DOCUMENT RESUME

ED 061 895 HE 002 969

TITLE	Interdisciplinarity: Problems of Teaching and Research in Universities.
INSTITUTION	Organisation for Economic Cooperation and Development, Paris (France). Centre for Educational Research and Innovation.
PUB DATE	72
NOTE	307p.
AVAILABLE FROM	OECD Publications Center, Suite 1207, 1750 Pennsylvania Avenue, N. W., Washington, D. C. 20006 ($7.00)
EDRS PRICE	MF-$0.65 HC-$13.16
DESCRIPTORS	*Curriculum Development; *Educational Development; Educational Innovation; *Higher Education; Instructional Innovation; *Interdisciplinary Approach; *Relevance (Education)

ABSTRACT

"Interdisciplinarity," the integration of concepts and methods between disciplines in teaching and research, may provide an important key to the innovations required in universities to meet the intellectual and social demands of the present time. This report is based on a seminar held in September 1970 and reports the subsequent reflections of a group of distinguished authors. A careful analysis of interdisciplinarity is presented and its impact on teaching and research as adapted to changes in both knowledge and society is examined. It is concluded there is real need not so much to eliminate any of the disciplines but to teach them in the context of their dynamic relationship with other disciplines and in terms of societal problems. The report is in 3 parts. The first, "Opinions and Facts," presents information collected during an extensive survey of universities on interdisciplinary activities in teaching and research. The second part, "Technology and Concepts," considers the subject within the framework of developing scientific knowledge and the requirements of a rapidly changing industrial society. The final part, "Problems and Solutions," studies institutional structures, curricula, teaching methods and teacher training programs, all of which are issues basic to any reorganization of universities. (HS)

centre for educational research and innovation

INTERDISCIPLINARITY

PROBLEMS OF TEACHING AND RESEARCH IN UNIVERSITIES

OECD
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

This publication was prepared by an Editorial Committee composed of the following people :

Léo APOSTEL
University of Ghent, Belgium

Guy BERGER
University of Paris VIII, France

Asa BRIGGS
University of Sussex, United Kingdom

and

Guy MICHAUD
University of Paris X, France

who was responsible for the publication in co-operation with the Secretariat.

Centre for Educational Research and Innovation (CERI)

INTERDISCIPLINARITY

PROBLEMS OF TEACHING AND RESEARCH IN UNIVERSITIES

This report is based on the results
of a Seminar on Interdisciplinarity in Universities
which was organised by CERI in collaboration
with the French Ministry of Education
at the University of Nice (France)
September 7th-12th, 1970.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
1972

The Organisation for Economic Co-operation and Development (OECD), which was set up under a Convention signed in Paris on 14th December, 1960, provides that the OECD shall promote policies designed :

- *to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy ;*
- *to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development ;*
- *to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.*

The Members of OECD are : Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

The Centre for Educational Research and Innovation was established in June 1968 for an initial period of three years, with the help of a grant from the Ford Foundation which was later supplemented by a grant from the Shell Group of Companies.

The main objectives of the Centre are as follows :

- *To promote and support the development of research activities in education and undertake such research activities where appropriate ;*
- *To promote and support pilot experiments with a view to introducing and testing innovations in educational systems ;*
- *To promote the development of co-operation between Member countries in the field of educational research and innovation.*

The Centre functions as part of the structure of the Organisation for Economic Co-operation and Development, under the responsibility of the Council of the Organisation and the Secretary-General. It is supervised by a Governing Board of independent personalities appointed by the Secretary-General, in their individual capacities.

CONTENTS

5

APPENDICES

7

PREFACE

The universities are often radical in their approach to society and conservative in the way they themselves reflect society — namely in what and how they teach. The fundamental reason lies no doubt in the fact that academic disciplines are the basis for the organisation of knowledge for teaching purposes. For the disciplines are not only a convenient breakdown of knowledge into its component parts, they are also the basis of the organisation of the university into its autonomous fiefs, and of the professions engaged in teaching and research. Thus, to meddle with the disciplines is to meddle with the social structure of the university in its entirety.

Viewed from the point of view of the student and society, however, the disciplines cannot be taken for granted as if given by some pre-ordained order of knowledge. For if modern science has taught us anything, it is that the impact of knowledge on action — whether in the field of social or natural phenomena — forces interaction between the disciplines and even generates new disciplines. The "inter-discipline" of today is the "discipline" of tomorrow. Indeed, the breakdown of knowledge into a hierarchy of disciplines itself reflects social values — is mathematics, philosophy, sociology or political economy the queen of the sciences ? Moreover, the criteria for the emergence of a new discipline are varied and change over time — is it method, field of phenomena or theoretical framework ?

One practical implication emerges from these questions — it would be unwise to be too simple-minded in either defence of, or attack on, teaching based on single disciplines. Indeed, the heat of controversy around this question results partly from a tendency to overlook the complexities of universities as institutions. Those who see the universities as producing scholars and scientists stoutly defend the discipline as the cornerstone of intellectual training. Those whose image is the university producing professional manpower (schools of medicine, engineering schools, etc.) would no doubt agree that a group of disciplines is involved, even if they also see the defence of their "discipline" as the defence of their "profession" also. Finally, those who think of the university as producing the "well-educated man" who is neither scientist, scholar nor professional would surely agree that various mixtures of disciplines should share this privilege.

In the reality, interdisciplinarity probably has a different meaning in the context of each of these three groups of students, and all three are to be found in most universities. A careful analysis of what interdisciplinarity really is, and its real impact on teaching and research adapted to changes in both knowledge and society, is therefore the only viable approach to the problem. That is precisely the purpose of this report, based on a seminar held in Nice from 7th to 12th September, 1970, and on the subsequent reflections of a group of distinguished authors.

This report works on the hypothesis that, for the reasons stated above, creative change in university education and research calls increasingly for an interdisciplinary approach to teaching. The guiding principle is not the need to demolish the disciplines, but to teach them in the context of their dynamic relationships with other disciplines and with the problems of society. This is justified if only because of the increasing social costs of the over-specialisations of knowledge. Indeed, it may be argued that one of the reasons for the tarnished image of science is public reaction to its power to produce specialised applications of knowledge, without a corresponding development of the synthesising framework which can illuminate their side-effects and long-term implications.

Interdisciplinarity is not a panacea for change in the universities, but it is a vantage point from which a good deal of critical and healthy reflection on the inner workings of the university can be stimulated. It is hoped that this report will promote such self-examination by the universities, and as such provide a stimulus for further research and innovation.

J.R. GASS
Director
Centre for Educational Research and Innovation

APPROACH TO THE PROBLEMS

Pierre DUGUET

Some people often wonder how useful international cooperation is, and they make no bones about extending this to international agencies. It is our pleasure to state emphatically that without such cooperation, the work which the office of CERI undertook some two years ago would have remained buried in some filing cabinet. In truth, only the combined thinking of people with different educational backgrounds and different jobs in various Member countries of the OECD has made possible a better understanding of a problem which, by its very nature, is international : how to unify knowledge and what the many implications of such unity are for teaching and research in the universities.

A certain amount of thinking on this problem has been done in the last several years, all of it more or less along sectorial lines. Our purpose has been to study the full breadth of the issue. This reminds me of a letter written by a professor from Paris whose opinion on "interdisciplinarity" I had requested when we began our project. My question brought to his mind what the painter Matisse said during a dinner party to a woman who asked him, "Sir, what do you think of Art ?" : "Madam, don't you have an easier question !" Yes indeed, the question of interdisciplinary teaching and research is vast and complex. This book, which is the product of a joint effort, attempts to cast light on that question, and even to offer some answers to it. It may be appreciated, rejected or hotly debated. That's all to the good, for its purpose is certainly *to stimulate thinking and discussion* in the hope that they will result in action in this field that we deem vital to the future of the University and its role in society.

1. A RESEARCH PROJECT ON INTERDISCIPLINARITY

At the outset, the purpose of our research was to check whether there was any one way of defining the problems of interdisciplinarity in countries where the structures and curricula of universities were organised in considerably different ways. Hence, on the basis of a very general document (CERI/HE/CP/69.01), an initial meeting of experts coming from only three countries—Germany, France and Great Britain—was organised in December 1969. This document already made a distinction between the institutional structures of Universities and the curricula offered in them. Yet the terminology used made such discussions confused at best. Professor Guy Michaud in a document (CERI/HE/CP/69.04), suggested distinguishing the four levels multi-pluri-inter- and transdisciplinarity, which cleared up these problems of terminology considerably and paved the way for epistemological thinking.

Therefore, from here on, without using the refined terminology which can be found in the first part of this book and which is discussed in the second part, we shall at least make the distinction between "pluridisciplinary" and "interdisciplinary". Pluridisciplinary for us simply means the *juxtaposition* of disciplines, while interdisciplinary means the *integration* of concepts and methods in these disciplines. This distinction is basic to the clarity of our statements, and the reader must not think it is merely a subtlety of language.

A second source of confusion must likewise be avoided. The foregoing adjectives can apply to either the structures of institutions or the content of courses or research programs offered in the universities.

With this in mind, the problems can be clarified by applying our terminology to these two cases. Hence, a university may be pluridisciplinary (i.e. collecting various disciplines) and offer either courses in a single discipline, or pluridisciplinary courses (teaching diverse disciplines), or interdisciplinary courses (courses showing the relationships among various disciplines).

The conclusions of this meeting were recorded in the document CERI/HE/CP/70.01. Two major observations became clear :

1. Interdisciplinary teaching and research are the key innovation points in universities.
2. Introducing this innovation comes up against enormous difficulties, even in the new universities.

On the first point, interdisciplinarity appeared to be the chosen entrance to the solution of a large number of problems raised by the University and present-day society :

— interdisciplinarity would help the drift of science and research towards unity ;

— it would make it possible to bridge the gap that currently exists between professional activities and the training the university offers for them ;

— it would de-fuse the student rebellion against "piece work" and would enhance both their willingness to return to the current world and their own personal unity.

On the second point, namely, introducing genuine interdisciplinary studies (with the "dose" of interdisciplinarity varying according to the level of study), the group of experts was merely able to observe that this difficulty existed. These difficulties are described in the first part of this book. One of them, however, should be broached right away, that of institutional structures. The organisation of universities into monodisciplinary Schools or "Faculties" which jealously protect their branch of knowledge, constitutes a major obstacle. No mistake should be made about it, however. While changing the institutional structures of universities is a *necessary* condition, it is by no means *sufficient* for introducing interdisciplinary teaching and research. That is true whatever the level of innovation involved and no matter whether the country involved has a centralized or decentralized system of higher education.

Two examples serve to corroborate this hypothesis. The first is the Latin countries, where most of the reforms which are planned or are currently being carried out deal with overall innovations at the level of the structure of institutions, for the purpose of rearranging the traditionally separate Schools handling a single discipline. This institutional pluridisciplinarity in most cases is not resulting in interdisciplinarity in the contents of the courses offered. The second example concerns the United States, where a large number of universities have been pluridisciplinary for a long time (which is obviously a tautology if one sticks to the real meaning of the term "university") and offer monodisciplinary or pluridisciplinary courses. (This is especially true as far as teaching is concerned, for interdisciplinary research has been expanding in the last several years.)

We are emphasizing this dichotomy between the structures of institutions and the contents of courses in order to refute the argument that interdisciplinarity is a problem particularly for Latin countries seeking to regroup their various "Faculties" into "Universities". Throughout this book there are numerous examples of interdisciplinarity involving, among others, the English-speaking countries.

At any rate, we have paid particular attention to studying the new universities on account of the relatively minor role played by structures when they were set up. Isn't it logical to think first about the purposes and functions of the new university, then to study their implications for curricula and teaching methods, and finally to consider what institutional structures would be best adapted to achieving such programs ?

Of course, the issue of the old universities could be raised. Perhaps at that point reforming structures could be combined with developing little islands of interdisciplinary teaching and research, to introduce this innovation most easily.

*
* *

The meeting confirmed the value of our research and led us in February 1970 to call together a group of high level experts, with a yet broader international range, for the purpose of investigating more thoroughly the problems raised at our first encounter, but also to advise us what steps to undertake next. This group was made up of the following people :

C.C. ABT	President of ABT Associates, Inc. (United States) ;
M. ALLIOT . . .	Professor at the School of Law and Economic Sciences in Paris (Currently President of the University of Paris VIII, France) ;
A. BRIGGS	Vice-Chancellor of the University of Sussex (United Kingdom) ;
J.P. DIXON	President of Antioch College, Ohio (United States);
I. DOGRAMACI . .	President of the University of Hacettepe (Turkey) ;
H. v. HENTIG . . .	Professor at the University of Bielefeld Pädagogische Arbeitsstelle (Germany) ;
E. JANTSCH	Expert connected to the OECD (Austria).

The basic document CERI/HE/CP/70.03 which was submitted for discussion, written by Guy Michaud, raised the issue of the role and function of the University in the emerging society, and asked a number of questions about how interdisciplinarity is *connected* to the functions of the university. We considered that interdisciplinarity played an important role in various fields for the following reasons :

General Education :

a) The first step is to get students to reveal their abilities and then to give them *guidance* in order to define what place they will have in society ;

b) it is also necessary for students to *learn how to learn* before they acquire any particular body of knowledge ;

c) lastly and more generally, it is important to allow students to *find themselves* in the present-day world, to understand and criticize the flood of information they are deluged with daily.

Vocational Training :

a) In most cases, practising a profession currently requires a person to draw upon several basic disciplines ;

b) if, in addition, one recognizes that in years to come each individual stands a good chance to change professions several times during his lifetime, due especially to shifts in the job market, one sees the need for offering people vocational training with a well-rounded background.

Training Research Workers and Research :

a) The purpose is to prepare students for research work (by doing research), meaning that they should know how to analyze situations, raise problems in a broad way and learn to get familiar with the limits of their own conceptual scheme. The training of research workers must therefore prepare them to be able to engage in fruitful dialogue with research workers in other disciplines ;

b) for cooperation among disciplines, as well as comparison of methods, henceforth seems to be a *sine qua non* of progress in research. Such cooperation has its own methods, which must be worked out and taught, and it implies that a model for classifying the sciences and showing how they overlap will be worked out beforehand.

Continuous Education :

Students must be educated in such a way that when they are grown up, they will be able to continue their "education" after graduation from the University.

Such education is both the result and continuation throughout their lives of the general education and vocational training they have received in three key ways :

a) They are retrained in their field of professional practice ;
b) they are committed to the social and political life of their community;
c) they get personal fulfillment in a leisure culture.

Links between teaching and research :

a) The courses offered must prepare students for interdisciplinary research by giving them an adequate methodology ;
b) research work in turn must provide the teaching programs with the tools and concepts required to constitute an interdisciplinary methodology ;

c) the result is that *teacher training* at every level of schooling should stress interdisciplinarity in order to make it easier for the future teachers to develop new attitudes and to enable them to encourage them in others.

As we pointed out, the primary purpose of this meeting was to investigate more thoroughly the issues raised at our first encounter. The high caliber of the participants led them to examine and discuss the core of the problem. As a result, three conclusions emerged :

— The need for careful thinking on the concepts of interdisciplinarity and transdisciplinarity.
— The need to make a survey of the Member countries of the OECD on interdisciplinary activities in research and teaching.
— The need to expand on the first point of document CERI/HE/CP/70.03 on the role and function of the university. It was agreed that the Secretariat would organise another meeting on this subject. This meeting took place in July 1970 at the OECD headquarters. (Basic documents CERI/HE/CP/70.11 and CERI/HE/CP/70.08.) A second purpose for this meeting was to advise the Secretariat on what steps to take and, more specifically, on how to organise a work seminar on interdisciplinarity.

2. A SEMINAR ON INTERDISCIPLINARITY

The overall plan was thought to be very ambitious and the deadlines too close at hand, to say the least. However, the group of experts had approved of the suggestion made by the Secretariat to hold a seminar in the autumn. This seminar was held, with the help of the French government authorities, at the University of Nice, from the 7th to the 12th of September 1970. Its imposing title, "Seminar on Pluridisciplinarity and Interdisciplinarity in Universities", reflected once again our determination to avoid both possible misunderstandings stemming from nomenclature, and our desire to aim the discussions at both levels.[1] Finally, the title indicated that we would devote our work to universities. Considering the totality of institutions of higher learning would only have increased our difficulties. Be that as it may, we are convinced that interdisciplinarity also plays an important role as an innovator in all institutions beyond the secondary school level.[2]

The goals of this seminar, set forth in the document CERI/HE/CP/70.10, were as follows :

a) First of all,

— to analyze the role of pluridisciplinarity and interdisciplinarity, and assess their respective places in a university which fits the needs of modern society ;

1. In this respect, some of the experts who attended the February meeting would have preferred the title, "Seminar on Interdisciplinarity and Transdisciplinarity". We chose to stick with a title which seemed to us would be better adapted to the variety of educational systems of Member countries.

2. In fact, this restriction has a purely relative value, since the term "university" has different meanings in different countries and can even be used to cover specialized institutions of higher learning.

— to clarify the concepts of pluridisciplinarity, interdisciplinarity and even transdisciplinarity, using an epistemological line of thinking ;
— to take a close look at those objectives in favor of pluridisciplinary or interdisciplinary training ;
— to study the means which allow for developing such objectives.

b) Secondly,

— to encourage comparison and imitation among the programs in various Member countries ;
— to organise the collection, storing and publication of data on interdisciplinarity (which would have the effect of encouraging the expansion of interdisciplinary attitudes) ;
— to plan seminars on topics which are essentially interdisciplinary ;
— to assess the advantages and drawbacks of worldwide reforms or pilot projects ;
— to suggest new university models ;
— last but not least, to give rise to reports and books on interdisciplinarity and on the problems which this concept raises.

Twenty-one nations which are Members of the OECD were represented. A full list of the participants is included in the Appendix, where the reader can see how wide a variety there was among the 43 delegates from Member countries and the 14 experts.

*
* *

It is useful to supply a few details on how this seminar operated. The schedule was set up such that the first day's session was devoted to defining and discussing concepts. Hence, the documents of J. Piaget of Switzerland, A. Lichnerowicz of France, and E. Jantsch of Austria included in the second part of this book were presented by their authors. It was a rough day, which may have satisfied those with a Latin, Cartesian bent of mind, but disconcerted those with a pragmatic Anglo-Saxon way of thinking. I remember one participant who disclosed to me that evening, "With all that, I no longer know if what I'm doing is multi, pluri, inter or transdisciplinarity !"

In fact, this session can take credit for having stimulated thought and avoiding confusion as the work went on. The second day was devoted, on the one hand, to presenting the results of the survey on interdisciplinary activities in teaching and research which had been suggested at the meeting in February (a description and the results of this survey are contained in the first part of this book), and on the other hand, to looking at some new universities in various Member countries which were all characterized by their interdisciplinary approach (three of them are described in Part III of this book, in Chapter 5). This session was very useful in that it allowed for an exchange of information on university innovations, and it should be noted that such information is hard to come by. The following day, panel discussions were planned on two models for interdisciplinary universities, one on a university for medical science and public health presented by I. Dogramaci of Turkey (document CERI/HE/CP/70.18), and the other on a university of environmental studies, presented by G. Michaud of France (document CERI/HE/CP/70.22).

We chose these two fields because they were naturally interdisciplinary. That made it possible for us to approach the issues of curricula, teaching methods, structures and costs. For instance, how should the many, different disciplines be combined in course curricula in order to avoid chopping knowledge up into little bits ? What kind of teaching methods are most conducive to this combination ? What institutional structures are most appropriate ? Doesn't this kind of teaching prove more profitable, as well as make for some increased costs ?

In the third part of this book, a stand is taken in favor of "universities with an area of special emphasis". In our view, this first of all means "universities" which group together major disciplines, and then give an institutional form to an "interdisciplinary field of knowledge". That can be public health, or the environment, but also technology or international relations. Such a university prepares students for a variety of professions in that the "area of special emphasis" is a broad one, but also in that its structural organisation includes room for both survey and intensive courses. Hence, a university of public health would prepare students to enter both the medical profession and para-medical professions, depending on their skills and desires.[1]

The fourth and fifth days were devoted to the work of 3 groups formed to work on the following topics : The Conceptual Tools of Interdisciplinary Research (L. Apostel of Belgium, chairman), Interdisciplinarity and University Structures (B. Girod de l'Ain of France, chairman), and Interdisciplinarity in Research and the Ties between Teaching and Research (M. Chagnon of Canada, chairman). The curious reader can find the reports of these study groups in the document CERI/HE/CP/70.28. Since these reports have been used in the second and third parts of this book, we have not published them in their entirety.

After these reports were presented, C. C. Abt of the United States introduced a descriptive model and a theoretical model and what they imply for the organisation of the university in terms of general education, vocational training, adult education and research (document CERI/HE/CP/70.19).

Finally, the morning session of the last day was devoted to studying the recommendations made to universities and national leaders, and deciding how to follow up the seminar. For lack of time, these recommendations could not be discussed point by point, as was necessary. Consequently, they were not adopted. To be perfectly honest, it should be added that it would have been difficult to reach a consensus on such a controversial topic. Nevertheless, anyone who wishes to know what recommendations were made can do so by requesting them from the Secretariat.

On the other hand, a goodly number of interesting suggestions were made on how to follow up this seminar. Hence, pursuing the objectives of this seminar (planning seminars on topics which are essentially interdisciplinary), CERI organised a "Workshop on Environmental Education at University Level", from 5th to 8th of April 1971. In addition, the Secretariat is beginning to set up a research project on medical and para-medical education

1. This raises the basic issue of setting up a "Common Core" for beginning undergraduates, after which students would turn towards short or long programs.

seen from an interdisciplinary point of view, and within the framework of a university of health.

Following this meeting, which we thought reached its main goals, we received a large number of letters requesting the report published on the seminar. Given the choice between a brief report which would have given a very general overview of the problem, and a book containing documents and thoughts, we preferred the latter option.

3. A Joint Publication

This book stems from a joint effort. It acquired its present form during a series of meetings. The Editorial Committee, made up of A. Briggs of the United Kingdom, G. Berger of France, L. Apostel of Belgium and G. Michaud of France, thought that the problems of interdisciplinarity would be shown most readily by dividing the material into three sections : one for presenting the data, one for encouraging thinking, and one leading to action.

— The first part, "Opinions and Facts", hence presents information which we collected during the survey on interdisciplinary activities in teaching and research. Guy Berger indicates clearly the difficulties which he encountered when breaking down and assessing the results. Our job is to insist on the fact that this survey far from touched on all interdisciplinary activities which are cropping up in institutions of higher learning.[1] Nevertheless, the answers received were numerous enough to allow us to get an accurate idea of the problems involved in developing interdisciplinary activities.

— The second part, "Terminology and Concepts", treats disciplinarity and interdisciplinarity within the framework of the development of scientific knowledge, and within that of the requirements of a rapidly changing industrial society.

The five documents which form Chapter 1 (prepared for the Seminar at Nice by H. Heckhausen of Germany, M. Boisot of France, E. Jantsch of Austria, A. Lichnerowicz of France, and J. Piaget of Switzerland) use different approaches and thereby make it possible for the reader to become aware of how broad and complex the problem is. L. Apostel of Belgium, who has written a worthwhile introduction to these five papers, has also, in Chapter 2, attempted, under the heading "The Conceptual Tools for Interdisciplinarity — An Operational Approach", to make a synthesis of the work of Bernal, Carnap, Piaget, Bertalanffy and Cassirer, although he knows full well that such a synthesis is impossible. As he himself said : "That's the definition that a humorist might give for our study !" This paper is nonetheless highly interesting for anyone who is seeking to expand an interdisciplinary research project.

— The third part, "Problems and Solutions", studies institutional structures, curricula, teaching methods and teacher training programs, all of which are issues basic to any reorganisation of universities with an interdisciplinary dimension.

1. In this respect, we would appreciate hearing from "interdisciplinary readers" about their own experiences.

This chapter also contains a few sample universities and two projects. One is a university "with special emphasis on international relations", and the other is a Center for University Synthesis, wrapping up a section which is especially designed for those who have the weighty responsibility for making decisions on university organisation.

***

Guy Michaud, who throughout this work has been of tremendous assistance, concludes this book with what he gladly calls a "coda". Much work remains to be done to produce a better understanding of this concept of interdisciplinarity, and to expand its applications in the universities and in institutions of higher learning generally.

Interdisciplinarity is of course merely one aspect of redesigning the university. It is by no means a panacea which would make it possible to cure all the ills from which the university is currently suffering. But it emerges as a major aspect in this transformation and as a powerful impetus for innovation.

Lastly, we are adding four appendices :

— Some bibliographical references. We thought such references would help the reader who wished to gather more thorough information. Nevertheless, as far as we know there is no book covering the topic as a whole, so that, in some cases, one need not pay too much attention to titles which at first glance may be deceptive.
— A list of those people who answered the questionnaire, along with the name of the interdisciplinary activity, its purpose or purposes (general education, vocational training, training research workers, research), and the major disciplines involved in each case.
— A list of those who participated in the Seminar. Certain names are marked with an asterisk, to show those persons who contributed to preparing the Seminar by drawing up papers in one of the following fields (based on an outline prepared by the Secretariat and published as CERI/HE/CP/70.12) : general education, vocational training, training of research workers for research, links between teaching and research. We take this opportunity to express our deep appreciation for their contributions.
— Finally, the appendix contains a list of all those mimeographed documents which are available on request from the Secretariat at CERI.

PART I

OPINIONS AND FACTS

This part was written by Guy BERGER, Maître Assistant, Département des Sciences de l'Education, University of Paris VIII (France).

SUMMARY

I. INTRODUCTION

Goals and Limits of This Study

The following study of the problems of interdisciplinarity in higher education makes no claim whatsoever to be exhaustive or systematic. It is based upon limited and relatively arbitrary information :

— limited, in that it is valid only for the countries involved in the OECD, and in fact we do not have information for all of them, only twelve countries having supplied information ;

— arbitrary, in that this survey, whose origins and nature will be explained later on, did not cover all the universities which it would have been useful to contact, and in that the number of answers, their origins and variety do not allow to speak in terms of a significant sample.

Such remarks would cast serious doubt on our work if our goal were to report on the state of interdisciplinarity in higher education, to supply a rigorous discription or to write a document in the history of higher education. Our aim is entirely different. This is a forward-looking, theoretical Research Project on a possible functioning model for the university. It aims to explore a certain number of scattered or regrouped islands, with diverse dimensions and structures, located in what we would gladly call the interdisciplinary archipelago, for we are highly aware of the disparity among these experiences, how parcelled out they are, how much or how little they have broken away from the system which surrounds them, at once provoking and rejecting them.

The direction this exploration takes will appear in the following sections, for an inventory only serves to define the problems in two ways, first, theoretically and epistemologically, with the aim of founding a new structure for knowledge and the conditions for obtaining it, and second, in the form of a model, with the aim of indicating what directions a possible university might take, using a description of scattered existing elements and the basic research which this description calls into play.[1]

Conditions for Defining the Problems of Interdisciplinarity

The "disciplinary" framework is relatively new in the history of Western science and teaching. Quite apart from any definition of what constitutes a

1. We have undertaken the task of rereading and systematically examining all the documents with the help of a group of students in the Science of Education at the University of Paris VIII : Miss Contandrianpoulous, Messrs. Courtois and Toubiana. Mrs. Coulibaly, a psychosociologist, was the head of this small team. In addition, she took an active part in preparing and writing up our work.

discipline — which is not our purpose here but will have to be examined if the organization of teaching and science are to be set up rationally—and apart from the various classifications of the sciences which have been proposed during the course of history, it can be observed that only those sciences which appeared recently, the so-called social science group (economics, psychology, sociology, anthropology, etc.), set themselves up immediately as "disciplines". Similarly, although the division of the University into Schools or Faculties is an old one, people moved easily from one to the other in the old university system, whose very name displays the claim to universality and in a way to unity. In addition, it is necessary to perceive that in many universities throughout the world there is currently emerging a desire for the integration of disciplines or at least for establishing interdisciplinary activities, as the persistent attraction of a founding theme of the university itself, and deeper still, of knowledge.

Even when interdisciplinarity is introduced in a doggedly modern and innovative perspective, even when it is offered as a vehement protest against "bits of knowledge" as alienating culturally as "bits of work" are in production, it can be considered to be an attempt to restore the goals of teaching, which was gradually diverted from its declared purpose, overcome by its own development or by its surrender to the broader and broader needs of society.

