are</u> those which have been carefully followed by the researcher when he was doing the research. Yet there are a number of published accounts which show this not to be the case.

Pantin (1968) for example, has published in research journals, his findings which describe the nature of the nerve impulse in coelenterates. The way in which each is reported is in accord with 'the scientific method' as is the case with most research publications. But this is not to say that in real life the sequences published occurred in that strict order. Chance, 'hunch', and emotional aspects are all involved, but are never noted in research journals. Text writers do not allow for these aspects. These writers in biological education assume that 'the scientific method' outlined from research journals is the actual way in which the research progressed.

Despite the apparent order or steps in the publications what actually happened is quite different. Pantin (1968) continues:

> "Now the actual order in which the experiments were done was quite different from this. The course of research shows quite clearly the importance of authority and contemporary fashion in directing one's attention to phenomena. It also shows the importance of the illative sense in reaching conclusions. It shows the importance of contemporary models and the importance of the aesthetic and emotional aspect in initiating research. Moreover the development of the work underlines the importance of chance - though the element of chance is that with which a scrum-half is familiar rather than that of a winner in Premium Bonds'
>
> (Pantin 1968).

Pantin then goes into biographical details and anecdotes about how he came to study the neurophysiology of anemones, illustrating how the above factors were involved. By 'illative' sense he means a "spontaneous divination by the mind that a conclusion is true, which uses every kind of information experience has given us, and which uses it in a way different from logical inference."

(Pantin 1968).

Research publications are less 'illative' than the actual research. 'Illative' characteristics, chance, and emotion are consciously kept out of research publications.

How does the difference between actual research, and the published results of research have anything to do with the distinction between what is factual and what is 'factualistic'? It seems to be this. Text writers glean information from research publications for inclusion into their text-books, and do not consider actual research activity.

A major intention of the text writer is to be able to transpose information to students in as simple and concise manner as possible. This has a number of consequences. Firstly, the tentative nature of hypotheses are neglected. That research is a progression of developing hypotheses and findings is neglected as complications which could confuse students.

Secondly, the 'illative' sense is neglected in text-books and research publications. It is assumed that actual research is mirrored in the way the research publication is presented. Biographical anecdotes are not considered. As a result 'the scientific method' is implicitly given import:

"In the published account of my experiments I showed that, just as the existence of nerve cells would lead one to expect, there was a system which conducted excitation in the animals (anthozoans) and that this excitation has all the properties of a nervous impulse found in the nerves of the higher animals. I began by proving that the class of phenomenan to which the nervous impulse belonged in sea-anemones was identical with what Keith Lucan and Adrian had shown to be true for nerves. I then gave evidence that the varied movements of which the animal was capable were due to a valve like control of the transmission of nervous impulses from one nerve cell to another, and from nerve cells to muscles. I then showed that the whole system was planned, rather like a disseminated brain."

(Pantin 1968).

In Pantin's published accounts of experiments, he did not discuss 'fashion', 'illative sense' or 'chance'. These aspects are also rejected by curriculum and text writers.

Other Strategies Used In Biological Education To Cope With The 'Knowledge Explosion'.

Some text writers and curriculum makers react to the problem by claiming to emphasise 'themes' or principles and processes instead of masses of detail. Others develop programmed learning type texts (Smallwood and Green 1968). Visual aids, and text-papers may also be incorporated into a particular course. Finally, 'enquiry processes' (Bruner 1960) are stressed in biological education. But the problem of 'the knowledge explosion' still remains:

"The expansion of teaching courses need to be proportional to the 'knowledge explosion' only if their purpose is the mere inculcation of factual information. Everyone pays lip service of course, to the notion that teaching leads to 'understanding principles' rather than 'knowing facts' - but in practice the teaching of science despite all recent advances, the 'discovery' method, the 'activity' approach, and so on remains largely a matter of imparting factual information. Or rather, information is imparted as though it were factual, when much of it really is not."

(Stenhouse 1972).

The lip service paid to 'enquiry processes' is well exemplified with the following statements taken from a current curriculum:

"It (the prescription) places great emphasis on THE DEVELOPMENT OF SKILLS AND ATTITUDES rather than the former stress on the acquisition of knowledge."

(The stress is given by the prescription makers in the preamble.)

Yet two pages later the prescription states:

"The prescription seeks to develop the following skills:

(1) The recall of relevant knowledge."

Recall is defined as:

"(remember) appropriate knowledge of facts, concepts, principles, theories, ways of displaying data, ways of finding relevent data, ways of judging the value of data, ways of using scientific equipment."

(Form VII Teachers' Guide. "Biology" Op.cit., 1971).

In the first instance acquiring knowledge is not regarded as a skill at all. Yet later the notion of 'recall' is regarded as a skill. Not only that, but it is first on the list of priorities of desired outcomes.

Secondly, 'recall' has been defined. It will be noted that what has to be recalled is everything which may be taught in a biology course. The 'concepts', 'principles' and 'ways' are all implicitly given the properties of facthood to be remembered. Merely recalling principles and processes is not adequate for the course.

This notion can be construed further. A stress upon 'factualism' makes biology an intellectually rigorous subject. The more terms and meanings that a student knows and can use in essays, examinations and informal discussions, the more 'learned' he apparently is. The following reply to this assertion seems apt:

> "Perhaps the most common implicit rationalization, especially with regard to the teaching of science, is to put the notion that 'proper standards', 'intellectual rigour' can be preserved only by close adherence to facts. If it were true, it would be 'rigor mortis'; but it is not true, and the presentation of theory or hypothesis as though it were fact constitutes a debauch of intellectual standards. No wonder so many students rebel against science teaching in this guise. The sheer 'learning up' of vast quantities of factual information is dreary enough in itself. On top of this the brighter students undoubtedly gain some inkling of the fraudulence of the whole business, and they cannot help but be disturbed and demoralised."
>
> (Stenhouse 1972).

What has this preamble to do with the importance of theory in biology? At the risk of repetition the lens analogy will again be noted.

Firstly, if theory was given import, fact could be distinguished from 'factualism'. A theory is a possibility for describing the world. There may therefore be many possible theories, ranging from old wives' tales to theories which seem to be so resilient that they are accepted as fact. The important point is that though one particular theory may be important as a possibility for describing the world, it is still a possibility. The analogy that a theory is a lens seems to be appropriate. When applied to phenomena, one lens will 'bring into focus' particular aspects. Another lens would 'bring into focus' other possible aspects. What comes into focus can be accorded fact-hood.

Tentative assumptions would not be accorded fact-hood in the manner in vogue. 'The scientific method' at present perpetuated in text-books would not be regarded with the enthusiasm at present given it. Emphasis would be placed upon various possibilities for describing biology. Alternative theories, the importance of 'illative' sense and emotion would be given a more significant place in biological education. For example, Tinbergen emphasises the creative nature of observation, when he attempts to find the categories of behaviour which are brought into focus by evolutionary theory. That is, he is observing in order to find categories to demarcate categories of behaviour because these categories may be transient, and not immediately obvious. (Tinbergen 1972).

Consider what could happen if this same observational approach was applied to current text-books by theoretically orientated biological educators, using evolutionary theory as a lens. Some of the information within the text would come into focus as being 'fact'. Much would not come into focus and it would be regarded as 'factualistic' and eradicated. Moreover, if the process of 'observation' of texts also incorporated history and philosophy of science, other aspects of the text-book currently held to be important, may also go out of focus.

The lens analogy could probably be fruitfully taken further. But the important point at this stage is to emphasise that it is the lens which is bringing certain aspects of the phenomena into focus. Similarly in this was it is theory which determines what can be counted as fact. This has been emphasised in a number of accounts, notably Hanson (1961, 1967), Kuhn (1962) and Koestler (1964, 1967).

An important theory in biology is evolutionary theory. It appears to account for most phenomena without too many anomolous situations. It is a possibility for describing the world. Tinbergen (1972) emphasises that 'observation' is very important in biology, especially his own interest, ethology. Tinbergen regards observation as a creative process. This process goes on within the context of evolutionary theory.