The nostalgia for the scientific and literary humanism of the eighteenth century, the eternal theme of a science of sciences or of absolute knowledge, the demand which science makes as the result of its expansion, the crisis in the university — all these elements no doubt blend together to give the current historic dimension to interdisciplinarity. Without referring to this background, it seems difficult for us to understand the diversity of the experiences which we shall attempt to present and analyze.

Another much more complex dimension must be added to this picture, attributable to the fact that every interdisciplinary undertaking occurs within a yet broader university structure, which itself derives its meaning only from its relationship to the entire teaching system, so that it is necessary to remember at every turn what are the overall characteristics of the cultural and educational activities for each country involved.

So it is that in most European countries and especially in France and Belgium, an elementary school already appears to be a "miniature Sorbonne" where, in accordance with a strict schedule, perfectly enclosed and separate courses follow in succession, with tight divisions seeming to be necessary for rigorousness. In this case, practising interdisciplinary activities at the University breaks intellectual habits which are deeply rooted in twelve or thirteen years of elementary and secondary schooling. Those who promote or witness the appearance of interdisciplinarity always experience it to be critical, often revolutionary and impossible to separate from other innovations with bearing on types of pedagogical communication, power-sharing and relationships to knowledge. In the United States, as well as in the United Kingdom and in Sweden, practising interdisciplinarity, on the contrary, involves carrying over into university teaching a goodly number of educational traditions from the elementary and secondary schools.

The very tone and nature of the documents which we shall present here reflects this. In one case, the university readily allows for interdisciplinary "enclaves", while in the other, it rejects or at least makes them marginal phenomena. We constantly bore in mind this dual reminder of a general history of science and teaching, and of the extreme diversity amongst school systems and particularly university systems. It could have led to drawing up separate monographs for each country. (Moreover, that is the solution chosen in the Case Studies on Innovation in Higher Education - OECD.)

But the very reference to research and hence to the development of science, as well as the existence of a crisis in the university in most countries, makes it neccessary to confront the problem head on.

It is up to the reader to connect the information which we bring forth to the original system involved in each instance ; we shall strive to specify which country is referred to whenever possible. The incongruity among the frames of reference would be an obstacle and would cause our descriptions to be intolerably long if the purpose of our work were to provide such descriptions. The editorial staff of this book has made every endeavour to consider it as a whole in spite of its multiple authorship. Furthermore, let us remember that the purpose of these first few pages is not only to provide factual information, but to pave the way for renewed consideration of the theory and the proposed models which stem from it.

Therefore, apart from the structure of the university system and more generally of higher education, we shall suggest an arrangement of the different forms of teaching and research within the following categories, repeated in the list of definitions offered to teachers and research workers, studied in the survey which we have to present.

In varying proportions, all university teaching, and to a lesser degree, all research can be thought of as fitting into one or another of these cases. Let us simply specify that these are temporary suggestions, and involve an endeavour to clarify terminology and concepts. These distinctions and definitions were drawn up and put forward by Guy Michaud. C.C. Abt restated them so that they could be put at the top of the questionnaire which we have to analyze.

Discipline . . . . A specific body of teachable knowledge with its own background of education, training, procedures, methods and content areas.

Multidisciplinary . . . . Juxtaposition of various disciplines, sometimes with no apparent connection between them, e.g. : music + mathematics + history.

Pluridisciplinary . . . . Juxtaposition of disciplines assumed to be more or less related. e.g. : mathematics + physics, or French + Latin + Greek : "classical humanities" in France.

Interdisciplinary . . . . An adjective describing the *interaction* among two or more different disciplines. This interaction may range from simple communication of ideas to the mutual integration of organising *concepts, methodology, procedures, epistemology, terminology, data,* and organisation of research and education in a fairly large field. An interdisciplinary group consists of persons trained in different fields of knowledge (disciplines) with different concepts, methods, and data and terms organised into a common effort on a common problem with continuous intercommunication among the participants from the different disciplines.

Transdisciplinary . . . . . . Establishing a common system of axioms for a set of disciplines (e.g. anthropology considered as "the science of man and his accomplishments", according to Linton's definition).

Chapter 1

ANALYSIS OF THE QUESTIONNAIRE

SURVEY CONDITIONS

The survey which the OECD decided to conduct based on a questionnaire entitled "Survey of Interdisciplinary Activities of Teaching and Research in Universities" was drawn up during a series of meetings, aided by preparatory notes from experts which were held between December 1969 and March 1970. These meetings and notes were designed to make it possible, comparing a certain amount of evidence from recent experiments, to set forth an initial evaluation, to define the problems involved, and if possible to work out a strategy for interdisciplinarity, and they resulted in two realizations :

— The realization of how important the problem was and how significant for innovation within university systems ;
— The sometimes pessimistic realization of how extremely complex and difficult the question was, for the first experiments analyzed on a scale of three countries (Germany, France, United Kingdom) produced an overall impression of failure (Cf. CERI/HE/CP/70.01).

The *ad hoc* Group of experts was made up of :

A. COTTA	Professor of Economics Director of Graduate Studies University of Paris-Dauphine France
P. DUGUET	Administrator at CERI/OECD
H. FRIEDRICH	Wiss. Assistent (Sociology) Göttingen University Germany
W. HARDER	Wiss. Assistent (Pedagogy) Bielefeld University Germany
H. HECKHAUSEN	Professor of Psychology Bochum University Germany
C. JEANTET	Assistant Professor of Molecular Biology Centre Universitaire at Marseille-Luminy France
N. MACKENZIE	Director Centre for Educational Technology Sussex University United Kingdom

G. MICHAUD . . . . . . Director
Centre d'Etudes des Civilisations
University of Paris (Nanterre)
France

M.J. PENTZ . . . . Director of Studies
Dean of Science
Open University
United Kingdom

D. RIVET . . . . Coordinator of Studies
Center for Economic Psychology
Ecole Pratique des Hautes Etudes, Paris
France

W.M. SIMON . . . . . . Professor of History
Keele University
United Kingdom

This Group was struck by the broad diversity in their experiments, some already old (Keele) and some recent (Bielefeld) or just being completed (Marseille-Luminy), some with a partial and some with an overall picture, some limited to one or two years of study and some covering an entire university program.

The very concept of interdisciplinarity, and the allied concepts of multi-, pluri- and transdisciplinarity at times seemed difficult to delimit. The causes of those failures noted could be boiled down to the following points :

1. Inadequately defined goals.
2. Lack of flexibility among teachers, especially professors, who all too often cling to their lecturing role and remain cloistered in their discipline, fearing a dialogue which might challenge their discipline or their status or one by means of the other.
3. Absence of individual or collective leadership with genuine power over the teachers and over those institutional means which make a team experiment possible.
4. Difficulty in setting up coherent, planned programs while avoiding a simple juxtaposition of disciplines and the temptation of an encyclopaedic approach.
5. Resistance of the traditional structures at all levels — separations among disciplines, examinations, diplomas, jobs for graduates.
6. Disarray which some students felt when confronted with a teaching method which often appears confused, incoherent and arbitrary to them, and which does not lead directly to any definite professional situation.
7. Very major operational difficulties (scheduling, budgeting, etc.)

In summary, there were problems involving goals and curricula, problems involving personnel, problems involving institutions, problems involving facilities. Hence it seemed necessary, during the course of preparation for the seminar in Nice, to conduct a large scale investigation which would make it possible to tackle all the problems just mentioned. Clark C. Abt was called upon to draw up the questionnaire, working in cooperation with the Secretariat of CERI, and the result was the document which serves as the basis of our work. (CERI/HE/CP/70.09).

THE QUESTIONNAIRE

The questionnaire is a relatively large booklet, 43 pages long, and hence well deserves to be presented as a "Study... in the form of a questionnaire... designed to collect information and opinions on different interdisciplinary activities (Research and Teaching) in the Universities involved".

The first part (31 pages) is intended for all those in teaching or research who deal with interdisciplinary activities, or preferably, for any team wishing to make a collective answer.

The second part (ten pages which are distinguished from the others by their color and which we shall hereafter call "blue pages") was aimed more particularly at those in charge of well-established activities who would therefore be more likely to provide middle- or long-run evaluative materials.

In addition to this general division, the questionnaire is cut up into several sections :

— Short "Instructions for Use" accompanied by some distinctions in terminology (cf. p. 5) to which proposed definitions should be added for General Education, Professional Education, Basic and Applied Research.
— Tables — one making it possible to identify and tersely describe the University ; the second particularly dealing with interdisciplinary activity. The latter table is supplemented by an open question on the analyzed activity and by a series of more or less specific inquiries about the student and faculty populations involved.

The following section allows for introducing the goals of interdisciplinary activity. It suggests a certain number of exclusive or compatible categories, distinguishing among the production and transmission of knowledge, the search for practical applications, the function of interdisciplinarity as motivation for learning or research, the intentional and unintentional changes in existing structures and institutions involved in setting up these activities.

A third section analyzes what we should like to call the intellectual and instructional infrastructure of interdisciplinarity. It deals, first of all, with defining what special area should result from combining disciplines. Is it better to concentrate on concepts, methods and terminology, or else simply on combining data, which is to say, having the several disciplines involved in an interdisciplinary program make use of the same sources of information, card files, computer programs, etc. ?

These questions are accompanied by a request for information about the kind of teaching done, whatever combination chosen, about the teaching means available, and about the amount and forms of communication between those involved in teaching and those in research.

Finally, a quick battery of questions completes the above, making it possible to study the institutional infrastructure (structure, examinations and degrees) and the material infrastructure (staff, offices, facilities, costs).

The fourth section deals with evaluation : first of all, an evaluation of what is desired, then an appraisal of the qualitative and quantitative changes which are due to interdisciplinarity, then an estimate of the obstacles and difficulties encountered.

A few open-ended questions are added which should make it possible to know what are the goals, expectations and uncertainties for the future.

The description of the "blue pages" will be much more terse. They were supposed to be a much closer analysis, and in a way an "historic" one, of the different sorts of combinations used (Cf. Section 3), and in particular were to provide a better approach to problems of evaluation, most notably, using a quantitative or cost-benefits approach.

Some broader questions were added on dealing with the connection between knowledge on one hand, and the relationship between the university and society, or between teaching and research, on the other. We personally regret that these questions only dealt with the "old" experiments.

The definitive draft of this questionnaire, or rather this study, was made at the end of April 1970, which with delays in distribution and shipment meant that, in most cases, it did not reach those involved until May or even June, in other words, in nearly all countries, not until the end of the academic year.[1] That was the first handicap. The breakdown of answers or refusals to answer allows one to judge how difficult it was to conduct the survey.

Overall Reactions

The very size of the study and the amount of work required just to read such a voluminous booklet made general and "chance" distribution impossible. CERI therefore started out by making a series of inquiries to those university Presidents liable to be interested, and then selected teams engaged in interdisciplinarity, so that this heavy chore would only be given to those who volunteered for it by accepting to answer. As a result, we have two series of reactions, first, reactions to the very issue of interdisciplinarity, and second, reactions after receiving the questionnaire.

Few genuinely negative attitudes appeared at the first level. Even if someone's refusing categorically to fill out a questionnaire at that time of the school year may be interpreted as a way to reject interdisciplinarity itself, we did not make this inference.

More frequently, people showed their disinterest by not bothering to answer, but here again, it was an area of pure conjecture. At any rate, we obtained more than 230 answers. Most of them requested that the questionnaires be sent, taking on the responsibility to forward them and get them filled out, or else informed us of the name of the person in charge of interdisciplinary activities, usually with the title of the activity and sometimes with a detailed description.

Although Presidents and Rectors are by and large in touch with what is going on at their university, it is not always clear to them what the definition of interdisciplinarity is. Hence, several officials referred to as being in charge of "interdisciplinarity" affairs disclaimed competence :

> "Our Institute is not an interdisciplinary one as you define it" (Mannheim).
>
> "I suppose that (the Rector) did not realize that your aims are to collect information on a real interdisciplinary activity and not on normal medical instruction. As in other countries, a student in medicine must acquire knowledge in physics, chemistry and biology and is obliged to take examinations in these disciplines..."

1. The need to gather enough data before the Seminar in Nice made it imperative to set a deadline on the time for thought and answering the questionnaire.

Some Presidents voiced doubt :

"a lot depends on your definition of 'discipline' and it is a little difficult for me to decide which of our courses you would classify as 'interdisciplinary' or 'pluridisciplinary".

"...I wrote that the Institut für Volkwirtschaftslehre und Statistik is part of an interdisciplinary activity. The director of this Institute has now explained to me that it is an inter-faculty rather than an interdisciplinary activity..."

Many correspondents, being personally involved in setting up interdisciplinary organizations, showed a desire to receive information on this topic :

"In view of the importance of such activities, we would very much appreciate it if you could kindly supply us with information relevant to the proposed Seminar" (Japan).

"We are currently examining the possibilities of setting up interdisciplinary programs in our university. Experiences in this area... would be very valuable to us." (Yugoslavia).

Those in charge of activities had very similar reactions, except that some of them emphatically refused to answer such a bulky questionnaire :

"Your enormous questionary too complicated and inapplicable... of such extreme length."

"Some of the questions we are unable to answer and others we did not understand".

"Quite intolerable burden".

Many simply filled out the questionnaire and sent it back, sometimes appending extra information or expressing (on rare occasions) doubts concerning the interdisciplinary nature of their activity. Sometimes they added from one to three pages of remarks, when the questionnaire seemed to them inadequate (in about a dozen cases).

Some discovered from reading the questionnaire that their activities were not interdisciplinary (Finland, Scotland...).

Finally, some negative reactions to interdisciplinarity or to the survey were noted. Some correspondents recalled that teaching always had been and still is interdisciplinary, and that all education and every science is built on numerous organized and hopefully integrated efforts. Others, on the contrary, rejected interdisciplinarity for its counterfeit modernity and mental confusion :

"Interdisciplinarity and pluridisciplinarity are by themselves no guarantee of intellectual quality ; (interdisciplinarity)... be used as a cloak for undisciplined thinking !".

This last kind of reaction is particularly interesting in that it emphasizes a contrast with a quite striking characteristic of most of the answers to the questionnaire. Very often those in favor of interdisciplinarity viewed it as a formal rejection of tradition or of a certain form of traditional rationality. Interdisciplinarity was thought to be a practical criticism, standing in opposition and in some cases even revolutionary.

Sifting through the letters received, observing the seriousness with which the questionnaires were answered, one sometimes catches a glimpse of an impassioned and polemical climate of opinion. In that sence, the letters are on occasion richer than the questionnaires themselves, and we had this impression again during the "Seminar on Pluridisciplinarity and Interdisciplinarity in Universities" which we were allowed to attend.

Answers to the Questionnaire

It was the authors' hope that the questions would give rise to a debate, at least amongst the teachers, and if possible between faculty and students, and that the answers would reflect the collective thoughts of groups engaged in innovative activities. That virtually never occurred, and at times it is hard to distinguish between the answers received and a traditional administrative form which some hapless professor was called upon by his research team to fill out at the last minute. We have dealt with such a case correctly in tables, but the open-ended questions (nearly all) are discouraging for the person who had to answer because of their difficulty and specificity, and so there are yes, no and no-comment answers.

Nevertheless, often the writer is glad to have been moved to reflect on a topic dear to his heart or is delighted to express his opinions about teaching, so that he starts in with gusto but is very quickly bothered by the large number of questions, some of which undoubtedly don't mean anything to him, and by categories which don't seem to match his own sense of reality. On the line calling for goals, a professor states what he is asked about again on the topic of intellectual or instructional infrastructure, and he mentions at the outset obstacles that he is asked about again at the end. Obviously some at times find the questionnaire stifling.

Some sections inspired only fragmentary or very meager answers. Few professors see a connection between practising interdisciplinarity and any specific mode of pedagogical communication. Questions calling for evaluation obtain evasive answers, such as opinions, hopes and regrets, but it is hard to be more specific. The blue pages are almost never filled out, less on account of the newness of nearly all the activities reported on than on account of the length of the study.

In summary, let us say that the material we accumulated is either very skimpy or very difficult to deal with.

The audience aimed at was badly defined. By systematically sending the questionnaires to universities, we overlooked the fact that in most countries they do not comprise the entire higher education scene, and their function and definition vary from system to system. In one instance we contact medical schools but not engineering schools, while in another engineers are trained in university institutes whereas medical schools have a separate entity. By its title, the Study covers teaching and research activities, but in practice few strictly research centers were contacted, with the exception of some graduate seminars.

At any rate, no questionnaire could have encompassed the structure of both a teaching institute and a research institute at the same time. Furthermore, everything being developed outside of an institutional framework has in fact been excluded, although this is most important and sometimes paves the way for other, more systematic activities.

The questionnaire, as we said, is a study which a goodly number of correspondents deeply appreciated as such (one Canadian university went so far as to state that the questionnaire helped it to define its own objectives), but in that this study intends to gather data which is as accurate and as comparable as possible, it fits the answers into a mould more or less prepared beforehand, draw conclusions on pseudo-rationalizations, and falls short of a reality often made up of a string of accidents and chance encounters. The quality of the questions is not impugned, for they go as far as it is possible to go without turning into a series of separate monographs which it would be difficult to collate. There were some rather unexpected reactions, which perhaps shows how ill-prepared teachers are for doing research in education. Underlying the questionnaire was the standard model of systems analysis. Yet with the exception of the answers coming from America, and even there with qualifications, it does not appear that this model was familiar to most of the professors, even those who are innovators or in charge of activities. At times they confuse goals and contents, and when they are asked whether "the outcome of their activity justifies the expenses incurred", they seem tempted to demand redress for the implicit slander.

The lack of agreement between the intellectual model underlying the questionnaire and that of the answers is made all the more striking by the fact that, no matter how the questions were formulated and numbered, with precise nomenclature, the correspondents frequently reply to factual questions by expressing "opinions".

In the handful of cases for which we had first-hand acquaintance with the activities described or with the correspondent himself, we were struck by how hard it was to avoid confusing an objective presentation with a declaration of intent. This lesson was driven home when we reread our own answer.

As has been stated above, this was particularly unavoidable because the questionnaires were almost never filled out collectively, except for one case in Wales, and the "customers" of interdisciplinarity, namely students, do not appear to have taken part in writing the replies. So we are tempted to extrapolate from this to declare that data basically deals with the conception that a certain number of university professors have of interdisciplinarity. That still requires reading between the lines.

By an inevitable paradox, when one is using current vocabulary, interdisciplinarity can only be approached in terms of disciplines. We have the list of disciplines which figure in a program of activities, and we know what kind of educational background the faculty and student participants have. But that is merely a juxtaposed list, and nothing makes it possible for us to know whether or not interdisciplinarity marks a return to the universal syllabus of the very classical and welldisciplined European secondary schools, since the questions set forth do not allow for discovering new methods to structure content or the real decision circuits in heterogeneous teams, which would be another way to "test" the degree to which disciplines are integrated.

Despite the precaution taken to preface the questionnaire with a short glossary, it does not look like those who wrote the answers troubled to sort out what belonged to each level of the suggested scale of terminology. If people can't come to an agreement on what it is they are defining, how can they be expected to come to an agreement on the terms of the definition ? The answers show that what one writer calls interaction is what another thinks is merely juxtaposition and thus what gets called interdisciplinary is what was hoped would be classified as pluridisciplinary, with the result that the integration of concepts often turns out to be a mere integration of terms, and so on. If interdisciplinarity is a means of aiming at universality, as sometimes appears to be the case, we have grounds to be keenly disappointed.

On the other hand, behind this more or less adequate system of classification, one gets a glimpse of agreements and sharp antitheses concerning the relationship to knowledge, the structure of fields of knowledge, and the meaning of universality. Those are the directions which we should like to shed some light on, over and beyond treating the information immediately at hand. With the university system everywhere undergoing a crisis, the concept of interdisciplinarity at time appears "totalitarian" and consequently obscure. Relationships and pedagogical communications, institutional structures, the relationship to knowledge, the meaning of the university and even that of culture in the social system, are all questions which seem to underlie the scattered efforts in the direction of interdisciplinarity which we have come upon. This must be guessed at sometimes through the mesh of a questionnaire which may well have been better geared to long established practices than to approaches to problems in a state of flux. This does not mean that it could have been drawn up otherwise, but it serves to place interdisciplinarity above and beyond merely being a way for a teaching and research system to work.

Chapter 2

"THE INTERDISCIPLINARY ARCHIPELAGO"

For the analysis of data which is made here, we are deeply indebted to two original studies published in limited editions by CERI and which served as basic documents for the Seminar in Nice already referred to several times. One of these is a report written by Dr. Abt, President of Abt Associates Inc. of the United States, who is not only the main author of the questionnaire but who also analyzed the replies made by American colleges and universities. The other is a report by Mr. J.G. Godin, dealing with the remainder of the answers.

Although the committee preparing this study chose to make a fresh breakdown of the results, it was certainly not to disclaim those two reports which in many ways are far richer than the present study, but rather to avoid treating the two sets of answers separately. Furthermore, as we stated at the outset, our goals are no longer what they were.

When preparing the Seminar and setting guidelines for thought and proposals which the present study incorporates, it was necessary to make a highly systematic treatment of all the data, whatever limitations and characteristics the sample had. Using the same methodology now, however, might give the impression that we were evaluating the role of interdisciplinarity in the university system in most of the Member countries of the OECD.

We know how much of a risk it would be to evaluate interdisciplinarity without providing accurate information on the Center for Genetic Epistemology at Geneva, on the Interfaculty Center in the Netherlands, on the well established projects which have been carried out at the Institute for the Philosophy of Science, at the Ecole Pratique de Hautes Etudes in Paris, at the University in Aix-en-Provence, to mention a few examples in France, or on curricula at Harvard University and MIT, on the Center for Space Studies at the University of Wisconsin, and on very interesting work done in Germany, Canada, Great Britain and so forth, to mention some examples chosen almost at random. Furthermore, we did not have set criteria which might make it possible for us to go beyond the information gathered on the basis of what we already had or that we were about to locate in books written on this topic. Therefore[1] our procedure was at times vaguer than those used in the two documents by Dr. Abt and Mr. Godin. This has not stopped us from making substantial borrowings from their work without stating so on each occasion, for they are too numerous to mention. The tables we set forth and the few sets

1. This explains why we did not suggest any bibliography, at least in this part of the study. We are dealing here strictly with the questionnaire.

of figures referred to are merely signs of the sample we have at hand. At any rate, they would take on meaning only if compared with other tables and other sets of figures dealing with activities which are not interdisciplinary. It should be remembered, however, that some of the institutions on which we have data have enrolments of nearly 30,000 students while the questionnaires sometimes cover the activities of only 50 of them, so that it is obvious we needed to be cautious in our manipulation of statistics and facts.

Section 1. THE GEOGRAPHY OF INTERDISCIPLINARITY

If we exclude some searching conversations which we had at Harvard University, MIT, and Antioch College, which helped in drawing up the questionnaires although they are not mentioned in our results, and if we likewise exclude a certain amount of information which was kept aside for the meeting in Nice and which will be presented in the third part of this study, the remainder of the answers are perforce weak and indeed very scattered.

We did not manage to reach a significant number of universities in any country, with the exception perhaps of Canada, France and the United Kingdom. We cannot claim to be thoroughly informed about all the interdisciplinary activities in a single university.

The table and list which follow show readily how scattered these results are.

OVERALL TABLE OF ANSWERS

Country	Number of answers	Number of Universities
Austria	1	1
Belgium	3	3
Canada	19	12
Finland	2	1
France	25*	9
Japan	8	2
Netherlands	5	4
West Germany	10	7
United Kingdom	35	17
Sweden	1	1
Turkey	6	2
USA	17	13
12	132	72

* Including 8 at Paris Dauphine (Paris IX) and 8 at Paris Vincennes (Paris VIII).

In overall processing of this data, we can scarcely go beyond this table by countries and this list. Indicating specifically which branches or Schools answered (School of Arts, of Sciences, of Medicine, etc.) would require that this division into Schools or Faculties prevail in every country. More important, that would neglect the essential fact that interdisciplinarity activity is in many cases helping to overcome this framework.

If we started out with the notion of a major disipline, we would be forced to make use of the usual, standard classification into disciplines, which means dividing up knowledge in a way which interdisciplinarity is struggling against. It would be paradoxical and dangerous to do so, for what characterizes a goodly number of questionnaires is that they are unidentifiable as soon as they use these categories.

Hence we shall confine ourselves to a general pigeon-holing by field of application, making use of the categories which have already been mentioned above.

FIELD TO WHICH INTERDISCIPLINARITY IS APPLIED

Country	General education	Professional education	Training researchers	Basic research	Applied research
	A	B	C	D	E
Austria		1		1	1
Belgium			1	3	2
Canada	12	3	10	6	9
Finland	1	1	2	1	
France	16	9	12	11	9
Germany		4	3	5	9
Japan	3	3	2	3	3
Netherlands		3	2	2	2
Sweden				1	1
Turkey		5	3	2	5
United Kingdom	17	23	12	8	10
USA	13	6	3	2	3
Total	62	58	50	45	54

This table, taken at the level of overall results, is obviously devoid of significance, except to make a rather unscientific contrast between the two extreme categories of General Education, which was mentioned 62 times, and Basic Research, mentioned 45 times.

The total number of references is far higher than the number of answers because each writer could assign several parallel functions to interdisciplinary activities.

On the other hand, a far more remarkable list emerges if we pull out and examine those questionnaires which stated that interdisciplinarity is applied to only a single field.

In this case we obtain the following breakdown :

General education . . . . 28 times
Professional training . . . . 10 times
(9 of which come from the United Kingdom)
Applied research . . . . 7 times
Training for researchers . . . . 3 times
Basic research . . . . once
(it happens to be in medieval ecclesiastical law)

In other words, General Education comes in way ahead of the other categories, revealing a striking contradiction between the kind of talk usually heard about interdisciplinarity and how it is actually put into pratice. By that we mean that some correspondents insist on turning interdisciplinarity into a basic method for making research move forward, and in the process they perhaps obey a particular university ideology that blows up pure knowledge more than they analyze the real function they assign to their activities.

Yet if we attempt to group teaching and educational activities together on one side, and all research activities together on the other, the answers just about balance out.

It seems far more interesting to us to compare the various countries involved, whenever we have a sufficiently large number of answers to establish a kind of national typology :

— In *Canada,* with the exception of professional training, all activities are about equally represented. The answers in the sciences, which are for applied research either on a problem or in a given area, are clearly the most common type. Another striking fact is the place biology has as the most often mentioned (eleven times) "discipline".

— In *France,* on the other hand, the social sciences and those disciplines traditionally connected to the social sciences are clearly in the lead. We fail to have a single example in which the physical or biological sciences show up alone. Professional training is rarely the goal, or else shows up by a fluke. Activities rarely seem geared to the goals of some area of the country or to the direct "needs" of society. (It is astonishing how many answers come from the Centre Paris-Dauphine, which is now called the University of Paris IX, and from Paris-Vincennes, now the University of Paris VIII. Both these cases are "experimental centers" which were created in October 1968 for the special purpose of setting up "pluridisciplinary" activities.)

— The few *Japanese* answers tend to be for the sciences. In only two out of eight cases are both training and research involved. Whenever general education is dealt with (two cases), it implies a highly humanistic approach, such as "a love for truth".

— In *West Germany,* the combinations are similar to those found in France. Perhaps the reason is that, once again, the answers come from so-called "experimental" universities. Nevertheless, research activities seem far more prevalent than training activities (general education was never even mentioned), which goes to show that interdisciplinarity is seldom a part of undergraduate work.

— For the *United Kingdom,* the one characteristic which sets it off from all other countries is the stress put on professional training as the leading field for interdisciplinary activities. Outside of that, and in contrast to France, for example, scientific activities got most of the write-ups, except for two or three instances, including the University of Sussex, which will be discussed in detail in the third part of this study.

— As far as the *United States* is concerned, general education is very clearly the leading activity. The diversity of the disciplines which are lumped together is much greater there than elsewhere. Most of the time the answers refer to broad teaching goals, such as instilling a love for truth, creating open minds, developing intellectual curiosity, etc.