Thus, in conclusion, the incorporation of evolutionary theory would reduce the quantity of facts to be learned (despite the 'knowledge explosion'). It would also serve as a resilient 'tool for thinking' in 'anticipatory' biology which will be discussed later.

But biological education does not seem to regard theoretical issues in biology as sufficiently important. Lack of theory in biology may enhance a 'drift' from biology:

> "The committee suggests in several places that many able students are deterred by the rigour of school sciences, especially when that rigour degenerates into a grammarian's formalism, when it is bolstered by an inordinate bulk of experimental work, and when it is overlain by vast bodies of factual information."
>
> (Thornton 1969).

A recent observation of science education in America also serves as a warning of possible consequences:

> "Science students are plainly 'turned off', It may be, as Jean Mayer of Harvard claims, 'largely the result of the Balkanization of teaching.' And it may be as Harvey Brooks suggest a matter of failing to make non-science students scientifically literate and scientific students socially literate (Harvey Brooks "Physics and Polity in Science" 1968). I am aware of the problems of specialisation. I hear the complaints of my scientist colleagues that teaching both science and the social impact of science would

impose an unbearable 'information overload'. I remain unimpressed."

(Kransberg 1972).

A possible remedy has been clearly stated:

"The remedy clearly, is for everyone to come to a much better understanding of what scientific activity is really like. This is desperately urgent with regard to those who teach science at whatever level. A great deal of scientific research can quite usefully be done by people lacking an understanding of higher methodology - but such a lack in teachers of science generates in those taught the sort of fundamental misorientation, the unhappy results of which we are now coming to see. Since virtually everyone undergoes formal training of some sort or another at the tertiary level, the immediate need is for changes in the education offered at that level."

(Stenhouse 1971)

B. 'Anticipatory Biology' Would Accrue.

Examples will be cited to show how theory is important in 'anticipatory biology'.

Firstly, the case of Neopilina the arche-mallusc. Evolutionary theory involves the establishment of structural, behavioural, and physiological relationships between organisms on the basis of present and past species. The study of lines of descent of organisms is called phylogeny. Detailed study of the present representatives of the Phylum Mollusca culminated in the postulation of a hypothetical ancestor. This ancestor could be regarded as a mosaic of the primitive features of the Phylum, based around evolutionary theory. In other phyla, the ancestor remains merely hypothetical. Yet with the Phylum Mollusca, an organism has now been found which very closely resembles the hypothetical ancestor. It is called Neopilina. The important point is that the 'discovery' of Neopilina was anticipated. Evolutionary theory makes this discovery zoologically significant.

Another good example of 'anticipatory biology' is noted with the discovery of the Crossopterygian fish Latimeria. This is a living example which closely resembles the first tetrapods which invaded land. Locket (1972) describes the interest generated in the finding of a live specimen:

> "But why all this fuss about a fish? Coelocanths were well known to scientists before 1938, but only from their fossil records; that went back a very long way to Devonian some 350 million years ago. Then there were many Crossopterygians (the group to which Coelocanths belong) but they were thought to have died out 70 million years ago; the last known Coelocanths were in Cretaceous chalk in England. So here was a living representative which not only antedated the dinosaurs by several million years, but which was a close relative of the Rhipidistians, believed to be the ancestors of the tetrapods including man. That would have been fascinating enough, but as far as comparisons could be made, the modern coelocanth turned out to be astonishingly similar to its fossil relatives."
>
> (Locket 1972).

The important point to note is that Latimeria had been found and known by the Islanders of the Comoro Archipelago for generations. But these Islanders were not versed in phylogenetic history or evolutionary theory. To them it was merely another fish. It had to be 'discovered' by a zoologist, in this case Smith, in 1938. 'Discovery' was to a great extent anticipated on the basis of theoretical evidence, and the postulation of what the Coelocanth would look like, should a live specimen ever be found.

It is interesting to observe that the movements of Latimera while swimming were also anticipated with interest by Locket:

"At last it was possible to make first-hand observations of the animal's swimming movements, and to test the truth of the much quoted assertion that the eyes are strongly luminous. The swimming movements were fascinating. Most fishes swim either by sinusoidal body movements or by lateral strokes of the tail; the coelocanth was not doing either, but swimming by using its second dorsal and anal fins in a sculling motion. The two fins moved in concert, both to the same side of the body at the same time. They were twisted on each stroke so that the anatomical anterior edge of the fin always led the movement, but the left and right sides were alternatively the side nearest the head. The motion was exactly that used in sculling a small boat over the stern with a single oar, but whereas the oar is rigid the fins are supple, and take up a convexity to the front of the fish, just as the blade of a marine propeller has."

(Locket 1972).

The detail with which Locket describes the movements reflects his interest in the evolutionary importance of the locomotion of Latimeria. No doubt he gained a great deal of satisfaction in describing the movements (anticipated by theory) which tetrapod ancestors probably used. 'Anticipatory biology' is not an isolated phenomenon. Peripatus is significant because it has a close resemblance to a hypothetical insect ancestor. Rhynia and Hornea are plant fossils which seem to resemble the first seed plants or spermatophytes.

How could biologists assess the nature of the Heidelberg man (Homo heidelbergensis) who lived 500,000 years ago, with the only evidence being a single fossil jaw? With no theretical background, the bone would have been merely another jaw-bone. The finding of Australopithecus by Dart in 1924 led also to its signifance as a possible human ancestor through knowledge of theory. (Nature Vol. 115. 1925). True the Piltdown man was assumed upon the basis of evolutionary theory, to be a significant skull in 1912. However, the accumulation of evidence based upon evolutionary theory revealed the skull as a fraud in 1953. Moreover, it took the ingenuity of an individual, who was theoretically orientated to create a fraud where palaeontologists, biochemists and anatomists were fooled for forty-one years. Dawson, a solicitor, was held to be the faker. He was an enthusiastic amateur. The New Scientist, Vol. 57, No. 837, 15th March, 1973 Pages 619 - 620 has an interesting account of those zoologists closely connected with the hoax.

Another example can be taken. The skull of vertebrates is composed of a mosaic of separate bones. Theory has developed the 'fates' of these bones which can be traced from the fishes to the mammals. For example, the bones of the inner ear have a tympanic function in mammals, yet they have a breathing and feeding function in fossil vertebrates, and in some present day 'lower' vertebrates. To a student unfamiliar with the theory behind the relationships of skull bones, the learning of the bones of each mammal skull would be most difficult, and reminiscent of the current problem relating to the 'knowledge explosion'. Describing bones of the skull vertebrates without knowledge of theory would prove an insurmountable task. Each bone would need to be described individually. With upwards of 15 - 30 separate bones for each skull, the complete specification would become indigestible for students. Currently, chemicals and metabolic pathways are being described without theory. The naming pattern is similar. Only the components to be specified differ. But theory saved anatomy. Descriptive anatomy became comparative anatomy, after Darwinian theory was accepted. Comparative anatomists (for example Goodrich 1958) traced the 'fates' of the bones composing the skull of vertebrates. Moreover, similar names have been used throughout the vertebrate group. Even the labelling of bones is theoretically based. More importantly, a pattern was developed. Economical short cuts, could be established once the theoretical patterns were laid down, and 'anticipatory biology' could be developed in biological education. The example drawn from comparative anatomy has important implications for current biology. The biologists and biological educators of the immediate post Darwinian era, recognised the problems relating to 'factualism', and the problems for students with complete specification. To overcome the problem of the indigestibility of information, theory and comparisons derived from theory were emphasised in biological education.

Current text writers and curriculum makers seem to have placed themselves in the same situation as the pre-Darwinian descriptive anatomists. The predicament is the same, yet current writers do not seem to be able to take advice from lessons learned by educators one hundred and twenty years ago. Complete specification and description at present is rife. Yet the solution to this predicament is also present, well known, and old.