We would have liked to round out this geographic exploration of our interdisciplinary archipelago by analyzing the various kinds of regrouping and conjunctions which we came across. We gave up on that idea because there would have been almost as many as we have questionnaires. Furthermore, we thought that the disciplines in themselves no longer meant anything. For example, the same conception of biology is not involved as it relates to city planning as when it is used as part of kinematics. So it was more worthwhile to sift through all the questionnaires and extract, empirically rather than formally, some general rules.

Section 2. SOME GENERAL PRINCIPLES FOR REGROUPING DISCIPLINES

The foregoing presentation has already made it obvious how broad a variety of activities, goals and disciplines is involved in this study.

The few trends that do appear are usually connected to the traits and habits of each country's university and cultural system. In Great Britain and Japan, interdisciplinary test cases most often involve the exact sciences, while in France and Belgium the social sciences are involved each time (isn't this a prolongation of the practice of teaching "philosophy" in the last year of the secondary schools ?), and in the United States and Canada it seems impossible to determine which of the two has the upper hand. Of course, we have far too few answers to be able to do more than frame vague hypotheses and state general impressions. But the fact that, for any given country, one particular team or university rather than some other chose to take part in the survey is not entirely meaningless. The difficulty is to be found elsewhere.

The wording, number and distribution of questions in the questionnaire makes it impossible to have more than a mere list, whereas it would have been vital for us to understand why any particular field of knowledge, activity or research implied the simultaneous need for such a speciality. This is all the more striking in that practically none of those answering felt the need to justify the number, character, or relative importance of the various elements involved in his project. Only a handful of groups working on problems of epistemology, such as that at the University of Sheffield in Great Britain, where a graduate project is tackling the notions of object and subject, emphasize their reasons for having brought together the particular experts they have. The limited number of statements we shall make are therefore of a broad nature.

1. *No constant relationship exists between the idea of regrouping disciplines and that of an interaction between the disciplines and regrouping people.* In some cases (most often in European universities and especially in French universities), the same person teaches several disciplines which he combines according to needs (this occurs in at least fifteen cases). In others, a major discipline (often represented by one professor) if need be calls upon the help of some fellow faculty members for some speciality on particular occasions. Except at the level of research and graduate or post-graduate seminars, there are very few examples of team teaching. In other words, most undergraduates, including those taking courses with interdisciplinary curricula and preparation, only occasionally encounter this interdisciplinarity as a standard feature of teaching itself and usually have to rely on their own ability to unify the courses they study successively. We have noted some examples of team teaching in the United States, generally in small colleges, as well as three at Paris VIII, a few in Canada, and so on.

2. Most of the time, *disciplines are regrouped around a field of study rather than on the basis of the structure of knowledge or of learning algorithms.* An engineering school inevitably involves mathematics, physics, engineering, psychology, sociology, business administration. Medicine requires a different configuration but one which is just as standard. These are therefore traditionally pluridisciplinary areas. In other words, interdisciplinarity can only be found at the level of integrating and organizing curricula, not just the "ingredients". The few times when we found surprising combinations (astronomy, dance, Hindi, geography... at an American university in California) the writers emphasize the variety which they recognize without really explaining why they do so.

3. *The number of regrouped disciplines is extremely variable,* ranging from two, three or four (in around 50% of the answers) to more than 20 (2 or 3 times in the USA and in Japan). One might try to find out whether criteria exist for defining the minimum or maximum number of disciplines allowing for effective interdisiplinary teaching. About ten questionnaires broach this issue, inasmuch as it relates to communication between teachers and researchers and the time needed for such communications, but never in terms of the possibilities for students to be involved.

4. *The criteria implied in regrouping disciplines vary widely.* No particular set of criteria seems to stand out. Nevertheless, it is possible to outline the following typology :

— *Regrouping one or several theory-oriented disciplines with one or several rather practice-oriented disciplines.*
— *Regrouping disciplines which are largely homogeneous* (purely practical ones, purely theoretical ones).
— *Regrouping a set of exact sciences and one or several social sciences.*
— *Regrouping a set of social sciences with one or two exact sciences, whether the latter be considered as a tool of the social sciences or as part of the rigorous intellectual training required.* That is particularly clear when mathematics show up as part of a set of activities in the humanities. Sometimes the emphasis is placed on the practical use of mathematics (in statistical computations or for constructing models), and at other times on its universal value (but in that case, what sort of interaction occurs, for example, between mathematics and literary history ?).
— *Regrouping on the basis of similarity or the amount of shared areas.*
— *Regrouping on the basis of disciplinarity or heterogeneity.* The most striking example of this is the State University of New York at Binghamton, where pairs of so-called matching disciplines are used for the purpose of furthering personal development. Among the possible pairs used are mathematics and music, theater and physics, engineering sciences and English literature.
— *Combined study of a set of methodologies independent of their object.*
— Lastly, and this is nevertheless the commonest of all cases, there are a large number of *what for convenience we call "natural"*

regroupings, which means regroupings which at the same time respect scientific traditions, the interaction of their objects and methodological requirements. As we have already indicated, in this instance there crops up once again the structure constantly found in all pluridisciplinary university systems, so that interdisciplinarity can only constitute an innovation in the area of teaching itself, which means that juxtaposed courses occurring in succession are replaced by an integrated program of teaching. At times, when dealing with few items, this sort of regrouping leads to founding fresh disciplines.

5. We have not found *any systematic proposal to make concerning the way integration should occur and how much emphasis each discipline should receive.* The problem is handled separately in each case on the basis of practical experience, and appears to rely on a series of "majors". In some instances, the major is made up of the field of activities, the social or technical problem to be solved, while in others it is easier to talk in terms of a major discipline with auxiliary sciences or fields of knowledge. This empiricism is always a first step, and is generally left behind later on.

This series of remarks may appear negative. In fact, it facilitates distinguishing between two levels. The assumption itself of interdisciplinarity is usually based on a tight set of arguments, and shows careful thought whose ramifications will be discussed in our remarks below. In contrast, we do not yet seem to have any rules for building. The parts which are to be assembled come from scientific or teaching traditions, from challenges to these traditions, from empirical needs, from conjunctions, and perhaps more often than is noticed, from the vested interests and personal traits of the person or persons responsible for setting up an interdisciplinary activity. But isn't this also true for so-called monodisciplinary activities ?

Furthermore, even if we have not found any *"principles"*, we have been able to note some *constants* which emerge from our systematic breakdown of the results, and which Mr Jean-Guy Godin makes some highly interesting remarks about in his report. We are repeating his remarks almost in their entirety.

Most of the situations which we have managed to study show the social sciences playing a major role. The social sciences certainly seem to show up very frequently, but more meaningful yet is the fact that they are the group which most readily combined with any of the other major fields.

The results of our study demonstrate how much teachers and students have a crying need for this new area of knowledge. It is knowledge which makes it feasible to criticize science and make it relative, but which is also a tool for self-criticism and self-relativization, and which determines how these will be applied by the other sciences. Hence, more than half of the interdisciplinary activities in Europe centered around majors in the sciences also propose to teach social sciences among the disciplines in the curriculum. In the United States, Japan and Canada, the percentage is still higher, but it fails to have the same overall significance since there it means studying various areas of application at the same time rather than providing a tool for the ideological analysis of the status of Science (e.g., the University of Halifax in Canada).

Inversely, the social sciences, particularly psychology and sociology, constantly express the need for the mathematical sciences, either because they are looking for tools or because they are searching for a way to raise the social sciences up to the level of the basic sciences. This need is thus a way to strengthen the status of these disciplines, not to make them more relative. Keeping in mind the distinction we have already noted between the United States and "other countries", we point out about these regroupings that we found only ten answers dealing with the teaching of literature. That is a field which therefore remains traditionally reluctant to make innovations or to reconsider its inner workings in the light of interdisciplinarity. We can nearly state a law, especially valid for European countries, which the answers received would suggest is also meaningful for the United States, Canada and Japan:

The ability a university activity has to get organized as an interdisciplinary activity is inversely proportional to the length of time since this activity has made its appearance in the university system, and directly proportional to how recent it is and to how much resistance there is to its being accepted as a repository of knowledge. That is not surprising, moreover, for interdisciplinary areas now accepted, such as social and city planning, engineering sciences and business administration, were first admitted as adjuncts to disciplines considered basic, and then as integration points for specialities before becoming fully-fledged parts of the university.

Finally, on the basis of the number and nature of the disciplines which have been regrouped, it is exceedingly difficult for us to sift out what is multidisciplinary. The survey simply shows that having too many disciplines at the same time is illusory, resulting is simple juxtapositions or in highly traditional ideas about general education. We never came across groups working together to organize curricula and prepare courses when there were too many different people and specialities involved.

Section 3. ORIGINS — MOTIVATION — GOALS

THE WEIGHT OF CULTURAL TRADITIONS

The foregoing breakdown of the results has defined the fields for interdisciplinary activity and distinguished between those dealing with general education, professional training, training for researchers, and applied and basic research.

In some ways, these fields may be also thought to be goals since they indicate what kinds of results interdisciplinarity is aiming at. Yet these categories are far too superficial, so that to understand what change from the standard goals of the university is involved, and to make even a qualitative evaluation, it is necessary to come up with much more precise dividing lines. Unfortunately, the answers obtained from the questionnaire do not make it easy to distinguish how much is due to the origins of interdisciplinarity, how much to the motives which may have led to it, and how much to what are real goals. At times this reflects a partial overlapping of concepts and a confusion in nomenclature among those answering, but it also brings to light a series of facts which the questionnaires scarcely guess is there. It is drawn up and itemized on the basis of extremely tight definitions granting a very small role to the daily process of hammering out the details of interdisciplinarity, to real conflicts, to wavering and faltering, to shifts and changes in goals. Furthermore, the notion of goals often enough proves inadequate, reflecting *a posteriori* rationalization. Concrete working conditions and events have more impact on what research or teaching program is set up than *a priori* goals, however well defined beforehand.

When discussing regroupings, we used the term chance encounters : an encounter between people, a matching up of interests, a conjunction of different centers of interest within a single individual. One particular instructor happens to be both a specialist on the Russian language and a professor of philosophy, and hence will undertake to study Soviet philosphy using the dual approach of language and philosophy. This particular example, which comes from France, was helped by the institutional requirement that students in the history of philosophy also study texts in a foreign language. We could offer numerous examples which serve to demonstrate the real influence of interpersonal relations among the faculty, cultural habits and the traditions of different school systems which may account for otherwise incomprehensible regroupings of disciplines. One case would be a psychologist who becomes interdisciplinary by moving towards biology or mathematics because he is trying to drift away from philosophy or the cluster of so-called social sciences to which he was traditionally yoked in the university system. A contrasting case would be a psychologist who discovers interdisciplinarity where logic joins epistemology, having been kept away from it by departmental divisions which had stuck him in with biology. So along with the burden of university traditions, we again encounter the critical, virtually polemical aspect of interdisciplinarity. Teachers and research workers are seeking not only to escape from their isolation into disciplines, but also from certain kinds of binds and connections. An historian who moves into economics is perhaps showing what he thinks of Latin epigraphy just as much as he is trying to develop his range of competence. So it would often become necessary to define one sort of interdisciplinarity in terms of its starting point and another as an end result. Naturally, only the second type should be considered genuine. A future doctor finds it natural to pick up material from biochemistry, but discovers or has the feeling he is discovering interdisciplinarity when he comes into contact with psychology or sociology.

We should therefore like to emphasize that the origins of interdisciplinarity are to be found in cultural and intellectual traditions. Although we found that in the United States the preponderant goal was general education, itself subdivided into the objectives of personal and social development, whereas in Europe most lines of argument in favor of interdisciplinarity stress the aspect of intellectual and scientific development, that does not mean that there is a contradiction between these two conceptions of interdisciplinarity but only that each is striving to demonstrate, within the context of its own system, that the answer it is providing to the needs in teaching and research is better able than the previous system to meet the needs that the university has accepted the responsibility for.

In other words, interdisciplinarity as it appears in the questionnaire very often is used against the old patterns in which the university functions and at the same time revives the goals for which it functions.

Perhaps some aspects of this struggle may be noticed in the next part of this study, in which Mr. Jantsch's essay contrasts with those by Messrs. Piaget and Lichnerowicz. To be sure, these essays are intensely different as far as their contexts are concerned, but more importantly, they stem from separate cultural traditions, one based on the idea that the university is essentially aiming to foster personal and social growth, the other based on the idea that the university is aiming to develop knowledge.

ORIGINS

Thus we believe that special attention must be paid to the interaction between the *origins* (all the circumstances and social and university requirements which may have led to setting up an interdisciplinary activity), the *motivation* (all the intellectual and emotional needs and the concerns which may have impelled people to act), and the *goals*, since it is this interaction which perhaps best exhibits the extraordinary diversity in regrouping disciplines that troubled us a moment ago. We have not found any classification system which would encompass the immense multiplicity of facts. We shall consequently suggest several different ones. The first basically depends on analyzing the origins of interdisciplinarity. According to the evidence we have had to sift through, we think that interdisciplinarity can be connected to five distinct types of needs, all of which, however, sometimes result in relatively similar patterns of functioning.

1. The first type of need is connected to the *development of science* but there can be discrepancies in the forms it takes. The first impulse is to follow a pattern of increasing specialization, resulting in narrower and narrower fields, nearly all of which correspond to the intersection of two disciplines. This intersection serves to limit the object of examiniation but also makes it necessary to utilize a manifold approach. Depending on the case, or rather on how far work has advanced, those involved will at this juncture talk either of interdisciplinarity or of a new discipline.

This tendency interdisciplinarity has to serve really as the foundation for a new discipline has been observed by numerous correspondents, particularly in scientific fields, and in some cases it is even considered part and parcel of interdisciplinarity.

At times, however, they seem to think that this new discipline should continue to require experts trained in other fields. On other occasions, they merely make use of interdisciplinarity as a symbol of a state of crisis, and as the means to explode an over-rigid discipline when the time comes or to approach new fields of knowledge. Examples of this type are to be found in every country, but they do not seem to absolutely dominate the modern university scene since they follow a traditional pattern of scientific thought, the one by means of which most of the currently living forms of science came into being.

One variant form of the preceding case may be thought of as the conjunction between a given discipline and a particular application of it arising from technical progress. (An example of this would be teaching and research in space medicine in the United States, stemming from the development of the biological sciences and from the need to respond to the existence and particular problems raised by space flights.)

A contrary impulse shows up in that this diversification of scientific thought has been matched by an attempt to latch on to some common elements. This is manifest, first of all, in research which makes use of mathematics, but nowadays we are witnessing the much more widespread emergence of a number of concepts held in common by several, if not by all disciplines, such as those of structure, models, etc. *In this case, interdisciplinarity has a tendency to get replaced by transdisciplinarity.*

That results in particularly interesting situations whenever, by means of a contribution from linguistics, for example, we observe that literature, mathematics, the sciences of man, and the arts join efforts (Paris VIII). The interest in that kind of situation resides not only in the confrontation between highly divergent approaches but in the fact that each of these approaches is extensively altered by the presence of the other.

If forced to do so, we could assert that the introduction of the computer and hence of the possibility of processing the same material in different systems or different materials in the same language, is a kind of subproduct of the development in science towards a unitary language. The computer has made its appearance in a number of American universities, most notably at Harvard, and has given rise to major interdisciplinary projects.

2. Without any connection to the development of science, except perhaps inasmuch as it is a reaction to this development, we should emphasize the importance of *"student needs"* (in the United States, Canada, France). At times these needs take the form of real pressure, while at others they are merely anticipated by faculties who strive to satisfy them.

Most of the time, this involves protesting against any parcellization and artificial division of a reality which is considered to be necessarily worldwide and multidimensional. In some European countries, this protest is deepened by also being a reaction to the characteristics of a notably irresponsive kind of secondary schooling which on occasion chops up disciplines even more strictly than the traditional university does.

In this context, interdisciplinarity shows up as a symbol of "anti-science", a return to a prior experience that it is certainly worth analyzing provided its basic unity is not overlooked. Discovering that even scientific propositions have political, economic and sociological repercussions hence leads to a form of interdisciplinarity. Obviously that does not imply integrating disciplines but rather making them complementary and really getting hold of the objects which each discipline sets out to study.

These student needs are never mentioned alone in the answers we received. They are a major theme in a large number of reports and allow us to better understand how closely interdisciplinarity is linked to the various innovative efforts being made in response to the present-day crisis in the universities.

Furthermore, faculty teachers and researchers have similar expectations, which should not be obscured by being put on the same level as student needs. Within the special area of their work, the faculty needs to meet "those on the outside", even if they are not aware of the short-run benefits and increased knowledge to be obtained from this. Younger teachers, research workers, and so forth are particularly likely to have this requirement, which consequently becomes a common source of friction, on the issue of interdisciplinarity, between the senior professors snugly established in one homogeneous discipline and their assistants who are far more concerned with getting in touch with other disciplines, even if their own work is temporarily slowed down as a consequence.

3. The previous case must be carefully distinguished from

interdisciplinarity arising from *the need for professional training,* even though the latter often gets expressed as a student request.

The word "expert" takes on different meanings depending on whether it is used on or off campus. At a university, a person is an expert because he works in a single discipline or one small aspect of that discipline, whereas in professional life the expert is nearly always the man who is able to connect up several different approaches to the same reality. A person would not be a specialized psychologist but rather a psychologist for business or for schools or would do psychotherapy, in other words, the person would be able to connect business management, pedagogy of medicine to his knowledge of psychology.

In most universities, saying that one is dealing with the concrete conditions of professional life does not mean that one is directly involved in preparing people for a trade. In other words, the reference to professional life is not quite identical to the third category which we set out in discussing the interdisciplinary scene, when we stated that some interdisciplinary activities are directly linked to specific professional training.

In some cases, whatever attention is given this training or whatever heed is paid to the day-to-day conditions of the profession, it is brought about by a definite contract made between the university, department or team concerned with interdisciplinarity and a definite need coming from either a particular agency or specific need in the environment. We have available some well-documented instances of this kind, the most typical one being the University of New Brunswick, where an entire bevy of activities centers around the study of swamps, their geology, particular geography, different technologies making it possible to drain them, and even how to build different contraptions used to drive through the swamps and to help to drain them. This case exceeds the limits, in a way, of what truly constitutes training for professional practice and becomes part of a fourth category, that of original needs in society.

4. By *original needs in society* we mean those situations which have cropped up relatively recently in which either all of society or some smaller area, such as the immediate area surrounding the campus, the city, region or country, suggests that the university study new topics which, by definition, do not fit into any of the already existing disciplinary frameworks. The most striking example of this is probably environmental studies. In most countries of the world, the evils caused by industrialization or by unruly and thoughtless expansion into new territory have brought about a new awareness of the necessity to make a fresh analysis of what is involved in human ecology and to work out some of the scientific principles of that ecology.

Some examples of institutions which have arisen to meet this issue are the University of Wisconsin Green Bay, the Center at the University of Rennes in France, as well as some interdisciplinary experiments in Canada, Japan, and so forth.

On the same level with environmental studies are urban studies, which in many ways are similar to the former, as far as planning, business activity studies, etc. are concerned. In both cases, the possible number of disciplines involved is obviously practically infinite, and scientific, technical, legal, psychological, sociological and overall considerations on the very conditions of human existence and the concrete needs for any given society, all have their place in interdisciplinary programs. There are, however, two sorts of answers to such original needs in society. In the first case, interdisciplinarity appears to be a substitute for general education, which from the very outset of undergraduate program, using one particular theme such as the environment, would try to form a new general culture similar enough to that of the Liberal Arts College.

In the second case, on the other hand, interdisciplinarity is seen as the end result after specialization, such that work and research groups bring together, at the graduate or post-graduate level, students who have already been trained in biology, sociology, architecture, medicine, and so on.

It would seem that this latter solution, which used to be the more common type, is slowly giving way to the first type, for most of those answering the questionnaire insist on how difficult it is for them to start with people already competent in a purely monodisciplinary framework and then to evolve towards a dialogue in which they relate and take into consideration the technical and scientific requirements of other sciences.

5. We should mention a fifth possible category, which is not often found but nevertheless does show up in some universities, that of needing to practise interdisciplinarity as it relates to *problems of functioning or even university administration*. The relatively important facilities in the research centers, along with the need for universities to manage their own budget and in some countries to sign contracts with a large number of agencies makes it necessary for the heads of different departments to get together and for the university as a whole to administer its budget as economically as possible. Very often, this occurs, as we mentioned above in another context, when a computer is brought into use or when some contract is signed with a government or a research organism which leads one university team to contact another with a view to undertaking some common task. Such problems involving management and the sharing of resources are especially interesting because, in this case. interdisciplinarity is directly connected to the issue of reorganizing and restructuring the institutions of the university system. Once again it is rather rare for us to find that this category, or at any rate, a program practising this category, fails to develop into a form of interdisciplinarity which goes beyond its purely administrative origins and tackles problems which are more scientific or which concern the general education of students and research workers.

We do not claim that our classification system is exhaustive, much less the only one conceivable. We merely hope that a number of phenomena will be brought to light by means of it.

a) In applied fields (general education, professional training, training researchers, and so forth), this classification system is woefully inadequate, and requires far subtler and more complex breakdowns. If a program in general education is tied to scientific needs, activities involving instruments will be observed to take the limelight ; if tied to student needs, self-expression. group communications, and interpersonal relationships will get talked of, even far from any traditional disciplinary framework ; if tied to profession requirements (decision strategy), or to the emergence of new social demands, yet other patterns occur. (For example, city planning requires practising the techniques for conducting surveys and learning to listen to others. Similarly, teaching mathematics in a developing country at times requires that the teacher have some background in ethnology and an ever-alert sensitivity to cross-cultural differences.)

We might start out all over again to draw up a new outline for each of the fields identified in our geography of interdisciplinarity. Even research as a privileged field of application is better able than a need of science to reflect the growing demand among students to transform the university from a place at which knowledge is transmitted into one at which knowledge is produced. The interdisciplinary structure would be different in each of these cases.

b) Emphasizing the disparity amongst needs perhaps makes it possible to grasp how astonishing the variety of regroupings is. Except when the initial definition of the problem is that of wisdom, *everything is in fact possible* and legitimate. Someone who sets out by studying the problems of environment also needs to know property legislation as well as snippets of chemistry and human ecology. Likewise, a doctor who in practising his profession, prescribes remedies, grants patients sick leave, should be aware of the economic repercussions of his decisions, especially in nations which have set up health insurance programs. In other words, at the level of interdisciplinarity and especially of pluridisciplinarity, none of the regroupings which we mentioned, no matter how surprising, is beyond the pale of possible official recognition.

c) Looking at origins is often the easiest way to draw the thin dividing line between true interdisciplinarity and pluridisciplinarity. It is clear that the search for a single language for all science, and student demands for making teaching systems relevant to their immediate experience may well lead to combining forms which are more basic than polyvalent declarations of intent or agreeing on the necessity to make good use of computer time.

d) Real patterns have also led to setting up an interdisciplinary situation within which one can understand why, with apparently identical goals, apparently similar organizational methods, and comparable curricula, we have come up with enormous differences from one questionnaire to another. At the same time, we are induced to doubt the entire approach to the problems of interdisciplinarity. There are practically no experiments which have been conducted on interdisciplinarity alone, whereas there are existing experiments dealing with the needs of science, individuals, society, and of the university, all of which end up rather quickly encountering the issue of interdisciplinarity. For interdisciplinarity is the lowest common denominator of innovation, without necessarily being its starting point.

Motivations

Except in the mind of planners, the true starting point for innovation is very often merely the conviction that any professor has experienced since beginning his studies, namely, that any particular concept or group of concepts ought to help shed some light on all knowledge or reality. He therefore bears a long-standing resentment against the teaching he himself was subjected to, which never really amounted to culture, and is familiar with the ups and downs of research projects which result suddenly in the need to borrow some concept or method from another discipline. Perhaps at times, without being able to admit it, he feels a desire to be successful at practising two divergent scientific interests.

It is hence a risky business to want to draw up a list, much less to imagine categories. Various independent or connected themes show up repeatedly in the answers. Sometimes we find motives which deal with student needs, while others express the needs of those instructors who filled out the questionnaires, and others are connected to the requirements of the entire university system or are even tied to an intellectual conception or some more or less accurate definition of the scientific field in which a group intends to work. We are indulging in the somewhat finicky exercise of reporting a few of the motives which seem to us to have been expressed in the answers because we are convinced that each case reveals different combinations, different patterns of integration along disciplinary lines, and even a different value given to interdisciplinarity.

Once this list is set up, we shall attempt to justify this multiplicity by taking a closer look at two or three sample universities which offer the advantage of having provided us with several answers coming from different groups.

1. *Motives dealing with student needs*

- Practising interdisciplinarity (on the undergraduate level) makes it possible for students to change their major field without losing time.
- Practising interdisciplinarity makes it possible for students to adjust to inevitable fluctuations in the job market.
- Practising interdisciplinarity creates possibilities for careers in new fields.
- Practising interdisciplinarity makes it possible for students to continue to remain interested and curious about their work, and they are more highly motivated as a result of feeling that the subjects they are studying are relevant to reality, and as a result of sensing the newness of the subject and the chance to have more enriching personal contacts.
- Practising interdisciplinarity educates graduates with a more inventive bent of mind.
- Practising interdisciplinarity emphasizes concepts and methods more than subject content, and thereby makes it possible for students to learn to handle instruments and to become more creative.

2. *Motives connected to the needs of teachers and researchers*

On several occasions we have already referred to how much importance we give to professors' personal interests. Looking through the questionnaires, we notice the following motives, which are often expressed with great vehemence :

- Finding a human solution to the issue of growing specialization, which would lead in fact to increasingly superficial knowledge.
- Learning to work towards the attainment of common goals starting with different viewpoints.
- Discouraging individuals from undertaking isolated tasks.
- Opening up new fields of knowledge and making new discoveries possible.

3. *Motives connected to the requirements of the university system*

These motives were particularly strong in those European countries which have relatively old or rigid structures, such as France and Germany.

Interdisciplinarity appears to be a means to blow up from the inside the barriers and obstacles to communication in the university, and to break down from the outside the sharp dividing line between knowledge and reality, between the university a..d society. At times such motives were voiced bluntly in terms of finding contracts, stirring up interest from local authorities, and so on.

4. *Motives connected to scientific interests*

They are manifold, and can be grouped in contradictory pairs:

— Broadening the field of knowledge ; making it possible to narrow it down by using multiple and convergent approaches.
— Emphasizing the unity among phenomena ; showing how varied they are.
— Becoming able to create a theoretical basis for the discipline being studied ; becoming able to apply it concretely.
— Making specialization possible ; forbidding specialization, etc.

Perhaps it is at that level that both the expectation concerning interdisciplinarity and the ambiguity of this exception come out most clearly. Such a kaleidoscope is yet more apparent when any one university is looked at. We shall take Paris-Vincennes as the first example since we received a relatively large number of answers to the questionnaire from them. The Centre at Vincennes (which is nowadays called Paris VIII) is an experimental campus created in October 1968 as the first application of the so-called Law of Orientation which was drawn up at that time by the French Ministry of National Education. This campus is essentially a center for studies in the humanities but nevertheless includes a number of scientific activities, such as computer techniques, mathematics, fields traditionally handled by the Schools of Law, Economics, Political Science, and Juridical Science, as well as a goodly number of activities which up to that time were totally absent from the French university scene, such a departments for art, theater, plastic arts, film-making, psychoanalysis, etc. The various answers to the questionnaires make clear how different or even contradictory are the practices, and, more important, the definitions and motives behind interdisciplinarity. Two instances of integration between mathematics and psychology are given, for example. In one, the purpose of connecting up disciplines is to facilitate the use of models and methods of mathematical formalization in order to solve problems of basic and applied research in psychology. As a result, the purpose is to make it possible for a given science to advance by offering it more rigorous methods. On the other hand, in the second instance, the underlying motivation is tied to the fact that the traditional teaching of mathematics does not allow for meeting the needs of psychologists, which results in the necessity to set up a program teaching statistics in a way which relates to the problems and methodologies of psychology and therefore makes it easier for students to assimilitate the statistics material. In other words, it is not a matter of using outside scientific formalism for the benefit of psychology, but of meeting immediate needs head on, even if that implies adjusting some aspects of statistics methods.

The Music Department considers interdisciplinarity to be the way to rejuvenate teaching and research in music by exposing them to living music and creativity. It deems it necessary to break with the "prerequisite theoretically-oriented knowledge so characteristic of existing musicology institutes", such that this break can only be accomplished by ceasing to isolate the field of music from its context, surrounded by mathematical research on one side, and on the other by a sociological acquaintance with the culture welcoming musical creation.

The Department of Theater Studies considers that its purpose is to meet the growing needs of a leisure civilization, which are connected to various aspects of cultural life, and therefore this department uses research and experimentation in different techniques for broadcasting culture, with a basic attempt to go beyond theater techniques and to reach towards knowledge of the social sciences, humanities, linguistics, and so forth. Finally, other examples can be found in city planning, where Dr. Laborit is trying to use biology as an approach to city planning, particularly by using the conviction that the biological concept of structure is the only concept allowing for a total account of existing phenomena, especially in human ecology and cultural life, and that this concept is perhaps the single most important part of any intellectual education. We should also examine the answers provided by historians who are seeking to set up a program in cultural history, which up to the present time has rarely if ever existed. An attempt will be made to give rise to what will be called "a militant culture", that means, to a type of involvement in society based on knowledge of the real situation and which is at the same time oriented towards knowledge production and motivating students much more than towards teaching. Yet other attitudes are to be found in a center for Latin American studies, reflecting an image of interdisciplinarity which is perhaps more traditional since it calls for connecting up the various historical, geographic, literary and economic approaches to the same objective reality. And yet again in the Department of Slavic studies, where more than history and economics are being called upon to help study authors or the linguistics related to the various Slavic languages.

When we study closely the 7 answers coming to us from the University of Tokyo in Japan, we once again encounter the same disparity. To be sure, the university involved is far older and has a larger student body, and naturally the scientific disciplines play a larger role there, but there is at least as large a number of different motives behind interdisciplinarity.

These include: developing love for truth and preserving individuality among students; making it possible to have more thorough research in some fields; opening up new fields of scientific activity; developing theory and giving the feeling of applying it to concrete issues; training more highly qualified teachers able to engage in information exchanges among themselves; increasing original scientific creativity; developing critical activities on subjects in the modern world which are relevant to Japan's place in it; increasing synthetic thought. These are the various requirements which we find expressed in all these questionnaires, and which in a quite different fashion and one which perhaps emphasizes much less than at Paris-Vincennes the idea that the traditionally self-enclosed disciplines must be cracked wide open, offer basically the same sort of diversity.

Goals

We should like to suggest a third way to categorize issues, drawn, moreover, from Mr. Godin's report, and which in this case deals with neither the origins nor the motivation, but rather with the goals involved. (In point of fact, if we wished to adhere to a strict nomenclature, we would consider this term inadequate, for in proper analysis, a goal gets expressed in terms of the resulting behavior. We therefore ought to speak in terms of the object of interdisciplinarity.)

One approach to setting up an interdisciplinary program starts out with a "university" type criticism of knowledge. Basically this involves exploring the frontiers of disciplines and the intermediary zones between disciplines. Another approach has interdisciplinarity stem from the determination to make university activities respond in a new way to the socio-professional or economic needs of a given country. In view of the growth of industrial societies and their need to train versatile personnel with broader and former educations than that overspecialized technicians received, the University ends up founding a new type of interdisciplinarity, either by establishing permanent adult retraining programs or preferably by including in its initial course offerings a wider variety of activities. Finally, a third approach is based on the opportunity of having research or an object outside the university, thereby bringing a productive function and the dimension of a kind of professional practice to the campus, which will catalyze teachers and students to succeed in highly variegated activities and areas of knowledge connected to the particular project.

It can be noted that this last classification is absolutely distinct from the preceding ones (the geography of interdisciplinarity, origins, motivation). Using some thought about professional practices and trying to increase student mobility, one can readily end up wondering about knowledge as it is being dispensed within the university system and taking a hard look at real life problems and teaching methods involving specific projects. In other words, whatever approach to problems is used initially, whatever the details of the rise of interdisciplinarity in any particular laboratory or university, whatever emotional drives or needs are being satisfied, the specific kind of practical application of interdisciplinarity seems to be independent of its chosen object. On the other hand, for the three groups of approaches which we have distinguished (Origins, Motivation and Goals), we can observe a number of clearly overlapping propositions.

1. Those who use interdisciplinarity as the means and expression of criticism from within of knowledge tend by and large to make remarks on the theme of substituting sought-after truth for transmitted or learned truth. Interdisciplinarity shows up as another way to raise an epistemological issue, and it makes it possible to break down those narrow barriers separating disciplines which merely reflect administrative or school decisions.

"Disciplines already have their object picked out, and their narrow dividing lines are designed to match the requirements set by school inspectors, which means they follow job opportunity patterns in the secondary schools..."

"Disciplines are not formed as a result of their natural growth but in accordance with administrative categories."

Interdisciplinarity likewise gets us away from the pseudo-ideology which holds that knowledge is independent from other branches of human endeavor and even the various branches of knowledge itself are independent from one another. In that sense, in Japan just as in the United States or in France, and whatever the primary intentions of its instigators, interdisciplinarity is a *political critique* of knowledge. "It is necessary", as one professor of economics put it, "to free the teaching of economics from its ideological bondage,... to supply scientific explanations for economic realities... Obviously any investigation which restricts itself to the economic field can be fruitful only within a framework of pure economic rationality... On the other hand, any truly scientific investigation, which means one which takes it upon itself to observe, describe and explain s ocial reality, must necessarily take into account relationships between its particular field of study with the remainder of reality".

The makeup of disciplines is hence thought to be the outcome of a dual approach which is purely empirical as far as knowledge is concerned, and purely ideological in practice. This results in pigeon-holing any understanding of the goals of teaching, in causing a gulf between transmission and discovery, and in artificially and almost voluntarily limiting inventiveness to pre-established closed-off fields. That is especially true for the social sciences. Whether a literary work floats around in a paradise of universal beauty, whether there are psychological processes as such, or whether a civilization is merely the *a posteriori* sum of a whole set of works, mechanisms and independent trends, are so many ideological postulates which have bearing on reality as well as on knowledge.

"Understanding... Etymologically this is an interdisciplinary word... Making things understood by putting in the right perspective the common denominator of all disciplines — the structural laws of life."

"We do not see any precise dividing line between research and teaching. Interdisciplinarity stems from our needing to understand and know."

"New structures can only be discovered by joining, crossing or reorganizing earlier structures coming from various disciplines." The result is a resurgence, under the heading of interdisciplinarity, of the old myth of reconciling knowledge and reality, which sometimes gets expressed modestly as the continued exploration of different realms of knowledge : 'To explore the between-areas of specific disciplines of traditional scientific division' and sometimes spreads out dangerously towards attaining limitless absolute knowledge and truth which can be loved unconditionally. (A few questionnaires from the United States and Japan, one from the Netherlands.)

2. In the second view, which calls for a new alignment of teaching and research activities to meet professional needs, most answers are based on the determination to put an end to the sharp division between the university and society. Before making any specific remarks, we cannot resist comparing this concern with the previous one dealing with the gulf between knowledge and reality. This is all the more striking in that many people are convinced that professional practice is the best way to readjust the university system to handle real life problems.

This search for a way to adapt teaching to professional activity is a long way from having a uniform ideological meaning. For some people, the requirements of modern economies should be met head on :

— "Training competent personnel"
— "Supplying executives who are more comfortable with science and modern society..."
— "Suggesting research to study man, which of necessity must be interdisciplinarity if it is to be effective".

— "Offering an alive teaching program tailored to the realities of social activities"
— "Reorganizing fields of knowledge in order to direct them towards solving problems". (In almost the same words, this phrase showed up again in several Canadian replies.)

For others, on the contrary, criticism of the "failure" of technicians and the overly rigid and narrow practices in which even professional groups engage will lead people to consider working out new training routes which may likewise serve as harbingers of future professional patterns. "Our goal is a practical one—supplying society with trained personnel capable of studying a report on city planning carefully", according to those in charge of the Centre d'Etudes Supérieures de l'Aménagement (Centre for University Studies of Regional Development) in Tours, France. Yet at the same time, they come around to recognizing that the need has not yet been expressed by society and as a result they are striving to hammer out new professional practices.

This example has not been chosen at random, since more than one interdisciplinary team can be found in Germany, Canada, Great Britain or the United States to be working on the problem of training (we are tempted to say inventing) city planners, or even more generally, specialists in human ecology.

This latter process, which at times anticipates a need which no professional organization has got around to expressing, often corresponds to teaching programs based on a theme or some geographic or historical subdivision : studying the Nord Department in France (Lille, France), the shores of Hudson Bay (Laval, Canada), Center for African Studies (Germany), Center for Southeast Asia (Japan and the United States), Latin American Studies (Hamburg and Paris VIII).

In each case, the viewpoint is obviously an interdisciplinary one, but it is achieved only by the combined simultaneous efforts of teams of specialists coming from different theoretical or methodological horizons. (Isn't that pluridisciplinarity ?) Instead of searching for more and more basic structural levels, which would mean creating new "interdisciplinary" disciplines answerable to that critique of knowledge, a kind of involvement crops up which is scarcely distinguishable from the ordinary practices of pluridisciplinarity.

3. Last but not least, for this is at least mixed with some of the foregoing examples, which have regroupings according to both geographic area and theme (University of New Brunswick in Canada which has a study of swamplands) interdisciplinarity can be set up around some *mediating object*[1] outside the university but often involving a laboratory, department or series of departments which takes charge of a public or private research or education contract. In such a case we can speak of the teaching methods for the "project", which joins together research and teaching, teachers and students both pitchi _ in to solve a problem.

In this event the university, as was stated earlier, takes on a genuine role in *production* in the standard sense of the word, and this new role usually shows up in both structures and interpersonal relations. The traditional form

1. This expression is borrowed from Mr. J.G. Godin.

of the department, with its hierarchy of tenured professors, junior faculty and students, is blown apart by the requirements of the job, so that it is in just such circumstances that the most striking institutional changes are to be found.

"Practical applications are stimulating and create the need for theory", as one of the documents put it. They also call upon people to question the university system, tenured chairs and ingrown laboratories just as much as they do the issue of students and young research workers not being allowed to participate in the decision-making processes.

Let us now imagine how the various classifications which we have outlined in turn might be combined in a single pattern :

- classification by field of application,
- typology or rather general principles for regrouping disciplines,
- classification by original approach to the problem,
- classification by explicit or implicit motivation,
- classification by "specific object".

One readily recognizies how wide a variety of forms interdisciplinarity takes on in actual application. This is particularly true when one bears in mind that virtually none of these categories excludes the others, and that when teamwork occurs, each member introduces his own concepts and aspirations within the group. If we wished to abandon the overall patterns and give an account of the actual practice of interdisciplinarity, we would therefore be forced, even after eliminating a large number of answers on the grounds that what was labelled interdisciplinarity was nothing more than the mere juxtaposition and coordination of disciplines, to make a survey of all the small islands that remained and try to respect the distinctive features of each of them.

We shall pass up such a wearisome process, and once again paint a quick picture, based on specific examples even if we do not refer to them directly. This time, however, a series of "case studies" will follow.

Section 4. THE APPLICATION OF INTERDISCIPLINARITY

INTERDISCIPLINARITY : STARTING POINT OR CONCLUSION ?

We think it is not worthwhile getting bogged down in details on the size of interdisciplinary centers, the number of faculty or students involved in any one activity, or the university level at which it is being done, provided three basic and in this case exclusive attitudes are clearly indicated.

- Interdisciplinarity may be thought of as the final outcome and crowning effort of some systematic educational program which in turn should be uniform, very specific at the outset and adhering to a single methodology. Interdisciplinarity is considered valuable only at the level of specialization, and is therefore limited to researchers, or at the very limit, to upperclassmen. Sometimes it is specified that it would be dangerous, superficial and alien to real needs if it were offered to beginning undergraduates.
- Others, on the contrary, deem interdisciplinarity the key feature of introductory education. This argument nearly always runs along the same lines as the previous one. Monodisciplinarity would be

dangerous, superficial and alien to the need of beginning undergraduates. Interdisciplinarity comes before specialization, and can take the form of a common program of required courses, such as that of most engineering schools, one medical university (Turkey), and the study of preparatory documents (Marseille-Luminy), or it can be an elective system where adjustments are made according to "the demand".

— Finally, some people think interdisciplinarity should be present right though an entire university program, being inherent in the very nature of knowledge and an elementary requirement of any education.

INTERDISCIPLINARITY AS A CONCEPT OR AS A CONTROVERSIAL PRACTICE

The three foregoing options clearly do not merely reflect intellectual differences of opinion, but obviously stem from underlying contradictory definitions, and also show distinct ways for people to express opposition to different university systems (cf. Introduction).

It is often presented as a set of opposites, as a universal answer to "what, within the university, stands for boredom, routine, rigidity and tradition" (J.G. Godin).

By making partial use of the initial breakdown of the questionnaire results made by Mr Godin, we find we can work out the following antinomic table for the "old universities", particularly those in Latin countries and, with the exception of the United Kingdom, in Europe generally.

	Traditional University	Interdisciplinary University
Teaching	school-boyish abstract	lively concrete
with the aim of	knowledge	know-how
transmitting	old knowledge	rejuvenated knolwedge
applying the teaching method	of repetition	of discovery
emphasizing	contents	structures
teaching based on	passive acceptance of a final academic subdividing of knowledge	continual critical and epistemological reflection
the university	stuck in "splendid isolation" and setting up a kind of knowledge which kills life	overcomes the gulfs between university & society, knowledge & reality
It requires	a purely hierarchical system and a rigidifying syllabus	restructuring based on how the institution works on the whole
It favors	isolation and competition	collective activity and research

The preceding paragraphs, which called for fresh thinking on the aims of the university, for criticism from within of the separation into disciplines, and more or less directly for revising the relationship between town and gown, must be amended, therefore, by establishing a new "practice" of university work in teaching and research and by founding a new pedagogy.

Before introducing these tersely, we must nevertheless recall that the foregoing table far from demonstrates the full picture, for it is possible to have interdisciplinary formalism just as well as disciplinary innovations, and especially, this Manicheism is much more noteworthy in the United States and to a lesser extent in the United Kingdom than elsewhere in Europe or, it would appear, in Japan.

Although all the American answers agree on the fact that interdisciplinarity makes it considerably more feasible to adapt teaching and research to practical applications, to take closer account of student drives, and in some cases to stimulate them, there is much less emphasis there on altering hierarchical structures — since they are on people's minds less —, on breaking down individual isolation, and especially on setting up innovative teaching methods. Depending on the situation, a major professor either prepares his courses by himself or works them out with a group of assistants or collegues, often enough with the help of the students themselves. But as those who wrote in indicate, that depends more on their personal work habits than on whether the subject involved is interdisciplinary or not. (Cf. the report of Dr. Abt, *op. cit.)*

Even if it appears that "small" heterogeneous groups" are more common whenever the subjects are interdisciplinary, that only reflects a specific university tradition which has only recently begun to show up in Europe.

COMMUNICATIONS AND PEDAGOGIES

One American institution states explicitly that the failure of an earlier interdisciplinary endeavour was "30 %" due to a slow elevator linking up the various floors on which the different disciplines were housed. We hope that was a mere witticism, but it nonetheless expresses how much weight direct interpersonal relations have, how important the number of communications (and hence the amount of available time) and qualitative ability to communicate are.

"...not only new pedagogy, but new school systems, with horizontal, instead of vertical differentiation, new curricula, new teaching methods, new role definitions. That means, interdisciplinary education should be due to new education goals. The adequate pedagogy would be of a more creative and emancipatory character." Professor Sandner, Latin-American Studies, University of Hamburg.

"Since interdisciplinary teaching should result in structures and not only in the engramming (storing) of content, a new, particularly vigorous pedagogy is necessary which will give students a major role." P.H. Laborit, Biology and City Planning, University of Paris VIII (Vincennes).

If it is hard to get an instructor or research worker out of his own private and protected area of competence, one can imagine how much resistence there is to introducing the practice of a dialogue.

In Nijmegen, the Netherlands, a single person at the university level runs and coordinates proposals for curricula, where this post of "orchestra conductor is important". In Ghent, Belgium, it is the virtual absence of rules and hence of requirements which makes it possible for the research group on "the study of cognitive and communications processes" to function well. Very often it is a single teacher working all alone who, either because he prefers it that way or because there is a shortage of personnel, handles interdisciplinarity. That is certainly one way to deal with the problem of communication but carries the risk of not changing pedagogical relationships much. Last but not least, some of the broadest teaching solutions are actually designed to make things take a multi-disciplinary direction.

"I think the trend should be towards an elective 'cafeteria-style', which means that students should be given the widest choice possible in setting up their programs and deciding upon their intellectual activities. Hence the importance of on-the-job trainee periods, discussion groups, reports, team projects, and so forth" (CESA, Tours).

The "innovation complex" shows up here once again. Should interdisciplinarity play a central role or be tacked on, should it be a goal or an alibi, should it be a long-range target or a starting point? What is clear, however, is that the moment the disciplinary framework is broken, the notions of "competence" and of "private field", which used to typify tenured faculty, are given a good shaking at the same time. When other teachers, and almost inevitably students are invited to cooperate on a task, the student-teacher relationship is fundamentally altered, and a *dialogue* is brought about when a purely "dual" situation is eliminated.

For any particular case, if the very core of the way the problems of interdisciplinarity are defined does not obviously imply setting up a new communications network, more active teaching methods and a new student-teacher relationship, it would appear from the foregoing observations that we consider the amount and quality of exchanges between teachers as well as between teachers and students to be criteria relevant to deciding whether to accept or reject the idea that we are dealing with an interdisciplinary endeavour.

CASE STUDIES

It would certainly be fairest to make very close factual analyses in the area of pedagogy. We have agreed to take from our documentary material a number of sample situations (Sussex, Hacettepe, Green Bay...) which will fit easily into the structure of the third part of this book.

We shall therefore be satisfied with a few swift illustrations which offer a cross-section of the remarks from the preceding chapters, and although not an honor roll, selection or model, nevertheless provide a variety which seemed meaningful to us.

We think it is important to insert at this juncture a series of "portraits" which in a sense complete our *inventory*. Once we have gone over the obstacles and difficulties encountered, which unlike all the rest are strikingly homogeneous, we will once again, be able to raise the broad question of interdisciplinary activities in universities.

We shall not make separate comments on each of these examples, but shall confine ourselves to taking a random sample of characteristics to make it possible for the reader to discern common traits or, alternatively, to reinforce certain kaleidoscopic impressions.

In our selection we have practically eliminated all those activities based on the study of medicine (Vienna, Austria). It was extremely difficult for us to decide how much of such training is traditionally pluridisciplinary, since it involves ever-present professional training, as well as the activity which would combine readily with another program, nearly always done in a hospital context rather than on a university campus. The same goes for the training, strictly speaking, of engineers (in Ulu, Finland, a large number of instances in Great Britain, etc.)

Belgium

BRUSSELS, Avenue Jeanne 44.
Free University of Brussels. Sociology Institute.

A Research Center is involved which, in addition to the trainee program, in 1970 included 117 members within the scientific program framework.

The job of passing on knowledge is only a secondary role there, for the basic idea is to do research.

The Institute is divided into 6 relatively independent sections (sociology, legal sociology, civilizations, economics, problems of work, and spreading culture). If we take a close look at two of these sections, chosen at random, we see that they include the following centers :

— *Sociology :* Human biology, Sociology of Education, Sociology of War, European Sociology and Economics, Sociology of Organizations, Study of the social and professional problems of Technology, General Sociology and Methodology, Sociological Studies of Public Health.

— *Spreading Culture :* Study of Techniques of Community Broadcasting, Sociology of Literature, Sociology of Music, Study of the Arts, Traditions and Folk Speech Patterns, Study of Cinema, Radio, Television and the Theater.

The Institute gets involved in "multidisciplinary" activities whenever it organizes introductory courses. Each section is set up with a pluridisciplinary structure, within a relatively narrow field, and based on an *inventory* of problems rather than on any *joint use* of methods or concepts.

"Interdisciplinary at the Sociology Institute shows up in the efforts made at the research level... For example, the Center for the Sociology of Law and Justice has formed a *legal studies group* doing truth interviews, and judges, lawyers, psychologists and legal reporters have been working together on a combined study of the administration of justice." Furthermore, the staff of the Center has taken on its own "interdisciplinarity by demanding they be retrained in the new disciplines (cybernetics, data processing, structuralism, and so on).

To be sure, this interdisciplinary operation — the case is both exceptional and commonplace — is connected to the concerns of the man who founded the Institute in 1902, Ernest Solvay, but it also expressed the need to bring more "social authenticity" into sociological thinking and to take into account "complex aspects of the entire social order".

Interdisciplinarity favors "the appearance of new outlooks" and "the birth of new disciplines". By increasing "efficiency", it improves "the value and amount of study and determines an increase in the demand coming from the outside (applied research)".

This form of interdisciplinarity, based on needs and drives which are essentially scientific in nature, is propelled more by "borrowings" from one science to another than by "systematically induced combinations". Therefore *conjunctures, borrowings* and *interferences* are involved, increasing the need to communicate without managing to reduce the difficulties stemming from the fragmentation of jobs and individual timidity, and which would require "the birth of a new kind of research worker".

Canada

HALIFAX, Nova Scotia
Dalhousie University, Oceanography Institute.

The Institute is concerned with advanced studies (40 approximately) and has the aim of providing professional training for researchers and of doing research of all sorts. Five disciplines are included: Mathematics, Physics, Chemistry, Geology and Biology.

The Institute is reponding to the social need to produce professional oceanographers who can be employed in Federal and provincial universities and laboratories, but what is actually involved is training a kind of unique specialist to match a unique science, even if it is derived from basic sciences.

The body of descriptive knowledge is perfectly separate, and the applications of certain physical principles in particular to the theory of fluids are unparalleled. The same is true for certain research in basic biology. But above all, oceanography is *necessarily* interdisciplinary when it comes to its bearing on ecology.

Hence it is not the fact that interdisciplinarity exists that determines what kind of communication is involved, what motives push towards combining knowledge and research, or what model or basic knowledge such and such a discipline employs. Rather it is the unity of the scientific object which underlies all the rest, and indicates what new concepts and new methodologies are called for. (It is therefore not possible to speak of a simple intregration of methodologies as the questionnaire suggested.)

As far as communication structures and teaching methods are concerned, there is no problem. The latter follow the procedure for advanced courses, based on laboratory work and introductory research. However, since no specialist could declare himself "competent" in this area, except on some basic theory, very tight coordination is required at all times.

Communication lines are set up as needed, and depend on how closely allied are the research areas or the fields of knowledge covered.

As a result, once again the organization of knowledge (an organization which is *accepted* and *determined* by the nature or the object) serves as the foundation for the contact, transmission and mutual fertilization of knowledge areas.

FREDERICTON, New Brunswick
University of New Brunswick

"Muskeg Studies with some Emphasis on Environment".

Interpretation.

This Research Center engages in professional training as well as the foregoing fields of application. It appeals to students with highly varied backgrounds but who have all completed their undergraduate work.

At the outset, it tries to meet the specific need of the local society for studying all aspects of swamp lands, and must also manage to produce basic research, ideas for vehicles to be used where there are no roads, suggestions for using peat, and overall improvement of the environment.

The interdisciplinarity (and the Institute) arising from the volunteer interaction among widely varying specialists results in :

— "delineations of SYSTEMS understanding of which requires contribution from contrasting disciplines (not multidisciplinarity by definition).
— creation of inventory in adequate terms in order to manage environment, or to assist therein."

Therefore, engineering, biology, mathematics (computers and systems analysis), geology, agronomy, chemistry, physics and so forth were gradually added on. A very forward-looking and pragmatic approach results in the destruction of vertical structures (by disciplines), cuts back on the excessive importance of departments, requires a high degree of administrative flexibility, and makes it easier for industry to join in.

It is not necessary to set up special teaching methods, so long as the drives and spontaneity of the various faculty and student participants is recognized. The Center's productivity has come to regulate all aspects of its functioning, in relationships and management as well as science. The ultimate stake is *"the survival of mankind"*. That is perhaps what allows each person involved to handle on an individual basis the loss in prestige he may suffer in his original discipline or "sub-discipline".

QUEBEC
University of Laval
Center for Nordic Studies

The Center reaches about 150 students, juniors, seniors and graduate students doing a Master's degree, within a university of 14,000 students.

Its basic purpose is to train research workers and to carry out basic research. The fact that it meets the needs of a course of study concerned with the western shores of Hudson Bay does not mean, therefore, that the aim is to satisfy an immediate social need and to train professionals for a specific task in the outside world.

The course offerings include geomorphology, ethnobiology, zonal geography, climatology, archeology and linguistics, in other words, disciplines which belong to rather separate spheres of knowledge which intersect only in this instance.

The purpose of this research is to come up with an overall knowledge of the area, as a basis for recommendations to make the Canadian North more inhabitable. Since this program is for undergraduates and beginning graduate students, it is for most of them obviously only part of their course load, and is included in their studies only by accident. Interdisciplinarity is hence not an organizing principle of the whole curriculum, but is connected to approaching any particular "subject matter".

As an institution, the Center for Nordic Studies breaks down the restrictive framework of school divisions, and allows students to encounter friends who have chosen parallel paths elsewhere.

The Center's orientation towards the outside is also expressed by teaching methods which are original compared to normal universities, in that they are based on seminars and small discussion groups, which make it possible to form teams which are balanced out not only by different areas of knowledge but by "mental valences".

On the research level, interdisciplinarity seems to :

— cut down on financial and human investment ;
— "make it possible to reach the threshhold of general and normative knowledge (whereas monodisciplinary research is doomed to fall short of that)" ;
— cause overly specific and unintegrated research work to be dropped.

France

TOURS
University of Tours
Centre for University Studies of Regional Development

"Awakened into being by the events of May 1968", this centre strives to set up courses which are relevant to a living reality, and at the same time to cooperate in stimulating urban and rural development while training some of the personnel for this development.

Such professional training lays no claim to completing general education. Instead it is a part of it, and includes ecology, geography, physics, geology, sociology, economics and law, computer techniques, civil and rural engineering, and English language.

It therefore accepts enrolment from students beginning their university career, whether their secondary school studies emphasized humanities or science, as well as advanced undergraduates.

The interdisciplinarity involved has two parts :

One is a break

> "Geography professors leave their colleagues at the School of Liberal Arts, and science professors gladly divorce their colleagues at the School of Sciences".

The other is a union

> "For instance, we have paired off geology, geomorphology, hydrology and aerology to organize a course of study of the physical environment. In the same fashion, a course on the human environment involves human geography, economics and sociology."

Interdisciplinarity shows up at the curricular level, but it is especially experienced in the "laborious care" taken by the faculty in meshing their course offerings, working out the contents together, and matching up subjects so as to form a coherent whole.

All teaching formulas are used, as a function of the situations and people involved, with the general trend towards giving more opportunities to the students to exercise initiative.

"Each credit hour of course work ought to get students to consider the basic question : Are you happy ?, and a second question, Do you like the disciplines you are studying ?"

For the moment, research problems have been set aside and everything is being concentrated on the outlook in education.

"One can expect major companies involved in public works, city and regional governments, and developing countries to call upon them to join in and help plan important projects (building new cities, highways, rural engineering works), especially to work to safeguard the environment."

PARIS
University of Paris VIII (Vincennes)
Music Department

We have chosen to study this example, in a university which was created specially to be pluridisciplinary and to encourage interdisciplinary activities, not because it was more original than the other answers coming from the same campus, but in order to cover an area which the other questionnaires which we have chosen do not cover.

The Music Department is designed to prepare people to teach music in the secondary schools, but it accepts any one who is an undergraduate or beginning graduate student in another field, as well as research workers and sociocultural group leaders. 50 % of the students are confirmed musicians, while 50 % play music as a hobby or sometimes not at all. There is a not inconsiderable percentage of mathematicians amongst them.

The program takes in various aspects of music, mathematics, psychology, physiology, acoustics, philosophy, history and psychology. In addition to that, all students take at least one-third of their course load in other departments, on an elective system.