It appears that biological education accepts the viewpoint that anything which is old is worse and anything which is new is better. New curricula are purported to be '<u>improvements</u>' over the old. This need not be the case. For example doubt has been cast on the value of the New Mathematics curricula and the P.S.S.C. Physics curricula have lost favour. (Layton 1972). The 'New' biology may also have doubt cast upon it. The 'drift' from biology is becoming as marked as the drift from physics at tertiary levels (Osborne 1973).

The solution to current problems in biological education is known, and is traditional. The incorporation of theory into present biology will create patterns which students can grasp. These patterns, once established are useful in developing 'anticipatory biology' in biological education.

The establishment of a pattern in comparative anatomy, early in a biology course, allows students to anticipate possible 'fates' of skull bones as one progresses through some examples of the vertebrate kingdom. Not all vertebrates need examining. A few examples will suffice, because theory acts as a 'crutch' which can be used to 'fill in the gaps' with other examples should the student later wish to study them. The learning of each bone in a skull for every vertebrate is the alternative albeit most difficult strategy. De Beer (1967) also outlines the point that a few examples well presented with theory is better than attempting non theoretical description of many examples. The traditional comparative anatomists knew that not all vertebrates required study if theory was made important.

The gaps in information were replaced by theory. Should they be confronted with an unknown skull students could readily attempt an explanation on the basis of theory. If the theory was sufficiently grasped it is probable that the students could 'anticipate' the significance of a number of features relating to the unknown skull. Furthermore, it is a very satisfying educational experience to have one's theoretical anticipations later confirmed.

It could be argued that 'anticipatory biology' is no more than hypothesis generation and confirmation. But 'anticipatory biology' embraces more than this. Contemporary biology attaches a great deal of importance to experiment. This part of biological research can be anticipatory in being a hypothesis confirmation activity, but it does not place importance upon another important aspect of biology, namely observation. Comparative anatomists did not experiment in the manner of present biology. Instead they thoroughly understood theory. On this basis they observed, anticipated, and observed to confirm or refute their theoretical anticipations. Observation to them was 'theory laden'. Current non theoretical biological educators would claim that they were 'subjective' and 'biassed'. Furthermore, some anticipations unlike hypotheses may never be able to be confirmed either by observation or experiment. For example some organisms, living or fossil, may never be discovered which closely resemble the ancestral echinoderms. Yet there is a description of what the hypothetical ancestor of echinoderms would look like.

'Anticipatory biology' is therefore theoretically based. Nor can theory be fully eradicated from experiment (Hanson 1971). It would seem therefore that it is better to develop a logically based theoretical position and conduct scientific activity on this basis, than it is to maintain an apparent non theoretical position. The non theoreticians in fact do hold some sort of theory, probably a weaker one than more logically orientated biological theoreticians (Beckner 1964). The non theoretician's theory (which he may claim he does not hold) reaches its ultimate in 'dust-bowl empiricism':

> "The position parodied as 'dust-bowl empiricism' construes experimentation and controlled observation as the very source, the development and the fulfillment of everything worthwhile in science. All else is

> 'mere speculation' or even 'metaphysics'! In extreme form, the scientist so oriented will tinker, roam and ruminate at random giving 'the world' (i.e. his chosen subject matter) every opportunity to 'express itself'."
>
> (Hanson 1971)

If a biologist claimed that he was non theoretical his activities would apparently be uncontrolled. Moreover it could be charged that his activities were random. No researcher would subscribe to this charge. Some sort of theoretical position must guide even a 'dust-bowl empiricist'!

'Anticipatory biology' could be used as an educational strategy in current biological education. The pre-requisite theoretical foundations lacking in the professed non theoretical biology would appear to need reinstating into current courses and texts. Weiss (1970); De Beer (1967); Koestler (1964,1969) could act as starting points. On the basis of theoretical formulations, students could anticipate likely patterns with biological phenomena. They would not necessarily need to start and stop many fragmented topics as in present courses. Biological courses could be reduced by applying theoretical orientation which would encompass the whole course or curriculum. Moreover a great deal of satisfaction will accrue when the theoretical notions held by students are confirmed by observation, reading and lecture. 'Anticipatory biology' would create interest, and serve to attract rather than repel students from biology.

C. Areas Of Biology Which Are Not Well Known Would Be Recognised.

Weiss states this position:

> "Half a century ago, when I began my explorations in biology, the field was sparsely populated, like pioneering country, with everybody who entered, thrown to his own devices. Text-books were few, comprehensive, original, and unique, almost every one of them bearing the signature of a master; but obviously there were wide gaps between the areas they covered. Yet they had one important feature in common; they tried, some more than others, to balance overindulgence in their particular speciality by pointing up the place and context and place of that speciality within the continuum of the living world. In this way we became aware of both the fundamental interconnectedness of all aspects of life, and the appalling dearth of concrete knowledge about interconnections provisionally labelled in symbolic terms."

(Weiss 1970).

Currently, biology does not stress areas of ignorance. The implicit emphasis placed upon 'factualism', and authority, gives students the impression that there is little unknown in contemporary biology, and given a few years the lot will be 'cleaned up':

> "In the symbolic year of 1899 the foremost German biologist Ernst Haeckel published a best selling book "The Riddles of the Universe" which became the bible of my youth. Haeckel was the first propagandist of Darwin in Germany, and the first to draw up a geneological tree of various orders of animals. Like Spencer and Huxley in England, he was a typical representative of the bouyant and arrogant optimism of the nineteenth century. His book enumerated seven Great Riddles of the Universe of which six were 'definitely solved' - including the Structure of Matter and the Origin of Life; the seventh was man's experience of freedom from choice. However this was not really a riddle but a 'pure dogma' based on an illusion having no real existence - so there were no more riddles left."

(Koestler 1964).

> "Both at school and at university, this confrontation with intellectual authority is especially acute. It is made apparent to each of us, not through the malign motives of our

teachers, but from the force of our own ignorance, that if we want to succeed, our best course is to do what our teachers and examiners expect of us. For this reason, there exists a strong temptation not only to accept all authoritative judgements as given, but to accept the horizons of school and university syllabuses as the boundaries of all sensible enquiry. The massive largely unavoidable insistence on authoritative knowledge faces the student with an unenviable choice: that of knuckling under and being right; or of being individualistic self sufficient and wrong."

(Hudson 1968).

Weiss (1970) mentions above that areas arid of research had been mapped out in 'symbolic terms'. However, 'symbolic' could be replaced with 'theoretical' without losing sense to his statement.

Theoretical outlines can therefore, map out unknown ground. At present in biological education this does not occur. If students in science are discussing great inventors, and discussion comes round to likely inventions in the future, they commonly reply that there is very little else to be invented. Their generation will never invent anything - it was easier for Faraday, Pasteur, Marconi and Bell, because the circumstances were right and science was on an upsurge. Invention and discovery always look as though the process was simple in an historical context. However, it would seem that a general lack of theory in all science has contributed to this frustrating situation. If the biological textsximply that all important discoveries have already been made, and most problems been solved, then there is little likelihood of students being attracted to biological research. It all seems known:

"There is little curiosity about science; so much is now established fact."

(A student's comment, Potts, 1968).

In emphasising their speciality, traditional text writers placed it within the framework of evolutionary theory. In stressing theory, in having an evolutionary frame of reference, the areas of biology arid of research could be recognised. As a result a novice research student could move into one of these 'arid' areas as a lone 'pioneer'. He however, was not blind in his movements, as he would be a novice intellectually armed with theoretical inter-connections developed in introductory courses. The novice researcher could therefore 'anticipate' probable fruitful areas for research. Moreover, and even more importantly, the early biological educators, anticipated the arid areas and what these arid areas entailed on the basis of a theoretical frame of reference.

Current text writers in stressing what is known, also emphasise authoritarianism. (Hudson 1968). Students in biological education must submit to the authority of the text-book and to the 'facts' therein. Theoretical notions, if incoroporated, would encourage discussion and argument, thereby reducing authoritar-ianism in biological education. Much doubtful and dubious information could be harboured under a shiled of authoritarianism - the stronger the authoritarianism, the greater the likelihood of their being doubtful information. If this was so, biology could develop into a cult. Biology would change to 'biologism' and dogma would prevail. (Frankl 1969). Prescriptions require elucidation in biology:

> "If a <u>prescription</u> is put forward openly, many people will disagree with it. There is a healthy streak of 'contrariness' in most of us. If it is put forward as though it were a <u>descriptive</u> statement of fact, however most of the contra-reaction will be inhibited. Nobody wants to look as though he is arguing against the facts!"

(Stenhouse 1971).

Secondly, if theory and theoretical issues were incorporated into current biological education, selected areas of biological research which are being neglected, could be given an airing. At present with emphasis upon the authority of fact, 'what is known' is being cultivated at the expense of 'what is not known'. Ignorance is not given emphasis in current texts, courses or curricula. A science, to be vigorous, must show that it is tackling little known areas. This is surely a way of advancing the state of biological knowledge. At present this does not seem to be the case. If it were, a great deal of emphasis would be placed upon theoretical discussion in introductory biological education. This theoretical emphasis would serve to firstly show students that there are areas arid of observational and experimental study. Moreover, these discussions may serve to interest introductory students to later research in these particular fields. Study of evolutionary theory, and its principles, would serve to indicate these obscure areas of biology.

Yet current biological education takes a 'backward' stance, emphasising past achievements, some of which masquerade under an enigma of finality. (Stenhouse 1972). A return to a 'forward' looking stance seems necessary. Concerted attack upon unknown areas, through prior theoretical discussion, seems of importance if biology is to survive as a vigorous science. (Commoner 1961).

The consequences for biological research has been well documented:

> "There are sectors in which brilliant progress is still being made on the old pattern by self directed individuals, for instance, in the physiology of vision; but time has changed

this approach from standard rule to rare exception. Besides, vast areas (of biology) are left wholly deserted and in obscurity. Who is to say what crucial clues to the understanding of life they hold which may be missed because of our compulsive submission to the spell of a few favorite topics? Will the established favorites of today keep being swelled by masses of epigones, acclaiming the familiar, and disdainful of the odd, adventurous and risky? Will more and more workers shrink to the posing of questions that fit the answers we already have? Is this trend inexorable or can it be countered?"

(Weiss 1970).

Tinbergen also sets the problem when he refers to the publications of Morris (1967) and Lorenz (1966):

"As examples I select Konrad Lorenz's book 'On Aggression' and 'The Naked Ape' by Desmond Morris. Both books were best-sellers from the start. Ethologists are naturally delighted by this sign of rapid growth of interest in our science (even though the growing pains are at times a little hard to endure). But at the same time we are apprehensive, ar at least I am.

We are delighted because, from the enormous sales of these and other such books, it is evident that the mental block against self scrutiny is weakening - that there are masses of people who, so to speak want to be shaken up. But I am apprehensive because these books each admirable in its own way, are being misread. Very few readers give the authors the benefit of the doubt. Far too many readers either accept uncritically all that the authors say or equally uncritically reject it all. I believe this is because both Lorenz and Morris emphasise our knowledge rather than our ignorance, (and in addition present as knowledge a set of statements which are after all no more than likely guesses). In themselves brilliant, these books would stiffen, at a new level, the attitude of certainty, while we need a sense of doubt and wonder, and an urge to investigate to inquire."

(Tinbergen 1968).

D. The Biological Nature Of Man May Be Incorporated Into Biological Education.

Theory may have direct relevance to Man. At present many publications are emphasising the biological nature of Man. Lorenz (1966), Morris (1967) and Weiss (1970) have emphasised areas of ignorance in biology. Current molecular biology, in not being strongly theoretical, does not explore these areas at all. The evolution and behaviour of Man cannot fully be explained in molecular terms even though this is implied in current biology.

Yet Man's own biological nature is important. It appears to be odd that biology of Man is not stressed. There is one exception. A seventh form biology course devotes a section to the evolution of Man. But other biological aspects of Man are ignored.

Tinbergen (1968) outlines some further reasons for ignorance about Man's behaviour:

> "What gives a student of animal behaviour the temerity to speak about problems of human behaviour? Of course the history of medicine provides the answer. We all know that medical research uses animals on a large scale. This makes sense, because animals particularly vertebrates, are, in spite of all differences, so similar to us; they are our blood relations however distant.
>
> But this use of zoological research for a better understanding of ourselves is, to most people, acceptable only when we have to do with bodily functions that we look upon as parts of our physiological machinery - the functions for instance of our kidneys, our liver, our hormone producing glands. The majority of people bridle as soon as it is even suggested that studies of animal behaviour could be useful for understanding let alone control of our own behaviour. They do not want their own behaviour subjected to scientific scrutiny; they certainly resent being compared with animals, and these rejecting attitudes are both deep rooted and complex in origin. But now we are witnessing a turn in this tide of thought."

(Tinbergen 1968).

Man is what he is because of his past. Mere description of Man as he is now is insufficient. Studies must go further than this to find reasons for the present state of Man. Reasons may be found, if investigation is made into the vicissitudes of past history. But investigation into the long term past may bring forward an even greater number of plausible reasons which could explain the present predicament for example of violence, and over population. Once these explanations have been brought forward, then these may be used as sources for controlling, and to some extent, predicting problems. Man, although a relatively recent organism, with a phylogenetic history of short duration, nevertheless does have a phylogenetic history. To ignore this history leaves a great deal of possibly useful information dormant.

Pussles to be solved on the evolutionary history of Man are complex. No living ancestral close relatives exist. No living direct ancestors exist. Paleontologists and evolutionists rely upon the retical background, (Dart 1925; Leakey 1965; Washburn 1960; Broom 19[illegible]; Leakey 1972) to fill in arid areas. Imagine for example, trying to determine the possible ecology and habits of the Heidelberg man from a 500,000 year old jaw bone, without the assistance of evolutionary theory. The ecology and habits of Australopithecus (Dart 1925) could only be determined through the heavy reliance upon theory. It is also interesting to observe how artists interpret theory and organic evolution when they put 'meat' on the fossil skulls and skeletons, when they paint early hominid scenes (Life Books 1964).

<u>Paedomorphosis: A Possible Theoretical Issue For Biological Education.</u>

Strongly theoretical notions are often used in traditional biology. One is paedomorphosis (Garstang 1928). This has its roots in Darwinian theory:

> "He showed that when considering the evolutionary history of a group, it is not obligatory to look for its possible derivation only from <u>adult</u> forms of other groups, for it may have been derived from the <u>young</u> form of another group by retention of its youthful features."
>
> (De Beer in Barnett 1958).

This theoretical interpretation has implications for Man, and De Beer stresses these:

> "Bolk, who in 1926 showed that in many morphological features, such as the absence of browbridges, presence of chin, dentition, position of the foramen magnum, delayed fusion of the bones of the skull ... adult man resembles the youthful anthropoid; and that these features could be explained by the retention into the adult stage of man of characteristics which are youthful and transient in the anthropoid."
>
> (De Beer op.cit.)

This notion of paedomorphosis was recognised as a possibility in evolutionary theory by Darwin:

> "In a state of nature, natural selection will be enabled to act on and modify organic beings <u>at any age</u> by the accumulation of variations at that stage, and by their inheritance at a corresponding age."
>
> (De Beer op.cit.)

Paedomorphosis is a <u>theoretical</u> notion. Evidence may be forthcoming to reveal that Man did not evolve directly from adult anthropoid apes. Instead from a juvenile but sexually mature form.

(Straus 1949). Thus it can be seen that theoretical notions may act as beacons for further research in arid areas of biology.