The department starts out by observing that existing Institutes of Musicology give no place to living music and to creativity, and it seeks to make a clean break with the *a priori* assumptions of *theoretically-oriented erudition* in these institutes, for the purpose of "showing that music is not, or at least is not *entirely* associated with a body of *knowledge,* and of showing that creativity is not, or at least is not entirely reducible to a *production.*"

Interdisciplinarity basically plays a role of "destroying old illusions, in that it makes it possible to throw out both the myths about handing down knowledge and those concerning the distinction between theory and practice. By "forming" fresh motives, by inducing a musical explosion by means of an intense flow of information, practices and people, the Department hopes to cause a complete change not only in the musical listening audience, but also in its performers.

Within this overall plan, several different types of combined teaching programs are offered :

— the epistemology of probabilities is combined with the physical training of musicians by means of a course on "music mathematics", in which "Markovian music" and transpositions based on the theory of Lewin fields are discussed in detail.
— electronic music is touched on by team teaching with the computer department and a seminar held in common.
— the psychosociological techniques of group leadership form the basis of six credit hours out of the 20 required by the program leading to a B.A. in Music Teaching *(Licence d'enseignement).*

— Last but not least, courses in ethnomusicology lead to contact with the sociological and economic issues related to the very existence of Music.

Entirely empirical methods of teaching are used, and the only rule is to change teaching methods as much as possible and to avoid the usual alternative pairs, such as theory versus practice ; concepts versus terminology, or learning versus creativity.

On the whole, interdisciplinarity is seen as complete an element for change as possible. "It is a radiating factor, which ought theoretically to banish all rigidity".

Federal Republic of Germany

University of the Ruhr-Bochum
Institute for the Sociology and Politics of Work

"The science of work is a research field which cannot be encompassed by a single discipline. It requires the participation and joint effort of several disciplines."

A Research Institute is located at Bochum. The research work done there matches the fourth category which we defined in distinguishing among the possible origins of interdisciplinarity.

Its aim is to establish a single theory for work, at the conceptual level, and to bring together as much sociological, economic and psychological information as possible at the data level.

For this reason, there is cooperation among many disciplines studying the same issue, including Sociology, Labor Law, Labor Politics, Pedagogy, Social Psychology, General Economics, and Business Economics.

By taking both data and the aim of a single theory into consideration, the institute has come up with rather varied types of work and combinations, with attention on both practical applications and on basic research.

"The Institute's goal is not to supply teaching programs directly. Among its activities... the foremost is finding solutions to certain practical questions. Some of the Institute's members are in charge of major courses at the University *in which the results of interdisciplinary thought are introduced.*"[1]

The purpose of interdisciplinary teaching and research is to look for the best solutions to practical problems. (In other paragraphs of the questionnaire, the care taken to avoid "erroneous predictions" is emphasized.) Those taking part find it clear that no single discipline can fully cover the fields of knowledge involved in one major problem.

The entire organization of the Institute is based on the idea of cooperation among disciplines, especially since the end result is an empirical theory "on arbitration procedures" defined by development models, and so on. In other words, "customers" receive specific answers.

The most commonly used method is the following : the representatives of various disciplines work up their own conceptions for each concrete problem, and then these are brought together to frame a common solution model.

---

1. Our italics.

This therefore shows an especially clear (and frequently found) model, which we are tempted to schematize in this manner :

— *a single, complex, concrete problem*
— disciplines noteworthy for :
  a) the variety of their viewpoints
  b) the possibility that the fields involved overlap
  c) the fact that no single discipline covers the entire problem
— different solutions, all of whith are necessarily incomplete, depending on the viewpoint of each discipline
— a synthesis
— *a single solution.*

United Kingdom

BIRMINGHAM
University of Aston
Interdisciplinary Higher Degrees by Applied Research

The University of Birmingham has gathered together under the direct auspices of three faculty members a set of varied activities which call upon scientific (physics, mechanics), technological (agricultural engineering, mechanical engineering, operations research, etc.) and social disciplines (sociology, economics), in addition to data processing and communications theory.

The purpose is to form university graduates who are "useful" to industry as soon as they are hired, and also to influence business structure by attracting the most gifted students in the sciences towards careers in management and business leadership.

In addition to their university courses, students work for a firm on projects which the company suggests but which are defined with the help of university specialists. These projects are of necessity interdisciplinary, and each student is looked after by a tutor.

When a project proves to be too broad, requiring too wide a span of competence, it is given to a group of students.

Hence we are looking at a situation which corresponds simultaneously to type 3 (origins), type 1 (motivation) and type 3 (object — the project's teaching).

In order to be sure to serve in a supervisory capacity, the team of professors and industry officials must acquire a coherence of its own, and therefore must combine the opinions which it will offer to the students. A large amount of time is thus devoted to meetings at the beginning to "master" the project. Thereafter, the students are given a great deal of latitude.

The three professors in charge work full time on this project, organizing lectures by specialists and serving as tutors. Only a limited number of students may apply for this kind of training.

CAMBRIDGE
Political and Social Sciences

This course involves some fifty full-time students working for two years beyond an initial year or two at the university, and leads to a B.A. degree.

It combines Sociology, Social Anthropology, Social Psychology and Political Science. It is designed for students with very different backgrounds. Although the majority are history or social science majors, about a dozen come from mathematics and others are literature majors.

To begin with, the project was a systematic method for innovation in an old university (type 5 ?). Its purpose was to define a new type of university course, but it seems very hard to determine how much would be merely pluridisciplinary (all that was needed to define a new curriculum), and how much is genuinely interdisciplinary (with an innovation and even integration of concepts).

Research is practically not engaged in as part of this endeavour, whose only concern is to improve the quality of undergraduate general education.

It is likely that the question that was originally asked has not been handled and that the autonomy granted this experiment within a purely disciplinary teaching system was highly inadequate.

CAMBRIDGE
Department of Agricultural Science and Applied Sociology

All the activities of this department are not involved in interdisciplinarity. According to the statement made by the professor in charge, such activity is now marginal and merely concerns biology courses (on cells, organisms, and environment). On the other hand, a rather large number of students are involved (280, 80, and 60, depending on the level).

The purpose is to form a combined teaching program for Botany, Zoology, Genetics, Biochemistry, Ecology, and Earth Science.

Each course handles the presentation of its particular science independently, but general seminars are organized.

In other words, the trend to define an environmental science and to "improve the level of students at graduation, especially as far as practical applications go", and the aim of combining disciplines at the concept level are not expressed in terms of a very thorough overhaul of the system. On the other hand, the "teaching means" play a very major role in furthering the combination, general discussions and especially *shared laboratories,* widely read textbooks, and television broadcasts.

These two examples at Cambridge University raise in a particularly acute way the problem of interdisciplinary experiments which form enclaves within systems which remain traditional.

SHEFFIELD
Seminar on the notions of subject and object

This seminar, which is designed for both education and basic research, is open to students (on invitation) and especially to professors themselves.

It deals with improving teaching and research by seeing whether there isn't a "common base for acquiring knowledge" and whether "students wouldn't be better off starting out by studying the axiomatic bases rather than a set of facts concerning a given subject."

"We are building a methodology to integrate nomenclature from different disciplines...", for instance, by studying whether the terminology of physics can improve the ways of looking at economics or sociology by introducing the new concepts behind these words.

Those participating in the seminar have been struck by unforeseen side effects. While they were especially aiming to build interdisciplinary models, they noted a considerable increase in their drive towards doing research.

They are striving to continue this effort to break down the dividing lines between disciplines at the teaching level, and they consider that one of the principal consequences (and also condition) of this extension would be the transformation of a university made up of departments into a university made up of far less numerous "Divisions" which regroup neighbouring or complementary disciplines.

The group has produced a collective book (Tavistock Press, Autumn 1970) which it hopes to use in teaching.

Turkey

IZMIR
University of Aegeus
Economics and Business Sciences

This term actually includes three types of teaching confined to beginning students, college graduates, or doctoral candidates, and all are basically designed for professional training and applied research..

The entire university is pluridisciplinary, and interdisciplinarity will be introduced in order to :

— combine knowledge from various disciplines
— save time
— avoid repetitions in common subject matters
— unify methodology and terminology.

It will involve all the students on this campus, and furthermore will make it possible to meet the needs of modern business firms by training personnel who are adaptable to economic and technical changes.

The university has no plans for specific teaching methods (lecture courses, then seminars for the Master's and Doctorate levels), and does not intend to reconsider its structures or particular fields of knowledge.

United States

AUSTIN, Texas
Austin College

One important part of this project for institutional change involves setting up a program for Basic Studies. The program offers itself as a *model for innovation* and is a means to revise and change the overall curriculum. Since the college as a whole has accepted this project, its current meaning as an instrument for change has been decreased.

Furthermore, the goal is to motivate the students and meet their need for unity, by organizing the first three years of undergraduate work around the study of the development of Western Civilization, based on the concepts of *faith and order*, and *crisis and reconstruction*.

During the senior year, students and their professors apply what they have learned in different disciplines to current social issues, such as urban revolution, poverty, the changing role of the university, and so forth.

Above all, therefore, this curriculum involves transferring knowledge having application to everyday, current themes, using universalist concepts.

Their structural changes are very important, team teaching has been set up, and curricula have been rather thoroughly overhauled.

"We have combined mass structures with individualized structures in order to make use of the efficiency of the mass situation while holding on to the kind of personal teacher-student relationship which we deem necessary."

As far as the disciplines involved are concerned, it is obvious that they are many in number, but allied to the social, philosophical and religious sciences.

Those general modifications which occurred in the institutional organization of the College are not described.

NEW YORK
City University of New York, Richmond College
Combined Studies Major

This program is very narrowly aimed at the students' needs and difficulties. Its purpose is to combine areas of knowledge outside the established academic disciplines, especially by giving credit for extracurricular activities such as counselling, tutoring, group therapy, student government counsel, welfare work, and collective art projects.

It develops or tries to develop "close cooperation between professors and students in preparing and setting up all courses and personal arrangements".

It is hard to really speak of combinations or interaction among disciplines, in that these disciplines have a rather minor role, except perhaps for sensitivity groups learning sociological survey methods, etc.

Heightened communication, group dynamics, joint and equal participation of teachers and students in preparing courses are both the means and basic end of the program, for even more than for "general background courses" it has the purpose of educating the person.

The thorough study and simultaneous practice of various methodologies in the social sciences are the basic contents.

It hence requires that some very specific scientific information be brought in to back up the program.

PITTSBURGH
University of Pittsburgh
Space Research Coordination Center

A major part if not the majority of the important problems involved in the American space program require that two or more traditional disciplines join in to solve them. The purpose of the Space Research Coordination Center is to gather together the disciplines called for by the leading space problems.

This Center therefore meets a "social need" by developing the means to make new discoveries using interdisciplinary research teams set up to work both at teaching and research. Each member serves as teacher for his fellows, but the actual details on how concepts are brought together are hard to figure out.

Using "team teaching" has not led to solving all their problems, and perhaps the Center's most important aspect has been its function as a meeting place and forum for communication in a multidisciplinary university.

Section 5. OBSTACLES AND DIFFICULTIES

This could be the longest section of all. In point of fact, it will be one of the shortest, and we have avoided bringing this issue up in each of our studies because all the questionnaires show a disquieting uniformity as to:

— the lack of facilities,
— the rigidity of institutional structures,
— the rigidity of the people involved,
— the resistance offered by disciplinary frameworks.

This could be expected, in fact, and we wonder whether these difficulties don't go far beyond the issue of interdisciplinarity, and characterize any teaching and research endeavour.

Rather than tie ourselves down to a picayune inventory of homogeneous answers, we prefer to take a close look at one specific case in point, for which we have an adequate amount of data (8 questionnaires), and can use an initial analysis made by Mr Hervé Hamon (Documents prepared for the Nice Seminar.) The experiment involved is the Centre Dauphine, at the University of Paris IX, a university which emphasizes economics and basically offers majors in business and management.

The overall study of a university whose clearly stated purpose is to set up new types of teaching and research programs makes it possible to go further than the foregoing observations and to expound on the difficulties encountered.

Obviously, problems crop up involving personalities and facilities, and there are conflicts between faculty members of different rank, between "tenured professors trained in a single discipline which guarantees their authority, and assistant professors, some of whom are eager to question everything, and moreover who are often under pressure from the students, whom they are close to". What is most apparent, however, are the deep theoretical conflicts, and occasionally the political strife. Clearly the concept of interdisciplinarity is not a neutral one, and when it is used as an innovative process, as we have already seen, the econometrist, the anthropological economist and the Marxist theoretician don't see eye to eye on how disciplines should interact. Terminology is the unifying factor between a professor dealing with two complementary methodologies, another seeking an overall approach to multidimensional man, and a theoretician working on a total, definitive science of man.

Behind this wide variety of experiences, behind these difficulties, frustrations and the illusions referred to here and there, the leading problem is perhaps interdisciplinarity itself, the uniformity of the concept, its real meaning.

Although it is clearly understood when referring to pluridisciplinary teams concentrating on a single object, research object or practical problem to be solved, it becomes much knottier when any claim is made to define a new way for knowledge to hang together, to put disparate fields of knowledge into the same pigeon-holes, or to set up a process for training an individual in both theory and practice, in the social sciences and exact sciences, in learning and creativeness.

In addition, interdisciplinary activities turn out to be fringe efforts whenever they fit into a system which otherwise remains traditional. That shows up very concretely at several levels :

— Admissions requirements are usually less tough than for ordinary disciplinary courses. Entrance depends more on the students' own interests and on their overall background than on specific conditions which must be satisfied. On the few occasions that we get the opposite impression, interdisciplinarity turns out in fact to be a kind of overspecialization stemming from the overlapping of two or more disciplines.

— The amount of time and space given over to interdisciplinary activities in the overall curriculum varies a great deal, which can only be interpreted as a sign of the degree of resistance offered by habits and the old system.

— They almost always enjoy the status of being officially recognized activities, for which credit hours, major units and degrees are granted. But often enough, especially in the United States, where there is usually the greatest latitude in such matters, such interdisciplinary courses get tacked on to programs, while the disciplinary course offerings continue to be required for the degree. Students are thus penalized for their study. Interdisciplinarity is a luxury or a whim which the university is glad to support and even encourage, but the system is not giving in or letting it take over.

This ambiguity is not brought to the fore merely by questioning the preceding institution. The resistance offered by many research workers and by most professors thinly masks the ambiguity of interdisciplinarity itself.

CONCLUSIONS

Glancing through the foregoing pages, one could get the impression that interdisciplinarity was merely a hodgepodge of elements, judging from the variety of activities which are called interdisciplinary, from the divergence or even contradiction between some of the concepts used, from the multiplicity of purposes, from the mixture of humanism and "scientism", from the coexistence between revolutionary aspirations and concern for meeting the needs of society more closely. It would be tempting to throw out the very notion that there was any unity involved, and to suppose instead that it was a mere chance encounter made possible by ambiguous nomenclature. Above all, one might adopt a normative attitude, thinking in terms of hierarchies, and speak of "true" and "false" interdisciplinarity, distinguishing lesser or greater degrees of integration which would approximately match the list of multi-, pluri-, inter-, transdisciplinarity, or else one could set up a tight typology for the purpose of clearing up such confusion.

It is our belief that such an answer would prove inadequate. The very dimensions of the area within which we would be able to set out the facts and opinions which we have given here vary. At this stage of development in our thinking, and in the absence of any theory, we have no basis for considering certain dimensions as particularly basic. We prefer to accept this multidimensional approach as a fact and to treat interdisciplinarity in consequence, which means respecting its universality.

The questionnaires have not made it possible for us to do more than touch on the subject. We have already pointed out that they perhaps overlooked the daily reality of actions and interactions, the actual origins, and so on. More basically, they do not allow us to ever get hold of one of the fundamental consequences of interdisciplinarity, i.e. the new ways in which contents are connected (organization of the subject matter). We have provided lists of the disciplines represented, but this terminology is by definition debatable and out of date, so that a new organization of concepts, new connections between methodologies, new dividing lines among fields of knowledge must be obtained.

Despite these provisos, a number of positive and negative features can be discerned which make it possible for us to assess the paradox of seeing these experiments in unification so scattered about and appreciate the need to revise the concept itself.

Interdisciplinarity as an epistemologically naive concept

We have already referred several times to a nostalgia for world unity, and the hope of rediscovering the obscure universality of original experience among the fragments of science. It is also frequently claimed that an object has an absolute identity, however many approaches are used, and no matter what a phenomenon means, based on the laws involved which reveal its origins and fix its structure.

The same molecule gets described differently by a physicist, a chemist, a pharmacologist, a clinician, a philosopher and a sociologist...

"Real World which does not know of academic division..." This realism involving the thing, the object, either turns its back on the most basic scientific practices, as in some cases, or else leads to a kind of transdisciplinary metaphysics which, in the name of the author's discipline, turns imperialistic, and tries to discover a common denominator for all other disciplines.

"...I was unable to avoid extending the data acquired in neurobiology to sociology, ecology, politics and city planning", the author of one of the most interesting and profound answers declares, thereby casting light in spite of himself on the phrase of non-compliance which we quoted right at the beginning :

"Interdisciplinarity is used as a clock for undisciplined thinking".

This "epistemological naiveté", which we have just shown stems from a realism which is often also naive, and from an analogical behavior which at times is difficult to distinguish from a form of disciplinary imperialism (especially, the imperialism of some mathematicians or biologists), extends to all fields.

It is a "naive" declaration that education in interdisciplinary practice should necessarily be interdisciplinary education.

... that interdisciplinary teaching necessarily leads to interdisciplinary research,

that increasing the drive towards intellectual productivity shows up immediately in an increase in such productivity, etc...

At times we feel *blithely free* of the yoke of the narrow, mediocre practices of disciplinary methodologies, and our enthusiasm is increased by knowing that most of the experiments are relatively recent. The problem of the scientific meaning of interdisciplinarity is almost never touched on, except obliquely through "realism" or by a sort of throwback to Kantian categories.

Interdisciplinarity hence has not yet been founded, and we are of the opinion that only a well thought out and rigorous approach would be capable of overcoming the upsets that some of the experiments discussed have stirred up.

A world-wide innovation

On the other hand, we are glad that interdisciplinarity is almost never an *isolated* phenomenon. In other words, on nearly each occasion, we observe, either in parallel or connected to it, changes in institutional *structures*, new teaching relationships, new views on the relationship between town and gown, and so on. It is a minor matter that the answers vary, for what is important is that this analysis of interdisciplinary activity, i.e., activity based on a set of shifts (or transfers) of certain frontiers of knowledge allows us to probe deeply into the totality of transformations affecting the university.

The fact that a university or a department or a single teacher may or may not make use of a subdivided area of knowledge can therefore serve as a good yardstick, however different from the sociological approach which studies student or faculty populations, making it possible to include the problems of how to organize the branches of knowledge in a study of university practices.

The issue of interdisciplinarity (or more broadly, of the various ways to subdivide knowledge within the University) is therefore a crucial problem, which we can use as the basis for studying or attempting to alter the university. Studying interdisciplinarity does indeed lead to basic thinking on teaching and research in the universities.

Once the weakness in our theory and the crucial nature of the topic are granted, it seems possible for us to understand the main characteristics of interdisciplinarity endeavours and the striking absence of uniformity in the data gathered in our survey.

In outline form, we can say that all the answers refer to three major themes, whether at the same time, while ranking them in importance, or by mentioning only one of them : the theme of the Unity of Knowledge, that of the Unity of Practice (professional or otherwise), and that of the Unity of the Person or the Subject.

Whenever the unity of knowledge is mentioned in first position, interdisciplinarity is ephemeral or instrumental, appearing in a moment of crisis, and leading to well-defined single models (transdisciplinarity) or to the birth of new disciplines.

"The purpose or interdisciplinarity is to produce new creative disciplines..." University of Edinburgh, Scottish Studies.

"The criterion for the effectiveness of interdisciplinarity is its ability to turn into a new discipline..." University of Besançon, Acoustical Psycho-physiology.

Therefore, some current experiments are, by definition, doomed to either disappear or stop being interdisciplinary, in the accurate sense of the word. Perhaps they will give rise to sciences with more complex methodology, which will continue to bear composite names, such as bio-chemistry and psycho-linguistics, but in the long run they will be the source for new specialities requiring pluridisciplinary training or drawing together advanced students from uniform branches for a final, common round of education, where they will be exposed to "a bit" of interdisciplinarity to learn to communicate better.

The practical, and more particularly, the professional outlook requires still more that people learn to communicate, so contact with interdisciplinary teaching will therefore be necessary. Interdisciplinarity cannot be based on this alone, since it does not consist of a new organization of contents, the desired combination occurring only at the practical level itself. Training a future engineer in certain sociological mechanisms does not involve teaching him socio-mathematics, but rather getting him to take certain sociological data into account when he applies his knowledge of mathematics, and this means simply recognizing the multi-dimensional nature of every real situation. A certain amount of pluridisciplinarity is in fact assumed in training whereas interdisciplinarity comes into play only at the level of pedagogical practices, where it appears more economical and amenable to future combinations of disciplines.

The makeup of this pluridisciplinarity (whose components are thus not connected by any intrinsic bond) varies, depending on the circumstances, styles, and changes in working conditions. A future business head will study less Law and more psycho-sociology, while a doctor will do less plant biology and more psychology, but he would do well to give up the latter if he plans to do only laboratory work, in which case he will do more chemistry, and so on.

On the other hand, and this is entirely independent of the ill-defined concept of general educational background, interdisciplinarity takes on an entirely different meaning when it is basically concerned with the unity of subject (or of the Person), the Subject which knows, or the Subject which acts, or the full Person who learns, acts, lives...

Teaching practices then form a perfect unity with the contents of this practice, whose purpose is to form a "unified" subject. The number, and to a certain extent, the nature and relative distance of the other disciplines set up at the same time count for less, especially as far as teaching is concerned, than the real interactions which occur, along with the modernity of their approaches, actual application of common definitions of problems, if not of common methods, and transformation of the university from a place where pre-defined knowledge is transmitted into a place where new knowledge is produced collectively.

This hence assumes, more than anything else, a complete overhaul of university faculties, for the professor would have to be willing to be more than an expert in some one discipline who happens to teach in addition, and also become a maker of *subjects* or personalities, not a maker of historians, sociologists or Hindu-language specialists.

The most interesting reports that we have scanned through are centered around a growing awareness of the educational dimensions of the university system, where the campus is a place where people live and meet. It is perfectly understandable that this realization is at times accompanied by a bit of epistemological naiveté, connected to an increasing political consciousness in the university, and in some cases the "increase in being" that it tends to produce doesn't take kindly to insidious questions on "cost-benefit" relationships.

The presence of interdisciplinarity no longer appears to be a mere readjustment or improvement of the traditional divisions in science, or a better adaptation of the university to social functions. It is becoming a whole battery of questions about the goals and functions of the university, and about the status of knowledge rather than about how it is divided up.

Once again we find we are confronting a world-wide approach to the reality of universities. This approach can certainly carry on the scientific movement, fits a large number of its requirements, calls for tight theoretical thinking, and above all, shows that the university system is tackling more day-to-day and commonplace, less well defined issues concerning the relationship between man with the world, with knowledge, with others, and with himself.

PART II

TERMINOLOGY AND CONCEPTS

This part, with the exception of the reports by Heinz HECKHAUSEN (Germany), Marcel BOISOT (France), Erich JANTSCH (Austria), André LICHNEROWICZ (France), Jean PIAGET (Switzerland), was written by Léo APOSTEL, Professeur de Logique et Théorie de la Connaissance, University of Ghent (Belgium).

SUMMARY

INTRODUCTION

In one of the classics of the "science of science", Derek J. de Solla Price (*Little Science, Big Science,* Columbia University Press, 1963) selects a few quantitative indices of the growth of science (number of scientists active during a given period, number of publications in given fields, number of discoveries during that period as estimated by competent judges). He comes to the conclusion that the growth follows an exponential curve, and is thus an accelerated phenomenon. This phenomenon, now already lasting for a few centuries, has begun to absorb sizeable parts of the Gross National Product, and thus demands internal organisation, due to its growing internal complexity.

This growth of research is accompanied (although with given time-lags) by a growth of the educational population (the numbers of teachers, of students, and the amount of schooling are increasing steadily). The enterprise of education, reaching industrial proportions, again demands internal organisation, just like "big" science.

These two phenomena cannot be understood in isolation and cannot be controlled in isolation ; although determined by partially different and independent causes, they are interdependent : the more science is produced, the more education is needed, and the more education is present in a society, the higher the probability of science production will be.

At the moment of writing, there have been some studies made of the organisation of education and of the organisation of science, but all these attempts meet one big stumbling block : the systems approach to human engineering shows us that a phenomenon can be optimalised only by viewing it as a whole, yet we only have the intellectual tools to view the problem piecemeal. In addition, the institutional tools we have only allow us to influence the phenomenon piecemeal. There is no general comparative "science of science" and even if the ideal of developing such a science exists in the mind of certain individuals, there are no instruments for making observations available to implement it, and no general models for the scientific phenomenon to be used as hypotheses about the nature of historic scientific process. The remark just made about the process of science can also be made about the process of education.

In this second part of the present volume, the editors wish to set out a few attempts which have already been made to consider science as a totality in evolution. Our point of view will be persistently operational. We are not interested in this volume in philosophical generalities, but only in preparing concrete administrative and political decisions. But—and this may come as a surprise to those of our readers who, involved in the heavy responsibilities of decision-making, are rather suspicious whenever general theorising is involved — it seemed necessary to us, for the very purpose of practical decision-making on the science and education explosion, to present a few highly theoretical studies. The purpose of this introduction is to stress the importance of certain conceptual problems in organising scientific research and educational promotion, and to explain the presence of the studies selected.

They have been chosen systematically, not haphazardly. Research and education, obeying the general law of the division of complex labour, are subdivided into certain subenterprises. In most universities people get a degree in physics or biology, not in general natural science. If and when they teach, they usually teach specialised subjects : French and not Romance Languages, Economic History and not History in general. The first problem that had to be studied when the systems approach to the organisation of science and education came forward, was how the general research and education process is organised and subdivided at the present time ? This inventory problem becomes, conceptually : what do competent people call "one science or one discipline" ?

This question may seem trite, but it is not. It is a difficult and deep question, and obviously it needs to be asked before it is at all possible to move on to the more crucial question : do we have to add to the actually existent division of scientific labour, certain mechanisms of co-operation and integration that, without obliterating the so much-needed division of labour, modify its pattern and produce certain new combinations of efforts ? When Heinz Heckhausen and Marcel Boisot studied the question of "what is a discipline", it became obvious that at least two approaches could be taken — the empirical and the formal approach. It was possible to observe the existent scientific situation and to ask what is meant by "discipline" in the various fields of Human Knowledge ? H. Heckhausen did this and came to the interesting conclusion that the meaning of the word varies from one field to another. Sometimes a discipline is defined with reference to its procedures for observation (spectrography), sometimes with reference to its explanatory models (physics), sometimes with reference to its object (history). Many other examples are available. This being the case, the conclusion is obvious : the field of research and education is not organised in a way that would be approved of by an operations researcher. Even if the slogan "interdisciplinary research and education" were shallow (we emphatically believe this is *not* the case), a short analysis of the present division of labour in the scientific field quickly shows such weaknesses that re-organisation is necessary.

But we did not think that a purely observational and empirical approach to the definition of a science was sufficient ; model building is needed. Here M. Boisot came to the rescue. A science is after all a structure, and we can look for the formal definition of such a structure. Having given such a definition (even if it is not the only possible one that one might think about), it appears that the problem of interdisciplinary co-operation and teaching emerges in a different light from every other definition of science as structure. Boisot's concept of discipline is the concept of a transformation of non-legalised facts into organised facts, related to each other by laws, a transformation that is never completely finished and always leaves behind a certain residue yet to be transformed. The very general level on which Boisot looks for a universally valid concept of science allows for many specific and divergent specifications and thus yields an indirect confirmation of Heckhausen's analysis.

The editors of this book would like to address themselves to the educationalists and scientists who do not feel the need for interdisciplinarity with the following *ad hominem* argument : you who want to defend the concept of monodisciplinarity, have you already analysed its meaning and implications ? And if you start to do so, will you be satisfied with the monodisciplinary pattern our universities show us at the present moment, or won't you rather decide that complete reorganisation (which for you means monodisciplinarity) is possible and necessary ? But—and now we show our hand—if you try to achieve your "monodisciplinary revolution", won't you need, in order to plan and execute it, the pluridisciplinary and interdisciplinary approach that the editors of this book defend ?