Paedomorphosis is a theoretical issue which seems to be plausible. Further investigation into fossil evidence with paedomorphosis as a theoretical basis may bring about novel and significant interpretations. Moreover, and even more significantly, many of the problems involving the biological nature of Man are theoretical, and may always be theoretical and refractory to experimental procedures. But this need not preclude these theoretical notions from being important. They are not necessarily 'mere theories' to be ignored because they are not susceptible to experiment. But they could be used as a starting point for small scale experiment. If this is not possible theoretical notions such as the one previously described may be the <u>only</u> type of comprehensive interpretation which can be placed upon some aspects of the biological nature of Man. (The writings of Ardrey 1961, 1966, 1970; Lorenz 1966; Russell 1968; Storr 1968; Tinbergen 1968; and Morris 1969 bear this out.)

The significance of the biological theory in relation to Man can be taken further. It can be contended (Piaget and Inhelder 1969) that because Man is a biological organism interacting with his environment, his problems are ultimately likely to be solved in biological terms. It is interesting to note for example, that a number of reputable physicists, (Schrodinger 1944; Elsasser 1958; Bohr 1958) have all comprehensively published in biology near the end of their lives. Why do physicists turn to biology in later years? Perhaps it is because they find that comprehension of physics is ultimately a biological phenomenon -

Man interacting with his physical environment. Or it may be that physics is a subject not sufficiently comprehensive to fully encompass the nature of Man interacting with physics. Perhaps Simpson has reasons for notable physicists writing about biology:

> "The life sciences are not only much more complicated than the physical sciences, they are also much broader in significance, and they penetrate further into the exploration of the universe that is science than do the physical sciences. They require and embrace data and all the explanatory principles of the physical sciences and then go far beyond that to embody many other data and additional explanatory principles that are no less - that are in a sense - even more scientific."
>
> (Simpson 1964).

It is surprising therefore to observe physicists turning from physics to biology, when current biology seems bent upon coming within the realm of physics.

Vitalism - A Second Possible Theoretical For Biological Education.

One major need of biological education, would be to gain the interest of students through incorporating major controversial issues in biology.

The notion 'vitalism' is presented as an example. Whether one agrees with it or not, it is an issue which is far from being dead. Some current molecular biologists, mechanistic in viewpoint, sympathise with it. (Mora 1963).

If this is so, then students would be likely to find the issue equally interesting and worthwhile. 'Vitalism' has been explained by a text writer in the following manner:

> "In the course of history, two major answers have been proposed regarding the governing forces of the universe. These answers are

incorporated in two systems of philosophy called vitalism and mechanism.

Vitalism is a doctrine of the supernatural. It holds, essentially that the universe and all happenings in it, are controlled by supernatural powers. Such powers have been variously called gods, spirits, or simply vital forces. Their influence is held to determine the nature and guide the behaviour of planets, stars, living things and indeed all components of the universe. Clearly most religious philosophies are vitalistic ones.

Whatever value a vitalistic philosophy might have elsewhere, it cannot have value in science."

(Weiss 1967).

Crick (1966) takes a stronger position when he states:

"There are still some people today who belive that the earth is flat, in spite of the enormous accumulation of scientific evidence to the contrary. And to those of you who may be vitalists I would make this prophecy; what everyone believed yesterday, and you believe today, only cranks will believe tomorrow."

Many texts, rather than be explicit about vitalism, merely ignore the issue altogether assuming that it is a dead one. However, Crick notes that vitalism is not dead when he states:

" 'Is vitalism dead?' It seems to me that reluctantly we must answer, 'No'. "

(Crick 1966).

Mora (1963) states in an article entitled "Urge And Molecular Biology" the following points:

"Living entities, at all levels and in almost all their manifestations have something of a directed relentless acquiring and selfish nature, a perserverence to maintain their own being and a continuous urge to dominate their surroundings, to take advantage of all possible circumstances and to adjust to new conditions.

The more 'vital' a living thing the stronger this urge. Often this domineering, this taking advantage, this fighting is directed against other living entities; but the acquisition or absorbtion of metabolites, the urge of self continuance goes on also in the absence of other living entities, for example when a bacterial or mammalian cell is growing or multiplying in a nutrient medium ... The question raised here is; Are present molecular approaches sufficient to lead us to the understanding of the differences between the living and the non living, or more explicitly, of what I call 'biological urge'?"

(Mora 1963).

Secondly, Dix (1968) a practising biochemist, concludes that life has a 'non molecular goal' and there is present a force which is the drive toward maximum benefit. This can be called a 'vitalistic principle'. Would Crick regard Dix and Mora, both molecular biologists, as cranks?

Biological education currently glosses over this important theoretical issue. Brief discussion of 'vitalism' is found in an embarassingly few paragraphs in the introductions of some text-books. Yet the difference between the 'living' and the 'non living' would seem to be a crucial one for biology. It would seem that 'vitalism' is equated with 'anti-science'. However it can be noted that some reputable journals in biology publish accounts of 'vitalism'. Mora (1963) and Dix (1968) are able to have their articles published in reputable biological journals.

If practising biologists can discuss this issue (and other issues) without being incriminated, or having their research 'infected', then it seems unlikely that discussion of similar theoretical issues among students at introductory levels will not denigrate their abilities as future successful biological reseachers.

Furthermore, the creation of interest by controversy within introductory courses would probably result in two important consequences. Firstly, a 'drift' from biology resulting through the boredom of learning masses of unconnected 'facts' would be averted. Secondly, a place would be made in biology for those individuals who are potential biological theoreticians.

It seems probable that a source of potential theoreticians is that increasingly large group of non-mathematical mixed 'arts-biology' students, who because of pre-requisites in chemistry and physics at tertiary levels, are not able to advance in biology, even if they wished to do so. New approaches to research and exemplification of arid areas can only occur through theoretically orientated biologists. At present these individuals are becoming more scarce. As a consequence biological research seems to be declining. (Levins 1973; Mellanby 1973).

What Is Likely To Happen To Biology If Theory Declines?

(a) Biological Research.

If theory is not emphasised, then ultimately basic research will slow down. It would probably take a few years before the 'drying up' process manifests itself. Evidence seems to be accumulating which suggests that molecular biology, because of its non theoretical nature, is 'running out of steam'. Take the following recent quotations as examples:

> "The basic research performed by federal and state agricultural research organisations is of meagre quality, suffers from a 'shocking lack of intellectual leadership' and is guided by policies detrimental to the interests of agriculture."
>
> (Science Vol. 180, No. 4084, April 1973).

A possible reason for 'the shocking lack of intellectual leadership' is the absence of biological theoreticians leading research. If there is no theoretical basis on which to generate fresh approaches to research in biology, then given time, the research institutions must 'run out of steam'. Recruitment and education of biological theoreticians now seems to be necessary. For example, attempts at increasing food production may fail. The consequences of this diasaster would be beyond the confines of agricultural research. If theoreticians are necessary, and it seems that they are, then a start could immediately be made at introductory levels.

Another approach which shows the inadequacies of a biology which is non theoretical is outlined by Weiss (1970) when he states as follows:

"I propose the following instructive past-time. Go to a library and scan back-copies of newspapers that have reported science items for the last twenty-five years, (there was no such spate of science news before World War Two as since). Note down the grand and grandiose predictions of how a given observation or insight would soon provide the cure of this disease or the solution of that mystery, or furnish new means for man to manipulate his destiny, and so forth. Then try to track the fate of those items through subsequent periods and discover for yourself how quickly most of the erstwhile burning news get cold, eclipsed, doomed to oblivion."

(Weiss 1970).

Many of these 'breakthroughs' in biology belong to the field of molecular biology. They have failed to live up to early promise. Furthermore the glitter and glamour may have been a feature of public relations necessary to obtain research funds. The initial caution, and provisional nature of these early 'breakthroughs' was neglected. It is probable that emphasis upon theoretical biology would have served to incorporate caution and proviso. Not only could biological theoreticians sustain long term and fruitful research if they held important positions at research centres; they could also assist in capitalising upon already known findings as bases for further fresh research.

This however does not appear to be the case. The reported early promise of many research projects has not been sustained. Weiss continues to give reasons for the temporary nature of 'breakthroughs'. He states the position in the following way:

" ... Does research in biology take bearings, as in navigation, from fixed stars, or does it follow the erratic lines of capricious will-o'-the-wisps ... Some research is still decidedly goal directed; some other research shows direction, but no goal; and there is also some that even lacks direction.

> Moreover, what used to be clear macrogoals for orientation have gradually crumbled into innumerable disconnected microtasks; and many of the original major targets for research have become splintered, blurred, obscured, or totally lost from view. Consequently the corresponding great focal questions whose resolution was the original concrete goal of research have not only remained unanswered but have faded to indistinctness."

(Weiss 1970).

It would seem that a major task in research is to pick out clear theoretical goals, and to gear research toward these goals. Furthermore the microtasks probably would require synchronising. It would appear to be the job of a theoretician, not only to outline goals, but also to decide upon sub-goals of the research project under consideration.

Weiss therefore supplies evidence for a general running down of molecular biology through a lack of emphasis upon 'theoretical' biology.

> "Within agricultural science, America's traditional anti-intellectualism survives as an anti-theoretical bias. This is seen in the reluctance to take intellectual detours, and a preference for the accumulation of direct experience with a crop as a guide to practice. It is reinforced by the search for marketable products, (mostly chemical) as the central strategy for improvement in agriculture, by the practice of research administrators to new problems before a deep understanding of why something works or doesn't work has been achieved, by the way in which the success of agricultural research is evaluated, and by a narrow acceptance of the present structure of agriculture as a given condition which restricts options."

(Levins 1973).

Zuck (1964) notes that the lack of theory in tertiary institutions will have long-term deleterious consequences:

> "To put a person committed entirely to molecular botany in charge of research, or research funds, or a department of botany; would be comparable to placing an electrician as dean of a school of architecture or a piano tuner as director of a conservatory of music. Only people trained in the various areas of more classical botany, dedicated to achieving a whole view of plant life, could hope to advance a general and more nearly adequate understanding of these magnificant organisms. To Steere's concept of taxonomy as the great unifying force, I would add evolution. Without these most powerful concepts, research on plants is largely meaningless, just as a piano tuner's thumping on the keys has no coherent meaningful message."
>
> (Zuck 1964).

This paucity of theory at the head of research institutions seems to be commonly commented upon. It may be a reason for the 'running down' of biological research at 'pure' levels.

Munson also outlines the problem:

> " ... biology has not yet begun to make the sort of impact on our everyday lives that the physical sciences and their resulting technologies have made, and that many believe biology will make. Genetic engineering, the regeneration of organs, choice of sex in unborn children, and consciously directed human evolution, though they have provoked much professional and journalistic speculation, are among the possibilities of future biotechnology yet to be realised."
>
> (Munson 1971).

It appears that biological research will continue to run down unless it is based upon strong theoretical assumptions. If this is to occur, it would seem that the responsibility for upgrading theory in biology lies with biological educators.

Curricula would be required to prescribe biological theory to students as well as to encourage individual students who have strong interests in theory. It seems likely that these theoreticians may be derived from the enlarging 'arts-biology' group of sixth and seventh formers. This group is hamstrung by prerequisites for advancement in biology at tertiary levels and generally appear to enter the social sciences. Evidence seems to be mounting which indicates a need for nurturance of this large, but generally ignored group of high school biology students. Moreover, it seems probable that members of this group could contribute to the survival of biology.

What Is Likely To Happen To Biology If Theory Declines?

(b) Biological Education.

'Factualism' would be reduced; 'reductionism' would be placed within the context of whole organisms, and 'technicism' would be distinguished from the science of biology. 'Anticipatory biology' would be stressed and observation would be upgraded. Another important feature will be discussed.

It relates to the need for students in biology to be supervised by their teachers:

> " ... I also fear that the vastly increased number of post-graduate students, many of whom are not fitted to enter the field of original research, has been seriously counterproductive. In a recent report of chemical departments, both professors and lecturers said they spend on an average more than 30 per cent of their time supervising research, and half of the lecturers and over 80 per cent of the professors spent less than 10 per cent on actually doing research themselves. This is surely the wrong way round - a research student who needs so much supervision should be doing another job."

(Mellanby 1973).

The situation described by Mellanby could possibly be prevented through the incorporation of biological theory in introductory courses. Research students with a theoretical basis from introductory biological education are likely to be adaptable in approaching biological research. A less theoretically orientated student is more likely to 'flounder' and require a great deal of assistance by teachers or supervisors.

Those students who have been previously educated in biology which is non theoretical seem unlikely to be adaptable and able to work independently, if the statement by Mellanby is accepted. Therefore research supervisors need to spend large amounts of time overseeing. More theoretically educated students would need less supervision and this would give time to supervisors for their own research. Also, theoretical biologists who are necessary to initiate and sustain research would find an important niche.

2. A Need To Emphasise The Observational Phase In Biological Education.

There is an alternative type of observation, currently rejected by biological educators, which could be fruitfully incorporated into biological curricula. This interpretation of observation is outlined by Tinbergen (1972):

> "One of the most fundamental points the ethologists raised was that studies should be made of the whole life-cycle of the species - a fine one was done on Cichlid fish - which implied of course that observation should precede experiment. At the time (the nineteen thirties and nineteen forties) it was not doing so...
>
> We placed a tremendous emphasis upon observation. Observation is a creative act and we have been in danger of skipping the whole observational phase. When you observe, when we observe we are hypothesising all of the time. We think in terms of evolution, in terms of natural selection."
>
> (Tinbergen in "New Scientist" An interview With Cohen. Vol. 55, No. 804, July 13, 1972 Page 93).

Cohen notes:

> "A man recently asked him (Tinbergen) what were the rules when he observed, what was the grammer. And he (Tinbergen) found he could not answer. He compared the situation to a primitive tribe that can speak its language perfectly, but could not begin to analyse its grammar, the rules abstracted out of the way they speak. The same goes for observation. Good ethologists know how to do it but they cannot self consciously dissect how or why. 'You can't for example teach all pupils how to observe. You could almost say, Either they have got it or they have not' (states Tinbergen). It surprises him too, how easy it is to miss things ... Observation is an individual thing, more individual perhaps than many life scientists would like to admit. It is ironic, too, how little study has been made of observation. Observing observation does sound a little like one of Russell's paradoxes, but it is not paradoxical at all. It could be argued that any

philosophy of the behavioural sciences is going to have to face the problem of what actually happens when scientists do observe - what they bring to an observation, what they select from it - not assume it is a replication of the impersonal (allegedly) observation of the physical sciences."

(Interview with Tinbergen in "New Scientist" Vol.55, No. 804, July 13, 1972. P 93).

Tinbergen is an ethological biologist who attaches great importance to observation. This has implications for biological education.

Firstly, observation, it seems, is not simply the taking in of segments of external reality:

"Biologists have shown that the relationship between an organism and its environment ... is one of constant interaction. The view that the organism submits passively to the influence of its environment has become untenable. How then can man as a 'knower' be a faithful record of outside events? ... man acts upon and modifies the reality he obtains, by transforming his world, a deeper understanding than reproductions or copies of reality could ever provide."

(Piaget and Inhelder 1969).

Tinbergen also emphasises this point:

"Naturally observation is always much more than the passive taking in of outside events; as many authors have pointed out, all observation is selective, and this selectiveness is determined from within ... I believe that observers and experimenters can find common ground in acknowledging with prejudices, even with hypotheses and that we begin to wonder when we find, either at the observational or experimental level, that what we observe is contrary to our expectation; we are amazed at the refutation of what we expected and it is this amazement that spurs us on."

(Tinbergen 1972).