We can only hope that Heckhausen and Boisot's attempts to define a discipline will be followed by many others. We are convinced that further thought, even by those who, for various reasons, are opposed to our cherished slogan of "interdisciplinarity", will bring them to new conclusions.

But it was not sufficient to show that the concept of discipline is a problem in itself. We also had to show that there already are conceptual tools available that make interdisciplinary research possible.

We thought that this very theoretical approach was needed because many people who were possibly in sympathy with our aims would feel that the goal cannot be reached.

We could not hope to show all interdisciplinary conceptual systems, all "interlanguages" (if we may use this neologism), but we could make a selection.

The contributions of Jean Piaget, André Lichnerowicz and Erich Jantsch have been selected.

The reader will find in them three clearly different intellectual climates. Jean Piaget and André Lichnerowicz consider the "republic of the sciences" (to quote Michael Polanyi) as an autonomous whole. They are not primarily interested in social, technological or political action and the forms of interdisciplinary thinking they presuppose. They claim that the internal dynamics and structure of research introduce certain forms of interdisciplinarity. Their definition of interdisciplinarity has to be derived from the various examples of it which they give. Erich Jantsch, on the contrary, looks upon science and education as interrelated with, dependent upon, and, in the future, determining the general structure of society. Questions of value are never touched upon in the Piaget and Lichnerowicz contributions, whereas they are predominant in Jantsch's contribution.

The editors of the present book wanted to include contributions of the two types. We wanted to appeal to those who cultivate science for science's sake, and we wanted also to appeal to those whose main concern is to harmonise the general aims of society with the aims of the scientific community. If and this is our conviction — general human values, widely agreed upon and present in the trends in our society, make it necessary to have interdisciplinary research and education (both presupposing and helping one another) and if moreover, internal trends in technology, education and science make it equally necessary to have interdisciplinary ventures, then the desirability of what we want to defend seems to increase very considerably.

The ideal method would have been to have representatives of the most important and divergent value systems of our times come forward and speak in favour of the types of interdisciplinarity they consider to be desirable. Limitations of space and time, however, did not allow the editors to show these many possibilities. It was then decided that at least one paper, presented by Erich Jantsch, would show how a certain model of society as a whole (only incompletely described) is presupposed by every proposal in the field of the organisation of education and research and how certain value judgements, widely shared, impose certain types of interdisciplinary work.

The Jantsch contribution is thus very clearly different from both Piaget's and Lichnerowicz's papers. These two investigators have chosen as their starting point an analysis of science itself, without any reference to the social whole in which science is embedded. This restriction was as clearly needed as Jantsch's approach. Two investigators had to contribute, because both the development of science and its present state had to be used as criteria for evaluating interdisciplinarity. Lichnerowicz's point of view is that of a twentieth-century physicist and mathematician ; while Piaget's is the point of view of a psychologist working towards an understanding of the psychogenesis of the scientific approach in the individual and more particularly interested in the development of science in its history. Both are mainly interested in research, and less so in education.

Both come to the conclusion that they can present an interlanguage, a conceptual tool for interdisciplinary collaboration.

Both also come to the conclusion that strong interdisciplinary collaboration is unavoidable.

A. Lichnerowicz, stating that every major science has a tendency towards imperialism, and aware of both the advantages and the dangers of such an imperialism, proceeds to observe that one formal science, mathematics, seems to become a universal tool for all disciplines, and he thus proposes mathematics as the universal interlanguage. Mathematics, present in more and more regions of research, Lichnerowicz argues, also has sufficient internal unity to bring a common language to all investigators.

J. Piaget finds the unity of scientific research in its development. As the result of his studies in the psychogenesis of mathematical and physical concepts, he comes to the conclusion that these developments are not determined by the characteristics of specific regions of reality but quite to the contrary, are due to the maturation of general structures, applied in various widely distant fields. It can be surmised that the psychogenetic study of the basic concepts used in the biological, social and psychological sciences will in the future show the same pattern of evolution. Piaget's developmental approach hence calls for the teaching of basic structures, fundamental patterns of thought, and more history of science.

The editors of this book thought that Piaget's concepts of analysing the general development in the interaction of disciplines, and Lichnerowicz's version of the Bourbake structuralism as universally present in all disciplines, would yield a powerful argument for interdisciplinarity, and at the same time would show at least two different but related interlanguages — the fundamental theory of general scientific development, or dynamics and structuralist mathematics, identical for Lichnerowicz with mathematics itself. (Statics.)

In view of the considerations just explained, we decided upon the following presentation :

A. Analysis of the concept of discipline :
   a) factually : Heinz Heckhausen
   b) formally : Marcel Boisot

B. Analysis of three concepts of interdisciplinarity :
   I. Interdisciplinarity from the point of view of the general value system of the total society : Erich Jantsch
   II. Interdisciplinarity from the point of view of research itself :
      a) mathematics as a universal language : André Lichnerowicz
      b) theory of the psychodynamics of knowledge as a universal language : Jean Piaget.

We must leave it to the interested reader to compare these five contributions and to draw practical conclusions for research and education from their contents.

The editors of this volume were of the opinion that, once the reader had been presented (Chapter 1) with these major perspectives on definition and evaluation of disciplinary and interdisciplinary thought, a last attempt should be made towards a synthesis. (Chapter 2) This final effort is naturally only a first endeavour and should be carefully criticised, as everything should be in this highly important but underdeveloped area. Léo Apostel, a philosopher, tries to systematise the different interlanguages present.

Chapter 1

SOME APPROACHES TO INTERDISCIPLINARITY

Section 1

DISCIPLINE AND INTERDISCIPLINARITY

Heinz HECKHAUSEN
University of Bochum, Germany

Clarifying the vague meanings attached to "interdisciplinarity" presupposes a cla ification of what constitutes a discipline. Therefore we will first delineate seven criterion levels for defining given disciplines on epistemological grounds. The distinctions made represents criteria for delineating divisions which do not necessarily coincide with the traditional organisation of departmental structures in present universities. The proposed clarifications along epistemological lines will then lead to a differentiation of various types of "interdisciplinarity". The following considerations held for empirical disciplines only, i.e. for those which deal with observables (and not for purely deductive disciplines such as mathematics).

In this paper, the term "discipline" is used in the same sense as "science", although "discipline" carries the notion of "teaching a science". To be sure, there is a difference between science as a research activity and discipline as a teaching activity—not least because of the usual "scientific lag" between the latest state of research findings and what is being taught. Nevertheless, science is science because research results necessarily have to be communicated publicly. Communication (or teaching) is a substantial part of the clarification processes of scientific thinking and hence of science itself.

I. DISCIPLINARITY

Disciplinarity is the specialised scientific exploration of a given homogeneous subject matter producing new knowledge and making obsolete old knowledge. Disciplinary activity results incessantly in formulations and reformulations of the *present* body of knowledge about that subject matter. In order to characterise the nature of a given discipline and to distinguish it from other disciplines, it is useful to apply the following seven criterion levels.

1. *The "material field" (Piaget) of a discipline.* The material field comprises the set of objects in an understanding on the common sense level. For example, zoology is concerned with animals ; botany with plants ;

psychology, physiology, anatomy and paleontology with man ; history of (a national) literature, linguistics, psycholinguistics, communication science with language, etc.

On the criterion level of the "material field" the various disciplines overlap enormously. This is why it is so superficial and useless to define disciplines by pointing to their diverse material fields or objects. On the other hand, the broad overlapping of "neighbouring" disciplines in their material fields appears to be the main cause of the common gossip about "interdisciplinarity' 'as a new and highly valued fad. Obviously, this overlapping in the material field creates the misleading expectation that disciplines with the same material field will not only co-operate but amalgamate into a single discipline.

2. *The "subject matter" of a discipline.* The point of view from which a discipline looks upon the material field cuts out a certain sector of all possible sets of observables offered by a material field. In short, the subject matter of a discipline consists of circumscribed subsets of observables of a material field. Thus, a subject matter is a more refined concept for the "objects" of a discipline than is the material field. But it is still a broadly defined preconception with regard to what kinds of data, within a material field are relevant for a given discipline. For example, behaviour (including the "mental life" of man) is the subject matter of psychology with its broad range of various kinds of relevant observables, whereas physiology's subject matter consists of the anatomical, physical and chemical properties of body functions which keep an organism alive.

To a certain degree the subject matter depends on axiomatics, i.e. predecisions concerning conceptualisation, theory construction and methodology (see points 3 and 4) within a given discipline. For example, guided by theoretical and methodological considerations, behaviourism tried to exclude introspective self-report data from psychology.

3. *The "level of theoretical integration" of a discipline.* This is the most crucial criterion level of a discipline. Each empirical discipline (i.e. leaving purely theoretical disciplines, like mathematics, aside) tries to reconstruct the "reality" of its subject matter in theoretical terms in order to get hold of that overwhelmingly complex reality, in order to understand, explain and predict phenomena and events involving the subject matter. In doing so the categorial nature of the relevant observables of the subject matter determines the categorial level of theoretical integration of the fundamental and unifying concepts. In psychology, for instance the level of theoretical integration is the behaviour of the intact organism (or personality) dealing as a molar system with a perceived environment.

On a more descriptive level, the observables are construed as perceptions, activities or performances ; on a more explanatory level of theory construction, the same data are taken as indices of the theoretical fruitfulness of hypothetical constructs such as drive, motive, adaptation level or cognitive dissonance. But even with the best hypothetico-deductive logic, and with terms borrowed from physics like "force" or "inertia", psychology's level of theoretical integration remains a realm of its own, as defined above, which cannot be translated into the theoretical integration level of other disciplines, say, into physiology's brain waves, or into chemistry's changing molecular compounds of the limbic system.

At least at present, there appear to be unbridgeable gaps between the theoretical integration levels of some empirical disciplines. On the other hand, some disciplines, like chemistry and biology are showing an increasing convergence of their respective levels of theoretical integration moving towards a unification with the theoretical integration level of physics.

With regard to their present level of theoretical integration disciplines can be distinguished according to their achieved state of maturity. At one extreme a discipline is still absorbed by mere description and phenotypic taxonomies of its subject matter as was Aristotelian botanics ; at the other extreme a discipline has developed a single theory system powerful enough to cover almost all the phenomena of its subject matter. As a rule, most disciplines have many different theories, unrelated to each other or even contradictory, for different bodies of observables or even for the same observables. To complicate matters further, mutually exclusive levels of theoretical integration may even exist within one single discipline. This is the case, for instance, in the present stage of psychology, where some researchers try to define stimulus or response variables in quasi-physical terms while others do the same in quasi-phenomenological terms. At this stage in a discipline's development, *intra*disciplinarity may be badly needed and interdisciplinarity (whatever that may be) appears to be rather premature.

4. *The "methods" of a discipline.* A discipline develops its methods for two purposes ; first, to get at the observables of its subject matter ; or, second, to transform observables into data which are more specific for the problem under investigation (e.g. by means of interpretative rules). A discipline is said to have established its autonomy if it has developed methods of its own. Methods are considered appropriate to a discipline in two ways : methods have to be adequate for the nature of the subject matter in order to reveal crucial information ; secondly, there has to be an inferential correspondence between the concrete methodological operations and the general statements made on the level of theoretical integration.

There are many examples within each discipline of how advances in methods spur progress in theory construction. At the same time new theory conceptions stimulate the development of new methods.

5. *The "analytical tools" of a discipline.* Analytical tools rest on strategies of logic, on mathematical reasoning and on model construction for complex feedback processes. Outstanding examples include experimentation, descriptive or inferential statistics, computer models and computer simulation, cybernetics, and information theory.

It goes without saying that by virtue of their high degree of formalisation, analytical tools are highly generalisable for different subject matters. As Caillois puts it, they are "diagonal sciences". None of the other criterion levels for defining a discipline are as unspecific as analytical tools in distinguishing between disciplines. Of course, the question always remains of the adequacy of discipline and of its level of theoretical integration to any given subject matter.

6. *"Applications of a discipline in fields of practice".* Disciplines differ greatly as to the degree of their applicability and their established practical applications in vocational fields. Compare, for instance, archeology and a

discipline in engineering. As a rule, disciplines with an emphasis on application and well-established vocational fields are eclectic rather than purist in their epistemological concepts of themselves as sciences. The obligation to find applications always has a strong impact on how the organisation, research and curricula of these disciplines are structured within universities.

Medicine is a case in point. The seeming necessities of practice have piled up a hodge-podge of multi-disciplinary curricula over the centuries. Very little effort is spent on clarifying the nature and problems of this multi-disciplinarity to medical students. Therefore, it is not surprising that practitioners basically view medicine as a single discipline, and that in turn may lead to strange convictions bridging the gaps between different levels of theoretical integration within a multi-disciplinary field of practice.

Disciplines with a strong obligation to vocational practice are noted for the "scientific lag" of their vocational practice (and even their multi-disciplinary teaching at universities) behind the present state of "pure" research in the corresponding disciplines.

7. *"Historical contingencies" of a discipline.* Every discipline is a product of historical developments and at any time it is in a transitional state. Some disciplines develop and change at a rather fast rate while others appear to be exhausted. The historical contingencies which speed up or slow down a discipline's development and progress are not exclusively due to the inner logic of the respective subject matter explored by able scientists. Disciplines are also under the sway of extradisciplinary and changing forces, such as public reputation, sociocultural values, political ideologies and economic conditions. The extradisciplinary forces not only control material resources, they determine the climate for growth. Last but not least, external contingencies add up to the *Zeitgeist* of the scientists themselves influencing their research interests and theoretical preoccupations.

II. Interdisciplinarity

It is the task of a science of science to spell out how the various disciplines differ with regard to the criterion levels of disciplinarity outlined above. The teaching of a discipline at the university should start by clarifying its disciplinarity in order to sensitize the student to the possibilities and limitations of the chosen discipline. Early sensitising to a given disciplinarity is an educational innovation, and can be best done by comparing supplementary subject matters in neighbouring disciplines.

Moreover, understanding a discipline's disciplinarity is crucial to awareness of the chronic mismatch between the present state of a discipline as a science and as a vocational field of practice. The student should be aware of this mismatch right away in order to enter the vocational field with a clearer notion of the requirements, scientifically speaking, which vocational practice ought to (and perhaps could) yet does not fulfil. An awareness of this sort will increase the motivation and ability of practitioners to be constantly on the lookout for a better fit between a science in progress, as taught at universities, and the routine practice of the related vocational field.

But what about interdisciplinarity ? The distinctions made between seven criterion levels of disciplinarity lead to differentiating at least six types of interdisciplinarity. At the same time, this typology points to various urges towards interdisciplinarity, in the research field or in the field of vocational practice and in the complex interaction between the two.

In what follows, six types of interdisciplinarity are distinguished in ascending order of the stage of maturity. One general property which appears to characterise all types of interdisciplinarity is that the disciplines of any given interdisciplinary cluster share the same material field. But as we shall see, even this low order of communality is not always the case.

1. *Indiscriminate Interdisciplinarity.* To this type belong all kinds of encyclopedic endeavours ending up in curricular mix-ups. An example is the vague idea of a "studium generale", put forth in Germany during the Fifties as an innovation in university education. The introductory study of diverse "basic" disciplines was thought to counteract the specialisation and narrow-mindedness produced by studying a major discipline. As a rule, encyclopedic curricula of the indiscriminate interdisciplinarity type have been constructed for vocational training just below the university level, as for elementary school teachers or social workers, i.e. for practitioners supposed to handle a broad variety of problems with enlightened common sense. Social workers, for example, are taught a mixture of sociology, social psychology, psychopathology, psychoanalysis, labour economics, and so forth.

The ear-mark of indiscriminate interdisciplinary marriage cannot be overlooked. There is no research approach possible which represents the corresponding counterpart of the naive superficiality of encyclopedic teaching. This is why indiscriminate interdisciplinarity is hard to establish in an open form on the university level. Disguised forms are represented by "imperialistic" disciplines claiming other sciences as their "auxiliary disciplines". (See below for auxiliary interdisciplinarity). The disciplinary character of many a curriculum, enriched by annexing satellite disciplines, proves to be more indiscriminate than auxiliary.

2. *Pseudo-Interdisciplinarity.* As already has been noted, analytical tools, among all criterion levels, are least specific for disciplinarity. Nonetheless, analytical tools such as mathematical models or computer simulation are fascinating by virtue of their very transdisciplinary nature. The transdisciplinarity of analytical tools even leads to the bold but erroneous expectation that disciplines sharing the same analytical tools might develop an intrinsic interdisciplinarity.

The School of Social Sciences of the University of California at Irvine, for instance, offers a programme in "Mathematical and computer models". In this case, "model" is conceived of as the uniting core for cross-disciplinary research and teaching while content is deliberately subordinated. The programme is an interdisciplinary subdivision of the School and comprises such diverse disciplines as anthropology, economics, geography, political science, psychology and sociology. Interdisciplinary topics in the programme include pattern recognition, game and decision theory, models of social interaction. These topics are thought to lead in different vocational directions : information and computer science, prelaw, teacher-training, administration. But how can mathematical or computer models bridge the gaps between the various subject matters and their respective levels of theoretical integration for disciplines like economics, psychology and geography ?

3. *Auxiliary Interdisciplinarity.* As we noted above, methods are the specific tools each discipline uses to get at observables in a given subject

matter and to transform observables into data sets specific to each problem. Often, methods yield information which has a certain index-value for the subject matter of another discipline and its respective level of theoretical integration. Thus, cross-disciplinary use of methods constitutes lots of auxiliary interdisciplinarities.

At the one end, auxiliary interdisciplinarities may be occasional and transitional. At the other end, a discipline may have established an enduring relationship to another discipline by being dependent on the methods of that "auxiliary discipline". For instance, pedagogy makes use of psychological testing, not only for applied educational decision-making but also for proving a theory of instruction or for evaluation of a curriculum. Psychology takes advantage of neurophysiological measures such as palmar resistance or muscle tension in order to set up an index for "central activation", a basic hypothetical const. ıct in motivation theory.

It is quite natural that a discipline somewhat naively gives credence to the index value of a method borrowed from another discipline. This may lead to criticism from the "auxiliary discipline", which uses more cross-disciplinary sophistication on the part of the method users. More sophistication in the cross-disciplinary use of methods in turn creates a more advanced stage of interdisciplinarity, namely, a supplementary one (see below), for example, psychophysiology.

4. *Composite Interdisciplinarity*. The particular propelling forces behind this type are the great issues challenging man's dignity and human survival: prevention of war, hunger, delinquency, pollution, landscape destruction, urban slums, etc. There are interdisciplinarities in the making in peace research or city planning. What brings together quite diverse disciplines is the stern necessity to apply problem-solving techniques under the changing impact of historical contingencies.

City planning for instance, asks questions of sciences as diverse as engineering, architecture, economics, biology, psychology and others. In a strict sense, even the respective material fields of these disciplines do not overlap, let alone the related subject matters and levels of theoretical integration. What keeps such a strange assembly of disciplines together, however, is a jigsaw puzzle-like composition of adjacent material fields within the complex compound which the reality of city life is. The interdependencies of multifarious conditions in the diverse material fields have to be explored for their influence on important issues of urban life like health, economic welfare, graceful living, opportunities for child development and other goals set by human values transcending all science.

Composite interdisciplinarity is noteworthy for its technological instrumentality in pursuing a hierarchical sequence of clearcut goals which change person-environment systems or even innovate such systems. A remarkable case in point is the Apollo project.

5. *Supplementary Interdisciplinarity*. There are disciplines in the same material field which develop a partial overlapping in a supplementary relationship between the respective subject matters. The supplementation is induced from a correspondence between the levels of theoretical integration of two or more disciplinary subject matters. Note that the theoretical integration levels of the involved disciplines are divided by category gaps which are insurmountable and have to be tolerated. But supplementary interdisciplinar-

ity creates a sort of correspondence between the respective theory levels. The correspondence is looked for and tentatively established in order to reconstruct life or social processes more fully.

An example is another programme of the School of Social Sciences of the University of California at Irvine. It is entitled "Language and Behavior", and is a study of persons and cultures asking questions about how they can be known, changed and developed, and how persons and cultures are interrelated. One topic, for example, comprises structural models of behaviour, in relation to formal descriptions of grammatical, semantic and social structures from various cultures. The formal descriptions are an attempt to build up a structural correspondence between linguistic, anthropological, sociological and psychological levels of theoretical integration. In the long run it may lead to the stratification, layer by layer, of supplementary subject matter.

As a rule, supplementary interdisciplinarity never extends across the whole area of the related disciplinary subject matters. It tends to originate in the borderline areas of a discipline, as is the case with psycholinguistics, psychobiology and psychophysiology.

6. *Unifying Interdisciplinarity.* This type results from an increased consistency in the subject matter of two disciplines, paralleled by an approximation of the respective theoretical integration levels and methods. For instance, some parts and perspectives of biology have reached the subject matter level of physics thereby creating biophysics. There appears to be an irresistable trend towards the unification of physics, chemistry and biology at the theoretical integration level of physics.

While such unifying interdisciplinarity already exists in large research areas, universities still continue to teach separate disciplines with some scattered auxiliary interdisciplinarity.

Section 2

DISCIPLINE AND INTERDISCIPLINARITY

Marcel Boisot
Ecole Nationale des Ponts et Chaussées de Paris, France

The subject of this paper is the search for various types of interaction between science disciplines, such interactions usually being known as interdisciplinarity, though opinion today is by no means in agreement on the content of this term. In order to achieve this aim, we found it indispensable to evolve an operative, i.e. non-descriptive, definition of what a science discipline is or might be.

Breaking down knowledge into separate fields derives from two tendencies which have strengthened each other as these fields widened over the course of time. The first tendency arose out of man's unconscious (or nearly unconscious) inclination to separate, classify for recognition and conceptualise the surrounding elements. This fragmentation of nature as a field of observation and study was thus inevitable and without doubt fruitful for gradually attaining a high level of understanding. The other tendency, a psychological one, is the result of scientists' propensity to circumscribe the field of their investigations intellectually in order to better formulate their problems and take fuller advantage of this directional accumulation of cognitive elements. But as a consequence, the scientist feels a certain solidarity with his own particular field, which may explain the wide disparity of definitions for the terms discipline or interdisciplinarity. Each definition put forward by the scientists seems to result from an analysis of individual experiences which involve mechanisms or procedures that are too restrictive for general application. The starting point of our study is precisely an attempt to disregard (apart from examples, of course) any particular set of specific circumstances.

FORMAL DEFINITION OF A DISCIPLINE

Let us then endeavour to grasp the discipline concept in its most general form. A discipline is concerned first with objects, methods and procedures and finally with laws, the word object being taken as a definable personalised element which is recognisable experimentally (observable), and sometimes also identifiable through a formalism defining it conceptually (e.g. the formula of the photon : $E = h\nu$).

These objects are not isolated entities, in the sense that they interact with other objects, whether or not of the same kind, and thus give rise to "phenomena". The aim of a discipline is precisely the coherent explanation of the phenomena generated by these interactions, and the logical approach consists of postulating a number of axioms and hypotheses leading ultimately to identifying laws which assume, above a certain scale at least, that nature is essentially deterministic. At each point of the space-time continuum, one of the forms of determinism is precisely to admit that the phenomenon can be said to reveal one law or a set of laws. The law only attains that status when it can be formalised in a manner appropriate to the various elements brought into play by an underlying phenomenon. This being so, we suggest the following as the most general definition of a discipline :

A discipline is a set comprising three types of elements :

1. *observable and/or formalised objects, both manipulated by means of methods and procedures.*
2. *phenomena that are the materialisation of the interaction between these objects.*
3. *laws—whose terms and/or formulation depend on a set of axioms—which account for the phenomena and make it possible to predict how they operate.*

The items in this set, which have internal and/or external relationships, are revealed through phenomena which subsequently confirm or invalidate the axioms and laws.

Taken in this sense, a discipline is a structure.

The many meanings of the word structure oblige us to specify the sense in which we are using it. We take the word structure, not in the very special in which we are using it. We take the word structure, not in the very special sense adopted by psycholinguists and cultural anthropologists, but as designating a system in which an organisation may be found and in which the sum of the parts does not coincide with the whole.

Within a discipline, a sub-discipline can be found and defined on the basis of the above criteria ; we can then say that a sub-discipline is a discipline (in the same way that a sub-set is a set).

In the discipline-set, the law-elements weave a texture on which the discipline is based. These laws quantify knowledge, and the aim when endeavouring to understand the related phenomena is the maximum accumulation of underlying laws. Although a set of laws does not entirely define a discipline as we understand it, it nevertheless helps to identify and describe it. The laws of a discipline thus build up its basic framework. We shall call this set (of laws) the *"legal set"*, so that a discipline will be designated here as $\mathcal{D}(\mathcal{L}_i)$, where $\mathcal{L}_i$ indicates the set $\mathcal{L}_1, \mathcal{L}_2, \dots$.

The phenomenon, as a special occurrence, totally or usually partially explainable by the operation of laws that disclose its origin and reveal its structure, is claimed non-exclusively by a discipline. But on the other hand, the set of laws governing a discipline, at a particular point in its development, is sufficiently representative for it to be identified by that set, which in a way is its signature. Generally speaking, all the phenomena which have been recognised in a discipline divide quite naturally into two categories :

— phenomena whose explanatory coherence classifies them within a theory because they are governed by the laws relating to it : we call this category of phenomena *"legalised phenomena"* ;
— phenomena revealed by experience which have not yet been explained and which fail to conform to the known laws relating to the discipline claiming them. We shall call this second category *"crude phenomena"*.

Scientific research is thus defined as the effort of transforming crude phenomena into legalised phenomena through the discovery of laws which enrich the existing edifice. If this approach is accepted, a particular discipline comprises two sub-sets at any given moment in its evolution :

— the "legalised phenomena" $p_L (\mathcal{L}_i)_{\ell_1}^{\ell_2}$ (where $p_L (\mathcal{L}_i)_{\ell_1}^{\ell_2}$ denotes a phenomenon explained by the set of laws $\mathcal{L}_{\ell_1}, \mathcal{L}_{\ell_1+1}, \dots, \mathcal{L}_{\ell_2}$,)

— the "crude phenomena" p_B

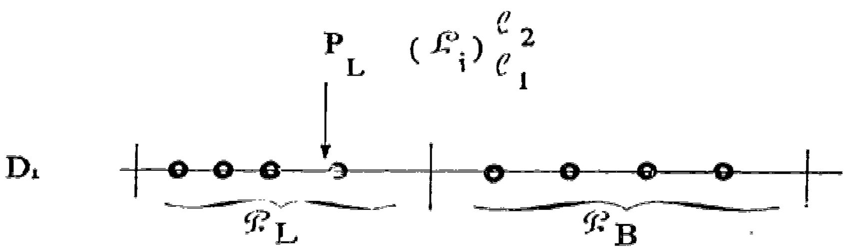
It is important to note that a phenomenon is never in fact completely "legalised". A new phenomenon, revealed for example by an improvement in the precision of experiment, can compromise the coherence of the phenomenological edifice and thereby entail the imperative need to supplement the degree of legalisation*. In short, the state of a discipline may be symbolically described by :

$$\left\{ \sum_j p_L^j \, (\mathcal{L}_i)_{\ell_1(j)}^{\ell_2(j)} \right\} \cup \left\{ \sum_{j'} p_B^{j'} \right\}$$

(where Σ as usual indicates the summation operation).

* or to modify it.

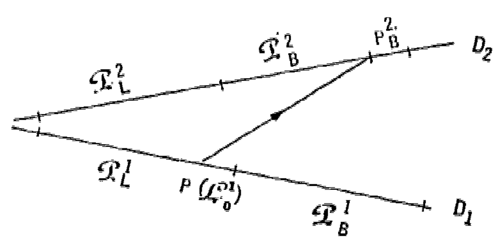
Let us then assume that a discipline $\mathcal{D}_1$ can be described by a straight line D_1 containing the "legalised phenomena" and the "crude phenomena", each arranged in a certain order such as the chronological order (although this is not strictly speaking necessary) :



$$\mathcal{P}_L \equiv \sum_j p^j_L \; (\mathcal{L}_i)^{\ell_2(j)}_{\ell_1(j)}$$

$$\mathcal{P}_B \equiv \sum_{j'} p^{j'}_B$$

In order to recall that $\mathcal{P}_L$ and $\mathcal{P}_B$ belong to discipline $\mathcal{D}_1$ we write them as $\mathcal{P}^1_L$ and $\mathcal{P}^1_B$. Another discipline $\mathcal{D}_2$ will be represented by a straight line D_2.