It can be recognised that the process of observation (itself a biological phenomenon) is regarded as very important to biological education. This despite the present situation where observations have been pared down. They are considered 'pure' and 'objective'. They are only significant within the structured context of experiments and practical exercises. But it can be seen that observation is extremely complex. Firstly, all observers bring with them assumptions, often unconsciously held, - 'theories' to an observational situation. What they get from the observational situation varies from observer to observer. If the observational situation is in itself complex (for example when observing behaviour of birds) then a number of observers may attain a wide variety of interpretations of one observational situation. It is probably this in-built observational variety which allows for interpretive variety. For example, Tinbergen and Lorenz (both ethologists) do not always agree about similar phenomena (Tinbergen 1968). Each does not passively submit to the phenomena being observed. Instead each reacts to the phenomena, and the products of this interaction vary a great deal. There is a major implication for education which requires elucidation. If observation of seemingly simple phenomena is variable among reputable scientists two possible strategies are open to education. The first is what seems to be happening at the present time. Students are being shown by curricula what to observe. Consequently, what has to be observed must be made simple. This seems to be the desired aim of most practical exercises. However this strategy is not likely to promote significantly new observations or new interpreations to biology. Theory is not advocated in current biology to assist in the interpretation of even the simplest observations. The students are not encouraged to interpret at all. They have little theory available to them in their courses with which to use as a basis. Therefore observation in current biological education is a 'lowest common denominator' type where it is hoped that all students will apply exactly the same interpetations and meanings to identical phenomena. This may be sufficient for the training of technicians who need to acquire similar skills. However it is not a strategy which will give biology a forward looking orientation, where original interpretations are being given to observational phenomena. Current biological education favours a position which relies upon knowing the past achievements. What is proposed is to allow for biology to look to new possible interpretations. This will not necessarily be attained by attempting to make all interpret phenomena in the same way (an impossible situation anyway according to Piaget and Inhelder).

Tinbergen maintains that observation cannot be taught. It seems that current biological education, in trying to teach observation, may be 'banging its head against a brick wall'. New interpretations will possibly arise only if observation is made more theoretical.

What Can Biological Education Do To Promote Theory In Observation?

Biological education can assist in contributing to 'what observers bring to the observational situation', and the 'what observers glean from an observational situation'. This can be achieved through incorporating theoretical biology as a prerequisite, and as a concomitant to observation. Education can develop the theoretical concepts necessary. Theory could be presented in a way which novel interpretations to observation are possible. For example the questions which Tinbergen outlines below require a theoretical basis:

> "1. In what ways does this phenomena (behaviour) influence the survival, the success of the animal?
>
> 2. What makes behaviour happen at any given moment? How does its 'machinery' work?
>
> 3. How does this behaviour machinery develop as the individual grows up?
>
> 4. How have the behaviour systems of each species evolved until they became what they are now?"
>
> (Tinbergen 1968).

These seem to be simple questions. Yet they may require a great deal of ingenuity and knowledge of theory to interpret. Knowledge of evolutionary theory for example, would cull out some possibilities for observation of phenomena and amplify other possibilities. Put simply, preliminary knowledge of theory would focus the observer to some aspects and not to others. Theoretical knowledge would determine possible questions which could be asked of a particular organism. Biological theory is sufficiently articulate and pervasive to allow for an enormous variety of legitimate questions which could arise.

Tinbergen stresses that observation is a 'creative enterprise'. It is not pared down to a mere look or a smell which is the case in present biological education. Questions are asked of the organism. This requires original and independent thinking. on the basis of knowledge of theory. Observation is used to attempt to derive answers to these questions. For example, to find out how a caddis fly species feeds may require knowledge of the evolution of insects as well as caddis flies, but also extensive preliminary observation may be needed before a student can set the animal in a situation where feeding is observed. Different theoretical orientations may develop different (and successful) ways of solving problems.

Observation would therefore enrich biological education if theory was upgraded and incorporated into courses. Upgrading of 'theory' in biology would not be difficult to do. Nor would it be expensive. No complex intricate equipment is necessary for its incorporation.

Tinbergen's interpretation of observation has a second important implication for education. Observation is an important and necessary preliminary to experiment. It seems that current biological education may be leaving out this preliminary stage. Current biology, in keeping with popular belief, implicitly and explicitly maintains that 'experiment' is 'new' for biology. This is not the case. Experimental biology has been going on for many years. Pavlov's research was experimental. But observation has been declining in importance over the years. Yet Tinbergen maintains that observation (and theory) is necessary as a preliminary to experimental research. Observation allows for the development of possibilities which can then be used as a basis for later research:

> "I believe that we should observe and describe before we experiment; and second, with regard to behaviour (as with all life processes) we should ask the question "What's the use of what the animal does?" Does it contribute to the animal's success, and if so, how? as well as the question "What makes it happen?"
>
> (Tinbergen 1972).

3. A Need To Incorporate The Methods And Rationale Of Natural History Into Biological Education.

At present it seems that a great deal of experimental biology is being carried on at advanced levels without preliminary observation. This strategy is likely to limit possibilities for research. Also there is the danger that organisms will be studied out of context of their natural habitats, and aberrant findings may be accepted as being 'true', merely because they have been 'experimentally' derived.

Biological education could assist in rectifying this situation by incorporating an extensive observation phase into biology. If Tinbergen's opinion is accepted, it may be best if introductory courses concentrated more upon observational activity, and left advanced biological education to deal with the experimental aspects of biology. Moreover, not all introductory students will become biological researchers. Students who are not intending to advance in biology, would (if observation was given importance) be made more aware of their surroundings. Attempts at 'experimental biology' in the form of laboratory exercises may be less effective in developing this awareness. Furthermore it may be necessary for experienced biological researchers to return sometimes to the observational phase to help clarify or develop hypothesesfor research. A third important implication for education, if Tinbergen's outline is to be taken seriously by biological educators, is that field observation would be an extensive and and integral part of biological education.

It is known that very young children have a keen interest in their surroundings. (Bailey 1903; Leach 1946; Beggs 1954; Comstock 1960; Terry 1971). It seems that this early interest is part of 'exploratory behaviour' (Tinbergen 1968).

Primary school curricula in New Zealand once emphasised Nature Study. (Since the late nineteen sixties it has been replaced by more 'experimental (and physical) science'). However, Nature Study emphasises observation in natural surroundings, and it capitalises upon the keen interest of young children.

Emphasis upon observation at secondary school levels (especially field observation) has been contracted. Yet Tinbergen (1972) is advocating an extension not a contraction of the observational phase. It is contended that this extension could be incorporated into secondary school biological education. This could be accomplished by introducing observational studies after the style of Nature Study. This approach is presented in a readily available form (Bailey 1903; Beggs 1954; Comstock 1960). It would serve to extend and develop the observational sequence currently being neglected. The incorporation of Nature Study (as with the incorporation of theory) would be inexpensive. Equipment for observing organisms in the field, and for keeping them in 'internal habitats' in the laboratory costs considerably less than some sophisticated experimental equipment currently being purchased.

> "With any subject, of course, your first concern as a teacher is to make it live for the child, so that when you come to teach nature study which deals with living things a child can touch, watch grow, and look after, your work has already begun for you. Because plants and animals change and move, children are immediately interested in them. But to keep the child's interest alive you should be more concerned with habits and adaptations of living creatures than about their external forms and outlines; A primrose far from being merely an example of botanical form, is a forerunner of spring, a thing to be looked after, with petals that attract bees and effective devices to use them for cross pollination."
>
> (Beggs 1954).

This quotation serves to highlight that observation of live organisms is most important even at very elementary levels in primary schools. It also emphasises another important feature, currently neglected in biology - namely 'habits' and 'adaptation'. Both of these notions are very complex and theoretical. (Lucas 1971; Tinbergen 1972). Yet these notions can be initially developed with children at very elementary levels. If theoretical notions in biology can be begun at primary school levels, then surely theory and observation can be successfully further developed at secondary school levels. Thirdly, interest is generated if live organisms are observed within the context of their natural habitats. Beggs in his book, instructs teachers to:

> "Concentrate attention on living things which are real to the child, rather than upon generalities which are remote from his world of thought. One live sparrow will hold his attention better than any discussion on bills and legs of birds."
>
> (Beggs 1954).

Implied in this statement, is that boredom will accrue if a great deal of discussion occurs. 'Discussion' can cover a wide variety of meanings, but at its worst it would be likely to create less interest for children than would observation of live organisms, with little accompanying discussion.

A number of authors speak of 'boredom' among students in science at more advanced levels.

Koestler puts this case strongly when he states:

> "It is the academic cant of relatively recent origin, that a self respecting scientist must be a bore, that the more dehydrated the style of his writing, the more technical the jargon he uses, the more respect he will command.

I repeat this is a recent fashion less than a century old, but its effect is devastating."

(Koestler 1964).

It would seem that in dealing with description and facts, current text writers seem to be guilty of the charge that Koestler makes. The devastating effects of which he speaks could include a 'drift' from biology. Moreover, text writers who write in the manner described implicitly hold that ability to dehydrate the style, and to incorporate jargon can indeed be equated with 'intellectual rigour'. (Stenhouse 1972). This tendency among biological educators is noted by many students who readily become aware of the fraudulence of such a situation, and hence 'drift' from biology by voting with their feet .

Secondly:

" ... science teaching nowadays in too many schools, is rather too factual, too dull, and not obviously relevent to human and social affairs. Young people get a mental picture of science as a rather arid and not really challenging subject."

(Brian 1968).

Brian is referring to the present general situation which stresses experiment and fact, as opposed to observation and theory. Far from creating interest, this mode of approach in biology may have long-term consequences:

"One of the valuable discoveries which the Dainton Committee has to report is that students following science tend to be looked after by well qualified teachers. The question now is who should tell these talented people that they must spend less time behaving as if they were teaching in Universities."

(Editorial in "Nature" Vol. 217, March 21, 1968. Page 792).

Teachers in biology appear to have difficulty in breaking from the ways they themselves were taught at school.

Consequently an 'orthogenic' situation occurs. This can have deleterious consequences for future biology. (Stenhouse 1972).

From the evidence cited, a major contrast has been developed. On the one hand Beggs (1954) emphasises 'observation' and 'theory'. He is quite explicit about the sustained interest which can be generated through theory, field observation and live organisms. On the other hand in secondary schools, current biology downgrades field observation and derides the extensive use of biological theory. Sustained interest has been reduced. A 'drift' from biology is occurring at tertiary levels. The "Nature" article (above) attaches a great deal of importance formalistic teaching in science in secondary schools, as a cause of boredom, and of the 'drift' from biology.

A solution therefore seems to be fairly obvious. Incorporate the methods (not the exact content) of Nature Study into secondary school biological curricula. This would generate interest in biology. The rationale and methods of Nature Study are outlined in Bailey (1907), Beggs (1954) and Comstock (1961). All authors stress field study, 'creative observation', (as outlined by Tinbergen) and biological theory (adaptation, 'survival value' and natural selection.)

The methods of Nature Study appeared to have been educationally profitable in primary schools. Current secondary curricula in contrast are using 'experimental', 'factual' and 'lecture' methods and generate contra attitudes in students.

A rejoinder to the need for the methods of Nature Study to be incorporated into secondary school curricula biology, could be that these methods are already being used through the emphasis which is currently being placed upon ecology. There are historical reasons for assuming that ecology is no more than 'cleaned-up' Nature Study or Natural History. Disney (1968) makes the distinction explicit, and he also stresses the importance of Natural History:

> "The idea that ecology has supplanted natural history (the former being regarded as 'cleaned up' natural history) ... is explicitly stated in so many words by other authors (e.g. Dowdeswell 1959.
>
> In seeking for the origin of this fallacious view of natural history it appears, surprisingly, to originate in Elton's two stimulating books (Elton 1927; 1933). He refers to ecology as scientific natural history, and again states "ecology represents partly the application of scientific method in natural history ... " The failure to define natural history coupled with the much misused phrase "scientific method", would seem to underlie this confusion of thought. The term "scientific method" as opposed to the terms scientific methods or experimental procedure, strictly represents not so much a bag of sophisticated techniques and mathematical tools as the refusal to accept any authority other than observable facts. In the famous aphorism of Louis Agassis (quoted in Allee et.al. 1949) "study nature, not books".
>
> In exposing this confusion of thought, my intention is not to indulge in a pedantic quibble, but rather to highlight the current neglect of serious natural history by biology teachers of all levels. Yet natural history possesses great educational potential. It normally finds a ready response with younger children. Furthermore it can provide genuinely challenging projects at all levels. Such projects not only serve as an excellent training in scientific investigation but frequently lay the foundation of a life-long hobby. Problems in natural history, have the attraction that they are normally conceptually simple, although they may require considerable ingenuity and sophistication for their solution. Thus the problem "what does species A eat?" is conceptually very simple, although seasonal geographical, age and sex differences may make its solution a most challenging exercise and may involve quite sophisticated techniques ... By contrast, many ecological projects (such as the construction of an energy budget for a stream community) tend to

worry some students on account of the assumptions that have to be made, and also the frequent use of (if not dependence on) second hand data that is so often involved.

Natural history can provide endless projects which train students in both experimental procedure, as well as the currently neglected skill of competent observation, and the imaginative use of circumstantial evidence."

(Disney 1968).

Theory, creative observation, and natural history are interrelated. Disney stresses the importance of evolutionary theory in natural history:

"Because of its primary interest in the individual species, natural history exhibits no overall concept such as the ecosystem in ecology. The naturalist aims, ultimately (in theory at least) to construct a comparative natural history of all organisms. In practice the naturalist tends to limit himself to a small group of species such as a genus ... or a family ... or to a special habitat. Although natural history has no concept analogous to the ecosystem, <u>the theory of evolution provided a unifying theme that prevented comparative natural history becoming a mere cataloguing of facts</u>. The biologists interest in relating structural and physiological adaptations to the ways of life or organisms, was enormously stimulated by the evolutionary outlook. The naturalist hopes that his studies will throw light on an organism's peculiar properties, as well as the evolutionary origin of those properties. The ecologist, by contrast, hopes that his studies on the regulation of animal numbers will reveal operative selection pressures involved in evolution. Evolution studies look to natural history for understanding of the function of many adaptations and to ecology for insight into the mechanisms of evolution."

(Disney 1970).

Tinbergen notes that Natural History in biology emphasises how little is known about organisms in their environments:

"The Naturalist knows perhaps better than any other zoologist how immensely complex are the relationships between an animal and its environment, how numerous and how severe are the pressures the environment exerts, the challenge the animal has to meet in order not merely to survive, but also to contribute substantially to future generations. He also realises how little we really know. Yet what we want to know is a great deal. We need to examine not merely whether a certain feature is of advantage to an animal; we also have to find out how it contributes to survival ... In these few words I have tried to outline in perhaps oversimplified terms what is really a major programme of research, a programme which, in spite of much fascinating work already done is still in great need of development."

(Tinbergen 1964).

Finally Natural History is important because it formed a basis for the derivation of two great biological theories:

" ... biology can, and does, deal with the activities of the whole intact animal. The old natural history, which superior persons are apt to dismiss as unscientific, but which nevertheless is, as W.M. Wheeler says, "the perennial root-stock or stolon of biological science" was concerned with the habits of animals as naively observed, and with their adaptation to environmental conditions. We should do well to remember that both the main theories of organic evolution, Lamarckism and Darwinism developed out of this despised natural history study of living and intact animals. Of recent years, two young and vigorous branches of biology have differentiated out of this original matrix of natural history - the study of behaviour, and the study of animal ecology."

(Russell 1933).

In conclusion, it is held that the incorporation of Natural History into biological curricula at introductory levels would serve to stem the 'drift' of students from biology. Boredom could be replaced by interest, doubt and wonder.

More significantly, with the current problems for Man becoming more biological the importance of 'Man in his environment' will become increasingly important. If individuals have been previously educated in the problems of how local common organisms overcome the vicissitudes of their particular habitats, through Nature Study or Natural History, these people are more likely to be sensitive to the principles of conservation.

Moreover, if Natural History methods were incorporated into current curricula, more students would be likely to study it. The sheer increase in numbers of environmentally aware individuals would serve perhaps to assure the survival of Mankind.

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