From this starting point, our aim is to find and classify the various types of interaction between the elements of D_1 and D_2.

THE VARIOUS TYPES OF INTERDISCIPLINARITY

I. *Linear interdisciplinarity*

When a phenomenon p^2_B — a crude phenomenon belonging to discipline $\mathcal{D}_2$ — is legalised by a law $\mathcal{L}^1_0$ belonging to discipline $\mathcal{D}_1$, we shall say there is *linear interdisciplinarity* in the sense that law $\mathcal{L}^1_0$ is borrowed and adapted by $\mathcal{D}_2$ for the benefit of p^2_B. Whenever this circumstance is possible, a common model exists between p^1_L ($\mathcal{L}^1_i$) and p^2_B whereby law $\mathcal{L}^1_0$ is transferred to join set $\mathcal{L}^2_i$ ($\mathcal{L}^1_0$ belonging to set $\mathcal{L}^1_i$). It is in this sense that we can speak of linearity.* (see figure p. 92).

The history of science offers many examples of laws originating in one discipline which have been successfully applied to others. D'Alembert's vibrating strings equation, originally claimed by acoustics, occurs again in the same form in electromagnetism and then later, taking account of Louis de Broglie's fundamental relation, in wave mechanics under the name of Schroedinger's equation.

The following table illustrates a few well-known situations of linear interdisciplinarity.

A	flux relationships current relationships continuity equation	applied to	atoms and particles electrons biological particles probability density: Ehrenfert theorem (in wave mechanics) automobiles
B	Coulomb's law	applied to	gravitation electrostatics magnetism economic flow between cities
C	D'Alembert's propagation equation	applied to	acoustics electromagnetism wave mechanics

Laws originate in a discipline.

In the simple case of the incorporation of a law $\mathcal{L}^1_0$ into $\mathcal{D}_2$, $\mathcal{D}_1$ plays the part of an operator and the relationship may be symbolically written:

$$\mathcal{D}_1 . \mathcal{D}_2 \Rightarrow (p^2_B \rightarrow p^2_L)^{**}$$

It is easy to imagine possible variants, such as

1. Re-incorporation into $\mathcal{D}_1$ of $\mathcal{D}_2$ laws as consequences of operation (1), which gives:

$$(\mathcal{D}_1 . \mathcal{D}_2)^1 \Rightarrow (\mathcal{D}_2 . \mathcal{D}_1)^2$$

2. Extension of this interchange which may continue and lead to a sequence of the form:

$$(\mathcal{D}_1 . \mathcal{D}_2)^1 \Rightarrow (\mathcal{D}_2 . \mathcal{D}_1)^2 \Rightarrow (\mathcal{D}_1 . \mathcal{D}_2)^3 \Rightarrow \dots$$

3. Interactions of the third order (or higher) involving three disciplines (or more).

4. It is very possible that in the case of linear interdisciplinarity, the constraints in $\mathcal{D}_1$ which limit the field of validity of a law $\mathcal{L}^1_i$, transferred to $\mathcal{D}_2$, are restricted by characteristics specific to $\mathcal{D}_2$. In other words, the limits of validity of law $\mathcal{L}^1_i$ are at most equal in $\mathcal{D}_2$ to the limits in $\mathcal{D}_1$.

* In actual fact, there is nothing to prevent the transfer of more than one law.
** Where the higher indices denote successive stages.

We would repeat that, whether simple or complex, this type of interdisciplinary exchange always operates through the adjunction and adoption of a law (or of several laws), in such manner that the law in question is taken over as formulated, requiring only some redefinition of the variables and parameters in order to adjust it to the new disciplinary context. Several epistemologists call this type of interaction between disciplines "multidisciplinarity", "pluridisciplinarity" or "crossdisciplinarity", although the distinction between these expressions does not appear very clear (e.g. see Erich Jantsch p. 97.)

II. *Structural interdisciplinarity*

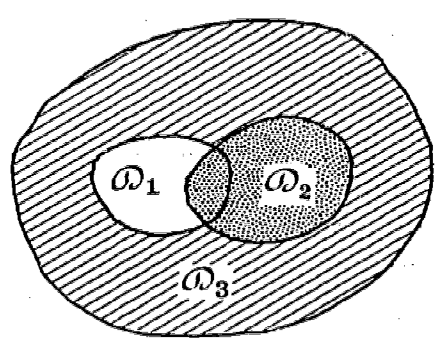
We shall use this term to designate the important case in which interactions between two or more disciplines lead to the creation of a body of new laws forming the basic structure of an original discipline that cannot be reduced to the formal combination of its generators, and itself complies with the definition criteria that we have suggested above. In fact, the syncretic tendency of the new discipline will potentially be to swallow up the original disciplines, which then in the new structure appear to be extreme cases. A typical example of "structural interdisciplinarity", is provided by electromagnetism, which today not only includes electrostatics and magnetism but is endowed through Maxwell's equations, themselves extended by Einstein's equation of relativity, with its own laws, which constitute a new dimension as compared with the laws governing the original disciplines.

The new discipline $\mathcal{D}_4$ appears as the combination of the two basic disciplines $\mathcal{D}_1$ and $\mathcal{D}_2$ and an area not included in $\mathcal{D}_1$ and $\mathcal{D}_2$ and indicated by $\mathcal{D}_3$. This is condensed into the expression :

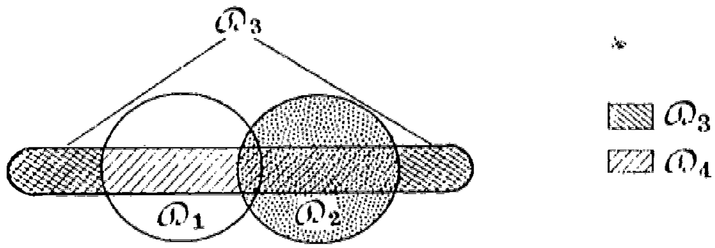
$$\mathcal{D}_1 \cup \mathcal{D}_2 \subset \mathcal{D}_4$$

$$\begin{cases} \mathcal{D}_1 \cup \mathcal{D}_2 \neq \emptyset \\ \mathcal{D}_4 \end{cases} \qquad (\emptyset \text{ null set})$$

$$\mathcal{D}_3 = \mathcal{D}_4 - (\mathcal{D}_1 \cup \mathcal{D}_2)$$



On the purely epistemological level, it is possible to imagine different relative arrangements of fields $\mathcal{D}_1 \cdot \mathcal{D}_2$ and $\mathcal{D}_3$, as for example the case in which $\mathcal{D}_3$ only partly intersects $\mathcal{D}_1$ and $\mathcal{D}_2$. This would then lead to the following diagram :



$$\mathcal{D}_4 = [\mathcal{D}_4 \cap (\mathcal{D}_1 \cup \mathcal{D}_2)] \cup \mathcal{D}_3$$

We are concerned here only with structural interdisciplinarity involving two initial disciplines. It is clear that the same mechanism may concern three initial disciplines or more. What is important to note is the fact that this type of interdisciplinarity generates a system of principles and laws which help to build up a new discipline. This oversimplified description gives a clearer idea of the interplay of the specific relationships likely to be established between the various fields involved. In actual fact, structural interdisciplinarity does not lead to such a clearcut situation, for it does not necessarily exclude linear interdisciplinarity.

Cybernetics provides an example of an original discipline developing out of the adoption and adaptation of principles and laws pre-existing in the initial disciplines (thus, integral transformations and feedback theory existed before the birth of cybernetics). It should be noted that for many authors the word interdisciplinarity denotes, more or less clearly, the situation we have just been examining.

III. *Restrictive interdisciplinarity*

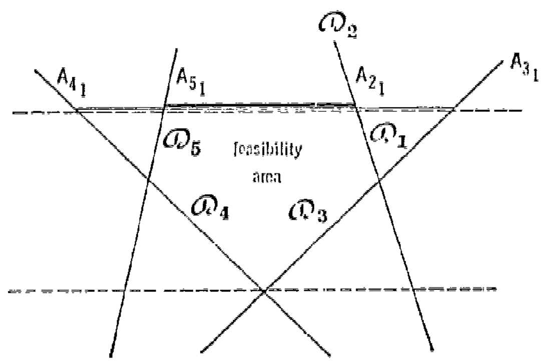
This expression indicates the case in which there are, strictly speaking, no interactions between disciplines as understood in the two preceding sections. Here, the field of application of each discipline brought into play by a concrete objective is restricted. The "restricting" disciplines act as constraints on the others. Each restricting discipline imposes technical, economic or human bounds on the others. In a city planning project, for example, the psychologist, the sociologist, the transportation expert, the architect, and so forth, as well as the economist, will each impose a number of constraints which taken together will limit the area of feasibility within which the project can be situated. The interdisciplinarity of this situation will be expressed formally by a system of inequalities of the type :

$$\mathcal{D}_1 . \mathcal{D}_1 = \in_1 \mathcal{D}_1 < \mathcal{D}_1$$

meaning that discipline $\mathcal{D}_i$ operating on $\mathcal{D}_1$ restricts the field of validity of $\mathcal{D}_1$ by the factor $\in_1$ ($\in_1 < 1$). In a more general case, the simultaneous application to $\mathcal{D}_1$ of several adjoining disciplines successively restricts its field of application. The following diagram illustrates the case of restrictive interdisciplinarity :

Field of application of $\mathcal{D}_1$

- - - - - no constraint
_____ limited by $\mathcal{D}_4$ and $\mathcal{D}_3$
_____ limited by $\mathcal{D}_2$ and $\mathcal{D}_5$



The word restrictive invites one to conclude that there is, strictly speaking, no structural modification of the adjoining disciplines.

Operative fields of interdisciplinarity

We continue in our endeavours to clarify the issue at a time when to many fields boast of interdisciplinarity even before this has been unequivocally defined in generally accepted terms, and now come to the question of what (on the basis of the definition we suggested above) are its various operative fields. We shall distinguish three of these :

A. *The philosophical field* dominated by the history of science and epistemology, in which science is taken as an object of study in itself, mainly with reference to its mechanisms and development. Scientific research is itself taken as an object of research (autotelism). Linear and structural interdisciplinarity are given precedence by the philosophical field.

B. *The ethical field* (or socio-political field) in which the various forms of interdisciplinarity (especially the third) are used as working procedures for the pursuit of a human goal.

C. Lastly, *the educational field* which uses a number of operative techniques for the purpose of training brains able to grasp, in an almost Gestalt psychology way, the unity of reality. We find the first three types of interdisciplinarity here, no longer at the level of creation as a methodology for research, but at the level of cognitive learning, the objective being the transfer of knowledge in an integrated manner—in reality as integrated as logic and teaching allow. Even in the educational field the procedures described above are to be found in full (see the second part of this paper, entitled "Operational approach to an interdisciplinarity curriculum").

Since the distinction among these three operative fields has not generally been recognised, along with the fact that no general agreement has been reached on the scientific and human objectives of scientific research, the heuristic aspects and the application mechanisms of interdisciplinarity are constantly being confused. We think that this uncertainty is reflected in the semantic requirements often expressed by those for whom interdisciplinarity among sciences is a living reality.

The so frequently expressed desire for a common interdisciplinary language no doubt also calls for exhaustive analysis, although we do not intend to undertake it here. But, on the face of it, it can be predicted that the three types of interdisciplinarity may lead to different linguistic requirements. When biologists and physicists, for example, pool their knowledge and experience, what they are hoping to get out of the exchange, at least in the initial stage, is an explanation of their respective languages and concepts which is clear and usable in the context of their joint researches. One could say that this involves a juxtaposition of languages in the framework of linear interdisciplinarity. On the other hand, at a later stage, when the structural interdisciplinarity level has been reached, they simultaneously feel the need for a specific, usually formalised, language capable of expressing the laws which govern the relevant phenomena.

Section 3

TOWARDS INTERDISCIPLINARITY AND TRANSDISCIPLINARITY IN EDUCATION AND INNOVATION

Erich Jantsch
Austria

1. Science and Human Purpose

The draft of this paper had just been put together, when I had the privilege of receiving a copy of the manuscript which Professor Piaget wrote for this seminar[1]. I may therefore be permitted to start my own paper with some cross-references to his thoughts, for up to a certain point, I feel very much in resonance with them. However, I also feel encouraged to venture out farther, and it will make my position much clearer if I try to point out where precisely I leave the platform set up by Professor Piaget's thoughts, as I interpret them.

Professor Piaget takes a courageous stand against positivism, which still dominates academic science—in Europe even more than in America—as well as university purpose and structure. He elevates the discourse from a world of

1. Jean Piaget, "The Epistemology of Interdisciplinary Relationships", p. 127.

empirical facts to a world of intelligible relationships and the focus of scientific activity to the study of structural interactions. This is a fascinating thought because it extends the systems concept—which seems to me even richer than Professor Piaget's "structures"—from the biological and social domains to science in general. Concurrent with this systems notion of science, the assumption is made that objectivity does not reside in facts, but in relationships to be found in reality. This is also the basis on which general systems theory has been established.

Professor Piaget speaks of *causal* relationships and he even calls them *necessary,* which seems to imply that these relationships are understood as being dynamic and that there is a *telos*, or even a *purpose*. But what is this telos or purpose of science ? Is it inherent in an "internal evolution" of the sciences, as Professor Piaget seems to imply ? Does this mean that the purpose is placed in God, or simply in Nature itself ? Or—and here is my point of departure from Professor Piaget's arguments—is it not becoming increasingly clear that man, through science and technology, has become the principal cybernetic "actor" on our planet, that his attempt rationally to construct new and dynamically evolving ecological configurations also burdens him with the main responsibility for this purpose ?

For our discussion, the crucial question is whether science and its internal system, or "structures", of relationships is independent of human and social purpose, or whether there is a feedback link tying them together. We have learned part of the answer by recognizing that not only scientific facts, but also scientific structures can be grasped by the human mind only through what we may call *anthropomorphic modes of organisation*—and we have further learned that these modes are neither isomorphic nor even unambiguous when applied to the structures of reality as we understand them. Modern physics is basically about the creation of anthropormorphic models of an "inhuman" structure of reality.

The other part of the answer, concerning feedback from social organisation and dynamics to science, is finding tentative formulation today with the emergence of "technological man" (Ferkiss) and the first traits of a post-industrial society in the face of growing complexity and uncertainty and a seemingly amorphous, disquieting world *problématique*. Until recently, such a feedback had rarely been explicitly recognized in theories of science and science planning. It seems to me that Professor Piaget's anti-positivistic "structuralism" may also belong to either one of two conventional views of science : science as a basic purpose of society, an autonomous cultural expression (modifying the centuries—old view of science as an individual creative expression, comparable to the arts) ; or science as a social overhead investment, assuming that science "underlies *all* the purposes of society, and is therefore to be carried out in an organisational structure which is patterned on the conceptual structure of knowledge"[1].

Attempts to elaborate on Karl Mannheim's sociological approach to science, his "Wissenssoziologie", and to conceive of science in the framework of a "social construct of reality", generally use a phenomenological approach today which fails to perceive a dynamic and purposive science/innovation system. The same holds for Lévi-Strauss' observation of a certain parallelism

1. Harvey Brooks, Can Science Be Planned ?, in *Problems of Science Policy,* OECD, Paris, 1968. This essay discusses conventional theories of science planning.

in the structures of science and societal behaviour. Most of these attempts try to preserve science as a "value-free" abstraction. Those spearheading a critical sociology (e.g. Herbert Marcuse) who do recognize the dynamics of social innovation and the role of science as instances of human activity, usually disregard the full human potential of purposive design of the social reality through the overall science/innovation system.

Alvin Weinberg's recently propounded view of science as a technical overhead for social goals explicitly recognizes, for the first time, a feedback relation between science and social innovation and suggests a re-organisation of scientific activity in line with recognized social goals. John Platt[1] has brought this view dramatically into the foreground of discussion. This re-organisation takes the form of normative, though fragmented, interdisciplinary approaches, as will be explained in Chapters 3 and 4 below. A certain danger may be seen here in the temptation to take a straightforward (non-systemic) problem-solving approach of the type which has proved so successful in attaining purely technological targets, and to neglect the systemic character of most of these problems in the social area.

A systems approach—as it is proposed in this paper—would consider science, education and innovation, above all, as general instances of purposeful human activity, whose dynamic interactions have come to exert a dominant influence on the development of society and its environment. *Knowledge* would be viewed here as *a way of doing, "a certain way of management of affairs"* (Churchman). Among other things, a new policy as well as new structures for the university may be expected to emerge from such an approach. They will constitute responses to the *specific situation* in which society and science find themselves today, and will be subject to continuous change. As a matter of fact, they ought to be designed explicitly with a view to their innate capacity for flexible change, in accordance with the dynamically evolving situation—in which science may not always play the role it does today.

Thus, we find ourselves in a dilemma : from what point of view should we try to elucidate the structures of science—God's or man's ? What is man's principal task in dealing with science, preception or creation ? Do we want Mozart or Beethoven—the image of man in God, or that of God in man—Palestrina or Wagner—meaningful structure or structured, passionately individual meaning ? Is choice really necessary ? Is there a choice at all ?

The answer is that there is no resolution to this dilemma, that it perhaps constitutes one of the basic paradoxes with which we must learn to live, and which enhance the meaning of human life. The human condition in the scientific-technical era may, again, find its ultimate expression in the spirit of the ancient Greek tragedy, in which man attains his full creative freedom in making the "structures" (not simply the laws) imposed by the gods his own for taking purposive action.

It seems only appropriate, therefore, to develop there a view complementary to Professor Piaget's search for reality in the structures of science and to bring into focus science in the hands of Prometheus. There is no profound contradiction between the two approaches, as long as neither of them is made absolute. *There is not a single system of science, there are as many systems as there are purposes.* No single purpose can ever be

1. John Platt, What We Must Do, *Science* 166 (1969) page 1115.

assumed to prevail, and certainly human purpose has not been in accord with the "purpose of Nature" since mankind entered its psycho-social phase of evolution. Elephants, birds, and insects, if they had science, would all develop systems of science very different from man's, because their purposes are obviously different. The "neutral" state would be natural ecology, from which we have irreversibly departed through science and technology.

I think the most essential feature of both Professor Piaget's paper and my own lies in the consideration of *inter- and transdisciplinarity as organisational principles*, actively modifying disciplinary concepts, principles, boundaries and interfaces. For Professor Piaget, they achieve disciplinary *co-operation* at the same hierarchical level; for me, purpose-oriented *co-ordination* from a higher level. I am not altogether sure, though, that Professor Piaget's concept does not also involve some hidden *ad hoc* co-ordination from a higher level, through a common axiomatics. In both approaches, inter and transdisciplinarity act as *inductive* principles, expressing human systems perception for Professor Piaget, and human systems creation for me.

But the burden of trying to identify and sketch a value-base and a purpose for the dynamic system of science is on me alone. I shall respond by tentatively adopting the notion of *creating an anthropomorphic world* as a general framework for the values to be brought into play, by identifying *self-renewal* as the purpose of education, and by developing an *integrated systems view of science, education and innovation.*

In my view, these assumptions constitute a valid starting point for the conception of a science/education/innovation system which may be considered relevant to the current dynamic situation of mankind which, counting with Julian Huxley, may constitute the fifth big "threshold" in mankind's psycho-social evolution. At each of these "thresholds", a restructuring of the overall system of man, society, Nature and technology has become necessary to ensure the survival of mankind.

Organisation for a purpose implies introducing normative and pragmatic principles which are beyond the traditional notion of empirical and empirical/conceptual science. Which part of the science/education/innovation system is accepted under the name of science, and which is not, is totally unimportant. What matters is that science has to be recognized as part of human and social organisation. The overall systems view will then permit us to discuss the role and structure of the university in meaningful terms, and to formulate operational concepts of inter and transdisciplinarity as key notions for the new university.

2. Education for Self-renewal[1]

We are living in a world of change, voluntary change as well as change brought about by mounting pressures beyond our control. Gradually, we are learning to distinguish between them. We engineer change voluntarily by

1. This part, as well as part 5, is adapted from the author's report on a study project, sponsored by the Massachussetts Institute of Technology during the author's visiting appointment during Spring, 1969, *Integrative Planning for the "Joint Systems" of Society and Technology* — the Emerging Role of the University. Substantial extracts have been published under the same title in *Ekistics, 28,* No. 168 (Nov. 1969), a full Italian translation in *Futuribili,* No. 15 (1969) and a full German translation in the IBB-Bulletin (Vienna, 1970).

pursuing growth targets along lines of policy and action which tend to rigidify and thereby preserve the structures inherent in our social systems and their institutions. We do not, in general, really try to change the systems themselves. However, the very nature of our conservative, linear action for change puts increasing pressure for structural change on the systems, and in particular, on institutional patterns.

We are baffled by the sudden appearance of such pressures for change in the educational system stemming from student unrest and from the notion that the current type of education may no longer be relevant. We are confused by the degrading side-effects of technology on the systems of human life, in the cities as well as within the natural environment. And we are riddled with doubts about the effectiveness of decision-making processes dominated by short-range and linear thinking and about the piecemeal and passive way in which scientists and engineers respond to them. Through its three functions—education, research, and service—the university is deeply affected by all of these pressures for change. To live with them, to absorb them and even make use of them requires a new purpose and a new structure for the university.

Structural changes have to be introduced, both within the university and in its relationships to society at large and to the various elements of the surrounding community. The penetrating and disquieting argument of student activists, that university reform inherently implies reform of our society, cannot be denied. But of all the institutions being challenged today, it is the university which is called upon to lead this process : no other institution is equally well qualified and legitimised.

It is necessary to deal with causes, not with symptoms. The general concern over the university, and above all the students' concern, cannot be resolved with patchwork and compromising, shock-absorbing strategies. There are no clear-cut problems to be solved—the classical single-track and sequential problem-solving approach itself becomes meaningless today. This may come as a "cultural shock" to our pragmatic and efficient society, valuing nothing more highly than "know-how".

The task is nothing less than to build a new society and new institutions for it. With technology having become the most powerful agent for change in our society, decisive battles will be won or lost depending on how seriously we take the challenge of restructuring the *"joint systems" of society and technology*—the systems of which both society and technology are integral constituents, systems of urban living, environmental control and conservation, communication and transportation, education and health, information and automation, etc. The outcome of these battles will depend, above all, on the competence and imagination of people in the key institutions dealing with science and technology : government at all jurisdictional levels, industry and the university. They have, in the recent past, acquired some skill in inventing, planning and designing complex technical systems. More than on anything else, our propensity for actively shaping our future will depend on the extent to which, and on the pace at which, these key institutions—or entirely new types of institutions replacing them—will acquire the capacity for dealing effectively with systems in an integrative way, cutting across social, economic, political, technological, psychological, anthropological and other dimensions. Instead of training for well-defined, single-track careers and professions (by duplicating existing skills), we will need a type of education which fosters judgement in complex and dynamically changing situations. Instead of delivering specialized, piecemeal research contributions and passive consultations, the university ought to take an active role in planning society, and in particular, in the planning of science and technology in the service of society.

Therefore, the leadership role demanded of the university in this vast process of institutional and social change, re-enforced by mounting pressures and crises, derives from its unique potential for *enhancing society's capacity for continuous self-renewal*. This role must now be seen not only as pertaining to the education function, but to all three basic functions of the university: education, research, and service. The alarming split in purpose and operation among these three functions, becoming visible in the university today, goes down to the roots of its crisis. It blurs the overall purpose of the university.

Self-renewal, the new purpose of the university, may be broken down further in line with the principal characteristics of a society having this capacity, as spelled out by John Gardner[1] :

— *Enhancing the pluralism of society*, by bringing the creative energies of the scientific and technological community as well as of the young people, the students, fully into play—not for problem-solving, but for a continuous process of profound self-renewal ;

— *Improving internal communication among society's constituents* by translating into each other the mutual implications of science and technology on the one side, and social objectives on the other, and by pointing out the long-range outcomes of alternative courses of action in the context of broadly conceived societal systems ;

— *Providing positive leadership* by working out measures of common objectives, setting priorities, and keeping hope alive, as well as by promoting experiments in society through ideas and plans, and, above all, by educating leaders for society.

The new purpose implies that the university has to become a *political institution* in the broadest sense, interacting with government (at all jurisdictional levels) and industry in the planning and design of society's systems, and in particular in controlling the outcomes of introducing technology into these systems. The university must engage itself in this task as an institution, not just through the individual members of its community.

The university ought to become society's strategic centre for investigating the boundaries and elements of the recognized as well as the emerging systems of society and technology, and for working out alternative propositions for planning aimed at the healthy and dynamically stable design of such systems.

The major changes which this new purpose will bring to the university include the following ones :

— Principal orientation towards socio-technological systems design and engineering at a high level, leading to emphasis on general organising principles and methods rather than specialized knowledge, both in education and research ;

— Emphasis on purposeful work by the students rather than on training ;

1. John W. Gardner, *Self-Renewal : The Individual and the Innovative Society*, Harper and Row, New York, 1965 ; and Godkin Lectures, Harvard University, March 1969.

— Organisation by outcome-oriented categories rather than by inputs of science and technology, and emphasis on long-range outcomes.

Part 5 will try to outline a few ideas of how these changes may be effectively introduced into the university.

With the new purpose, the education, research and service functions of the university, which have increasingly grown apart, will again merge and, in fact, become one. This emerging unity corresponds to an integral view of the education/innovation system which will briefly be elaborated in the following chapter.

3. A Purposive Education/Innovation System

If education is accepted as being essentially education for the self-renewal of society, it becomes an important, or even the most important agent of innovation. Going even further, we may speak of an integral education/innovation system in which both education and innovation become aspects of one and the same structure of thought and action. Such an education/innovation system constitutes a most suggestive example for the systems notion according to a recent definition : A system is a relationship among objects described (or specified, defined) in terms of information processing and decision-making concepts (Mesarovic).

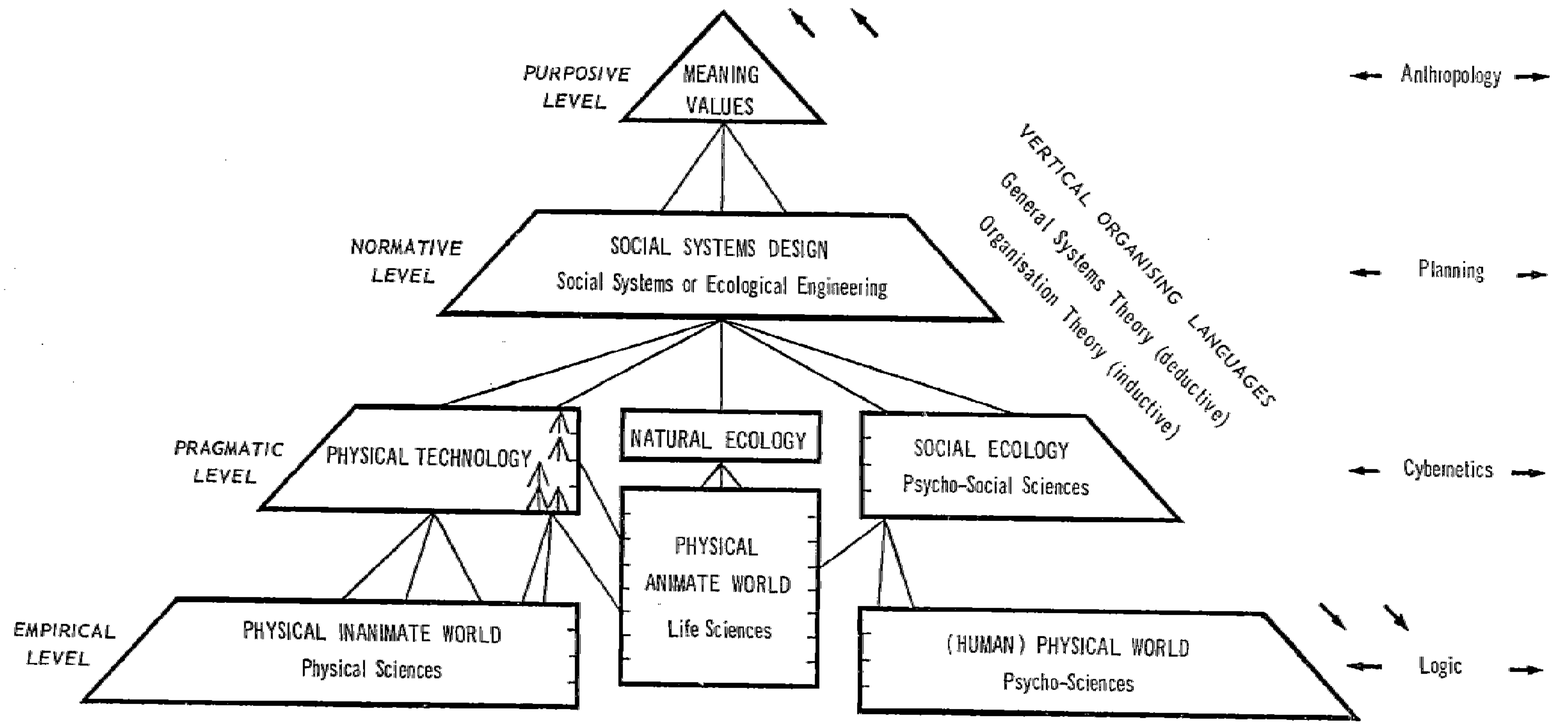
Scientific, or more generally, educational disciplines become organised in such a system in a particular way which depends on the *normative* orientation of education and innovation. The boundaries of disciplines, their interfaces and interrelationships no longer correspond to an *a priori* system of science. In order to emphasize this viewpoint of a *human action model*—as distinct from a mechanistic model—we may simply speak of an education/innovation system, instead of a science/education/innovation system.

Figure 1 attempts to sketch such an organisation in the form of a multi-level hierarchical system. The viewpoint applied here is that of the system of human society and its environment—a *partisan* viewpoint which starts from the assumption that man has become the chief actor in the process of shaping and controlling the system. It may be called the *anthropomorphic viewpoint* which, by definition, cannot be "objective". Nor would it be at all possible to form the notion of an integral education/innovation system without a purposive, thus dynamic, and inherently "subjective" view in mind.

The traditional dissection of knowledge and knowledge-transfer into a variety of disciplines has been developed from another viewpoint, namely that it should be possible to arrive at a mechanistic explanation of the world *as it is* by putting empirical observation into a logical context. Such science has been called by Churchman "simply a defective part of the social organisation." Disciplinarity in science is essentially a static principle which becomes meaningless if considered in the framework of a purposive system. It is no wonder that in a time when science is becoming increasingly understood as basis for, or even integral aspect of, creative human action, the emphasis is shifting to more orless interdisciplinary approaches. However, it has not yet become fully clear what interdisciplinarity and the intermediate steps toward it really mean.

In a purposive education/innovation system, interdisciplinarity has to be understood, as a *teleological* and *normative* concept. Above all, we must ask : *What is the purpose. Interdisciplinarity ?* It involves the organisation of

Figure 1. THE EDUCATION/INNOVATION SYSTEM, VIEWED AS A MULTI-LEVEL MULTI-GOAL HIERARCHICAL SYSTEM
Branding lines between levels and sub-levels indicate possible forms of interdisciplinary co-ordination



science toward an end, in other words, the linking of adjacent hierachical levels in the system as sketched in *Figure 1*, with the aim of co-ordination.

With this notion, and with the introduction of a purpose, the education/innovation system according to Figure 1 assumes a specific meaning in terms of systems theory. Otherwise, it might at first glance appear as a stratified system, where the different strata signify levels of abstraction. Each stratum would then have its own set of terms, concepts and principles. Crossing the strata in the downward direction would give increasing detailed explanation, while crossing them in the upward direction would give increasing significance. Empirical science, in many instances, has been developed in such a stratified way. The biological sciences, with their strata from whole organisms and organs down to cells and even to molecules, provides here the most suggestive example. Possibly, Professor Piaget's "structures" of science may also be viewed as corresponding to such a stratified system, with interdisciplinarity bringing a higher stratum into play.

In a purposive system, or human action model, however, *interdisciplinarity* constitutes an *organisational principle* for a two-level co-ordination of terms, concepts and disciplinary configurations which is characteristic of a *two-level multi-goal system*[1]. The important notion here is that with the introduction of interdisciplinary links between organisational levels, the scientific disciplines defined at these levels change their concepts, structures, and aims. They become co-ordinated through a common axiomatics—a common viewpoint or purpose.

It should be noted here that the four hierarchical levels depicted in Figure 1 are further subdivided into a fine-structure of hierarchical sub-levels. For example, there are such levels between basic technologies and complex technological systems, between relativistic physics and macro-theories such as reactor core physics. The notion of interdisciplinarity may also be applied to links between these sub-levels, which may be formed across different "blocks" of science, for example in biochemistry. What is essential is that a new common axiomatics can be introduced from the higher level.

The ultimate degree of co-ordination in the education/innovation system, finally, which may be called *transdisciplinarity*, would not only depend on a common axiomatics—derived from co-ordination towards an "overall system purpose"— but also on the mutual enhancement of epistemologies in certain areas, what Ozbekhan calls "synepistemic" co-operation. With transdisciplinarity, the whole education/innovation system would be co-ordinated as a *multi-level, multi-goal system*, embracing a multitude of co-ordinated interdisciplinary two-level systems, which, of course, will be modified in the transdisciplinary framework. Transdisciplinary concepts and principles for the whole system change significantly with changes in the "overall system purpose" towards which the top co-ordination function of "meaning" in Figure 1 is oriented. For example, adopting a notion of "progress" (as inherent in Christian thought) at this top level would imply a totally different education/innovation system from one for which "ecological balance", or a notion of cyclical development (as inherent in

1. For the different concepts of hierarchical systems, see : M.D. Mesarovic and D. Macko, Foundations for a Scientific Theory of Hierarchical Systems, in L. Whyte et al. (eds.), *Hierarchical Structure*, American Elsevier, New York, 1969. For a rigorous treatment of multi-level systems, see : M.D. Mesarovic, D. Macko and Y. Takahara, *Theory of Hierarchical Multi-Level Systems*, Academic Press, New York, 1970.

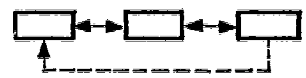
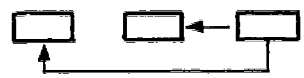
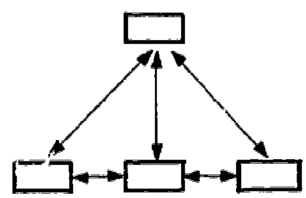
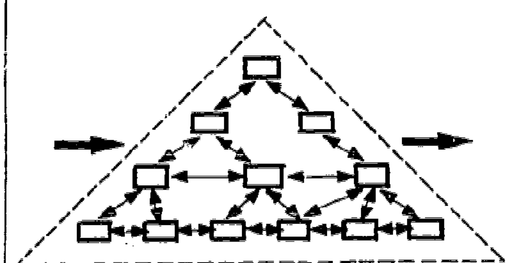
TABLE 1. SUCCESSIVE STEPS FOR INCREASING CO-OPERATI

	General Notion
Multidisciplinarity	A variety of disciplines, offered simultaneously, but without makir explicit possible relationships between them
Pluridisciplinarity	The juxtaposition of various disciplines, usually at the same hie archical level, grouped in such a way as to enhance the relationshi between them
Crossdisciplinarity	The axiomatics of one discipline is imposed upon other disciplin at the same hierarchical level, thereby creating a rigid polarizatic across disciplines toward a specific disciplinary axiomatics
Interdisciplinarity	A common axiomatics for a group of related disciplines is define at the next higher hierarchical level or sub-level, thereby introduci a sense of purpose; *teleological* interdisciplinarity acts between th empirical and pragmatic levels, *normative* interdisciplinarity betwe the pragmatic and normative levels, *purposive* interdisciplinari between the normative and purposive levels
Transdisciplinarity	The co-ordination of all disciplines and interdisciplines in th education/innovation system on the basis of a generalized axiomati (introduced from the purposive level down) and an emerging epist mological ("synepistemic") pattern

Hinduism and Buddhism), were adopted. We arrive here at the same crossroads as in all attempts to view whole systems and aim at their improvement: we lack a deeper understanding of purpose, and thus an unambiguous direction for our organisational efforts. Nevertheless, we cannot hope to act with a true purpose—in other words, to manage the multi-level multi-goal education/innovation system in a meaningful way—if we do not search for and bring into play values and norms, a policy for mankind, to guide education and innovation. Our best efforts must therefore focus on the top structure of the system.

The various steps for co-operation and co-ordination among disciplines, as they are currently discussed with a view to higher education, may now be defined and, at the same time, identified as organising principles for hierarchical systems of increasing complexity, as proposed in *Table I*. It was necessary to introduce here a new intermediate step, which may be tentatively

Ↄ CO-ORDINATION IN THE EDUCATION/INNOVATION SYSTEM

Type of System	System Configuration
ıe-level multi-goal ; no co-operation	
e-level multi-goal ; co-operation (but no co· ›lination)	
e-level one-goal ; rigid control from one disci- nary goal	
'o-level multi-goal ; co-ordination from higher el	
ılti-le· ı multi-goal ; co-ordination toward a ɾmon system purpose	

called cross-disciplinarity and which threatens to blur aims and purposes in the development toward higher forms of co-ordination. As a matter of fact, most of the approaches called "interdisciplinary" today are at best pluri- or cross-disciplinary !

Multi and pluridisciplinarity involve only the purposeless or purposeful grouping of rigid disciplinary "modules". Crossdisciplinarity implies a "brute force" approach to reinterpret disciplinary concepts and goals (axiomatics) in the light of one specific (disciplinary) goal and to impose a rigid polarisation across disciplines at the same level. Only with inter and transdisciplinarity does the education/innovation system become "alive" in the sense that disciplinary contents, structures and interfaces change continuously through co-ordination geared to the pursuit of a common system purpose. *Inter and transdisciplinarity thus become the key notions for a systems approach to education and innovation.*

The education/innovation system, as sketched in Figure 1, is built from the bottom level upwards. This is inevitable since, in a multi-level multi-goal system, the upper organisation levels cannot achieve anything without the activities at the lower levels, just as a conductor cannot achieve anything without his orchestra. On the other hand, this means that two major obstacles on the way to inter and transdisciplinarity have to be overcome : one is the rigidity of disciplines and disciplinary concepts and axiomatics developed at the lower levels ; the other one is the application of lower-level concepts and axiomatics to higher levels. Both obstacles, indeed, prove very severe in the development of a meaningful social science and in current approaches toward an interdisciplinary social technology, as will be discussed briefly below.

At each level, an "organising language" is tentatively identified. This notion goes beyond that of a merely expressive language or deductive science. An "organising language" has the quality of an operator in achieving systemic co-operation and co-ordination. Mathematics seems to be a more ubiquuitous operator, underlying part of the "organising languages". Certainly, there are "structures" implied in these operators, but it may be more appropriate to consider them as anthropomorphic "structures" than as "objective" ones. It would be interesting to pursue this subject further on the basis of a purposive organisation of science.

The *empirical level* in Figure 1, with *logic* as its "organising language", may be subdivided into three bodies of science which all developed from the basis of empirical observation and logical interpretation towards higher levels of conceptualisation :

a) Physical sciences, with the traditional disciplines ;
b) Life sciences, which occupy a special position and extend over both empirical and pragmatic levels, from basic knowledge up to complex biological systems and parts of medical technology ; and
c) psycho-sciences, which include psychology and much of the behavioural sciences as well as aspects of human perception and creative expression, such as the arts and religions.

These sciences aim at describing the world as it is and usually claim "objectivity", a concept which is doubtful, at least in the domain of the psycho-sciences. Interdisciplinary types of teleological co-ordination have become fruitful, particularly between hierarchical levels within the physical sciences as well as between physical and life sciences (e.g., biochemistry on the one hand, and molecular biology on the other) and, to some extent, between the life sciences and the psycho-sciences.

The *pragmatic level*, with *cybernetics*, the science of regulation and control, as the common "organising language", represents a higher level of organisation and may be subdivided into :

a) Physical technology, embracing many hierarchical sub-levels from basic technology over simple technical products to complex technological systems, together with their functional interactions with societal systems ;
b) The more systemic part of the life sciences and natural ecology, which has been successfully harnessed in the development of agricultural technology ; and
c) Social ecology, or simply culture, based on psycho-social sciences, comprising, *inter alia,* history, sociology, linguistics and

communication in general, communicative aspects of the arts, micro-economics, political science (in its narrow pragmatic meaning), cultural aspects of anthropology, and the traditional ethics of the individual. Or rather, there ought to be such a science of social ecology, applicable in a pragmatic way.

One of the two obstacles mentioned above has thus far prevented the full establishment, in an interdisciplinary way, of the pragmatic level. The narrowly interpreted "scientific method", or the part of it which is used to defend empiricism, was transferred to the pragmatic level. Physical technology, in many instances, first developed from empirical observation and logical interpretation, followed by conceptualisation of operating principles, such as found in the steam engine, the steam turbine, and aircraft, to mention just a few. But all these technologies quickly became interdisciplinary melting pots for various physical sciences when the need arose for manipulatability, and therefore for theory. To what extent the technology-oriented axiomatics "trimmed" the concepts of physical science is demonstrated by chemical engineering, reactor physics, aircraft and rocket design, where complex interactions of micro-phenomena are cast into handy macro-phenomenal theories which suit to perfection the needs of specific pragmatic applications of technology.

Such a swift adaptation did not take place in the area of social ecology, or the psycho-social sciences. Here is the profound reason for the frequently denounced lagging behind of the social sciences. As Churchman[1] remarks, "perhaps one of the most ridiculous manifestations" of the disciplines of modern science has been the creation of the so-called social sciences", which pursue the same mechanistic ideal of "objective" empiricism and conceptualisation as the physical science disciplines. "Instead of social science partitioning itself into special disciplines, it should recognize that social science is not a science at all unless it becomes a natural part of the activities of social man." Above all, social science ought to express the potentials of human freedom, creativity, and responsibility. Instead, social science, particularly in the United States, is becoming infested with the reductionist concepts of the behavioural sciences. Neither the old analytical nor the younger phenomenological schools of social science tell us how to conduct our social life, but tend to discourage us from developing any pragmatic or normative, i.e., value-dependent, social science by making us believe that social science is inherently data-rich and theory-poor. The vigorous development of a critical sociology has increased our understanding of the inter-relationships between technology and social science, but does not yet provide useful building blocks for a normative social science.

The *normative level,* with *planning* as its "organising language", deals with social systems design, bringing into focus social systems or ecological technology in its broadest sense. It has as its core Churchman's "ethics of whole systems" and branches out into aspects of social systems technology, such as law, macro-economics, and institutional innovation. Typically, it focuses on large social and man/environment systems, ekistics, and a varity of "joint systems" of society and technology. Few of the fields at this level have as yet found valid frameworks—ekistics may be farthest advanced in this

1. C. West Churchman, *Challenge to Reason,* McGraw-Hill, New York, 1968.

respect—and the current concepts of law and macro-economics hardly meet the interdisciplinary challenge offered them by the scientific/technological era. It is at this level that the broad conceptualisation of man's active role in shaping his own and the planet's future unfolds.

The *purposive level* (or level of meaning), finally, brings values and value dynamics into play through interactive fields such as philosophy, the arts, and religions, structuring in an interdisciplinary way some of the fields at the normative level. The "organising language" at this level ought to be anthropology in its most profound sense, the science of how to create an anthropomorphic world and how mankind may become capable of surviving dynamically changing environments. That most of anthropology today is not much more than empirical behavioural science, illuminates drastically the confusion created in modern science by the traditional cultural postulate of "knowledge *per se*" and the corresponding emphasis on empiricism. Of course, the psycho- and psycho-social sciences will have to provide important bases for the new anthropology through a succession of interdisciplinary "elevations" of their concepts.

It appears futile to discuss what, in the education/innovation system as sketched in Figure 1, should be called science and what should not be. In a narrow, positivistic sense the notion of science applies only to the lowest system level. Whether this science is organised and co-ordinated again by science or by categories of thought and action which are given other names, is a matter of arbitrary definition. What is essential is that inter and transdisciplinary organisation and co-ordination of science are necessary if education and innovation are to follow the purpose of society's self-renewal.

The horizontal "organising languages" of logic, cybernetics, planning and anthropology, in order of increasing systemicity, intermesh with the vertical "organising languages" of *general systems theory* (deductive) and *organisation theory* (inductive). If the education/innovation system is viewed as a purposive system for the self-renewal of society, as outlined above, we should, in Ozbekhan's words[1] "be able to investigate in a more orderly way than has hitherto been possible, whether methodologies arising from anthropology and general systems theory—both of which deal with phenomena that pertain to whole groups—might not be forged into a methodological structure for planning." With such a structure for planning, it will then be possible to link the normative, pragmatic and empirical levels in an interdisciplinary way and ultimately aim at a genuine transdisciplinary co-ordination, i.e. at managing the education/innovation system in an integral way.

4. University Experiments in Normative Interdisciplinarity

How far has the university gone in penetrating the education/innovation system ? Clearly not very far yet. In particular, the education function of the university has not been capable of adjusting to the requirements of interdisciplinary organisation beyond the level of elementary technology. To a large extent, education in technology is still categorised by disciplines and departments called "Mechanical Engineering", "Electrical Engineering",

1. Hasan Ozbekhan, On Some of the Fundamental Problems in *Planning, Technological Forecasting,* Vol. 1 No. 3 (March 1970).

"Chemistry", etc. This had led to two grave consequences. One is a schism between the education and research functions of the university at levels of higher interdisciplinary organisation, which is already becoming a problem at the level of complex technical systems ; university research and development in these areas is increasingly set up and carried out outside the educational structures. The situation has become aggravated by the focus on defence and space research in American universities. The other consequence is a growing mismatch between engineering education and the requirements of industry, which is re-organising itself in terms of technological or even socio-technological system tasks. In the contemporary university or institute of technology, computers and information technology are still subsumed under the heading "electrical engineering" or, at best, have been put into new Computer Science Departments, focusing on the product, the computer, not on its role in society. The growing "alienation" of students from physical science and technological fields of study both in America and in Europe is an aspect of this incapacity of the educational structures to adjust to purposive types of organisation.

The sorry state of the social sciences will not improve rapidly where conventional social science departments deal with the conventional wisdom of empirical or behavioural social science. However, innovative university programmes, particularly some which are geared to undergraduate study, are paving the way for a meaningful pragmatic and normative social science. Theme Colleges of Community Science and of Creative Communication at the Green Bay campus of the University of Wisconsin provide a good example here. Even more significant may become the influence of systems-oriented educational and research programmes, such as Urban, Regional, and Environmental Centres or Departments, which may be expected to create their own approaches to social science if what is readily available is judged to be irrelevant for social systems design.

In the meantime, the social side of the education/innovation system produces a number of cross-disciplinary approaches which all have in common the fact that they fail to recognize the systemic character of science and technology as integral aspects of the "joint systems" of society and technology. One of the most conspicuous attempts at cross-disciplinary polarisation is the reformulation of management, planning, and organisation—even explicitly the planning of change—in terms of the empirical and reductionist concepts of the applied behavioural sciences. Other cross-disciplinary attempts to dominate by imposing specific disciplinary concepts across a level of the education/innovation system, start from economics. Purely economic criteria and linear methods (e.g., econometrics) are applied to scientific research and development, to education, and now also to environmental problems and aspects of socio-technological systems which will be subjected to a crude economy/diseconomy approach. The recent and drastic failure to explain, or at least to describe the "technological gap", a truly systemic phenomenon, in disciplinary terms—as an economic or trade gap, a market gap, a licence and royalties gap, a technological development gap, a management gap, an education gap, etc.—seems already forgotten. The belief of economists in the supremacy of their disciplinary thinking, and the readiness with which their claim is accepted in a materialistic world, constitute one of the main obstacles to a systems approach to education and innovation.

Most of the current university experiments emerging from the social side of the education/innovation system and expressing themselves in structures such as Schools of Public Affairs, Public Policy Programmes, or Programmes in Policy Sciences, constitute essentially *cross-disciplinary approaches*. A good example is Harvard's Programme of Graduate Education for Public Service which started in the Fall of 1969. It is structured into the four main areas of analytical methods, economic theory, statistical methods and political analysis, whereby existing "modules" of concepts and methods (mainly belonging to economics and political science) are employed. The implicit assumption in all these cross-disciplinary attempts is that a rationale can be found which the "hard" sciences and technology may be subjected to without being part of. In other words, science and technology are seen as "neutral" tools which may be put to any use, implying also an unbroken faith in sequential problem-solving. The "seamless web" (Ferkiss) into which human society has been transformed by technology, cannot be grasped in this way.

A less pretentious approach is simply to identify methodological approaches involving pluri, cross and interdisciplinary types of co-operation and to teach them as part of a "common language". A number of courses in forecasting techniques, i.e., as part of the "planning language", have recently been introduced at universities, mainly in the United States. Full-scale normative planning and the systems approach are also discussed in some seminars.

Teleological interdisciplinarity is well established in the modern institute of technology, both in terms of educational and research structures, and in the research (but usually not the educational) structures of the university. Some examples will be discussed in this seminar. But it is not at this first step, which at best links the empirical and pragmatic levels—as much as there is still to do on the social side of the education/innovation system—that relevance to the present situation of mankind can be established. Rather it is at the next higher step, which links the pragmatic and normative levels of the education/innovation system.

The first approaches to *normative interdisciplinarity* become visible where basic themes of society or need areas are recognized and accepted for a fundamental re-organisation of the educational and research disciplines involved. The scientific/technical and the psycho-social sides of the education/innovation system become integrated in these approaches. It is quite obvious that only universities with well-developed structures on both sides can try this. The discussion of whether universities should deal with technology, or institutes of technology should adopt social science—a discussion which, in Europe, is still dominated by a belief in a fundamental polarisation into scientific/technical and humanistic cultures (C.P. Snow's "two cultures")—finds its resolution in the normative systems approach. On the other hand, it still presents a hard-to-overcome obstacle on the university's way to interdisciplinarity reaching up to the normative level.

Some university structures, corresponding to this approach, focus on the *educational* function. Significant large-scale examples are :

— The College of Agricultural and Environmental Sciences at the Davis campus of the University of California, organised in five broad areas of systemic nature, including a systems approach to environmental problems ;
— The Theme Colleges of Environmental Sciences, Human Biology,

Community Sciences, and Creative Communication at the Green Bay campus of the University of Wisconsin, currently geared to undergraduate education, with graduate programmes in preparation ;

— The Programme in Environmental Science and Engineering at the School of Engineering and Applied Sciences of Columbia University, New York ;
— The planned Graduate College on the Human Environment at the Madison campus of the University of Wisconsin ;
— A University of Planning (or Environmental Design) at Solothurn, Switzerland, currently in a preparatory stage.

Other structures focus mainly on research and frequently assume the form of interdisciplinary centres in which faculty members and graduate students, pursuing their "formal" careers in traditional departments, may find a "second home" and some funds for research. Examples are various urban centres (e.g., the Harvard/MIT Joint Centre for Urban Studies), the Harvard Program on Technology and Society, the Center for Research on Utilization of Scientific Knowledge at the University of Michigan at Ann Arbor, the Center for the Study of Science in Human Affairs at Columbia University, and the Program of Policy Studies in Science and Technology at George Washington University. A special research domain (Sonderforschungsbereich) "Planning and Organisation of Socio-Technological Systems" has been proposed in the Federal Republic of Germany, and may soon be established at one or two universities to be selected for a "focal" approach. The weakness of many of these centres lies in their passive attitude, which does not attempt to organise and stimulate research on systemic problems to the degree necessary in view of the complex and interdisciplinary character of such research. To some extent, a certain dominance or even cross-disciplinary claim from the social side may be observed to sneak in, somewhat distorting the original aim.

Among the most significant steps taken toward normative interdisciplinarity are experimental university programmes attempting an *integrated education/research/service approach.* Conventional-type engineering departments may engage in "technology assessment" (i.e., technological forecasting in a social systems context), as has been done at the University of California at Los Angeles (U.C.L.A.). To some extent, Schools or Departments of Architecture, Urban and Regional Planning, or Environmental Design, have always been explicitly or implicitly systems-minded, and have developed half way toward a normative interdisciplinarity dealing with important areas of social technology. The Athens Centre of Ekistics (Greece), with its international mixture of students, may serve here as a small, but stimulating model of a truly interdisciplinary education/research/service approach involving the normative level. More broadly oriented experiments include the following ones :

— Specific socio-technological systems design studies within the framework of the " Special Studies in Systems Engineering" programme at the Massachusetts Institute of Technology ; Project Metran (an integrated urban transportation system) and the Glideway System Concept (a high-speed interurban transportation system) made considerable impact by stimulating thinking and concrete systems and hardware developments, the latter for example, in relation to MIT's Project Transport for a highspeed ground transportation system for the American Northeast Corridor, which became the core of a large decentralized project on a national basis ;

— The Program on Science, Technology and Society at Cornell University, which has recently started up ;
— The graduate Program for the Social Application of Technology (PSAT) at the Massachusetts Institute of Technology, planned to start full-scale in the Fall of 1971 ;
— The planned Center for Advanced Studies — a Systems Center, an Environmental Center, and an Energy Transformation Center, which may well merge into one — at the Hartford Graduate Center of the Rensselaer Polytechnic Institute.
— The Program of Environmental Systems Engineering of the University of Pittsburgh ;
— The Center of Environmental Studies at the University of Wisconsin in Madison, which will also develop educational programs.

These experimental structures usually have their own faculty and are started with a view to becoming the core for larger innovative structures. They already include many elements of the function-oriented departments, and to some extent also of the systems design laboratories, proposed in the following chapter.

On the other hand, the grandiose idea for an international postgraduate "systems university", to be located in Europe — a concept developed by an international committee — collapsed due to the lack of imagination the moment governments, and through them industrial confederations, became involved. The future International Institute for the Management of Technology (IIMT) in Milan, Italy, has now been approved by European governments on the basis of providing a framework for six-week training courses for industrial and public managers.

No interdisciplinary link at the highest level, bridging the gap from the normative to the purposive level, has yet found expression in university experiments. The current struggle for innovation takes place one step down, between the pragmatic and normative levels. Only a number of courses and seminars on values and value dynamics have made a rather modest beginning, and even they are not sufficiently imaginative. *Purposive interdisciplinarity* would correspond to the feedback link between values and normative planning, between anthropomorphic meaning and social systems design. Such an interdisciplinary link would play a decisive role in shaping a new anthropology dealing with the conditions for action and survival in the industrial and post-industrial societies, a new view of human creativity in the arts as well as in planning, and a new understanding of elements entering the guiding images of social policies, from C.G. Jung's archetypal images over explicit values to complex anticipations of the future. It would furnish meaning and criteria to the level of social systems design.

5. A Transdisciplinary Structure for the University

The essential characteristic of a transdisciplinary approach is the co-ordination of activities at *all* levels of the education/innovation system toward a common purpose. Even the more imaginative proposals for new structures and curricular patterns in the university usually stop short of conceiving of such a co-ordinated scheme — perhaps because a clear view of the purpose of the university is still lacking. In this chapter, a possible transdisciplinary structure for the university will be briefly outlined, which the author has tried to develop with a view toward the future of the Massachusetts Institute of Technology[1].

The basic structure of the transdisciplinary university may be conceived of as being built essentially on the feedback interaction between three types of units, all three of which incorporate their appropriate version of the unified education/research/service function :

— Systems design laboratories (in particular, socio-technological systems design laboratories), bringing together elements of the life sciences and the humanities, law and political science. Their tasks will not be sharply defined, but rather broad areas will be assigned to them, such as ,,Ecological Systems in Natural Environments", "Ecological Systems in Man-Made Environments", "Information and Communication Systems", "Transportation/Communication Systems", "Public Health Systems", "Systems of Urban Living", "Education Systems", and the like. These broad areas will and should overlap. Apart from designing and engineering specific systems, these laboratories will have the task of long-range forecasting, identifying aspects and boundaries of systems emerging from the simulation of complex dynamic situations. They will also be responsible for exploratory and experimental systems building at smaller scale, and they will provide opportunities for a throughflow of professionals for their self-renewal.

— *Function-oriented departments,* taken an outcome-oriented look at the functions technology performs in societal systems, and dealing flexibly with a variety of specific technologies which all might contribute to the same function. Examples of such functions are "Housing", "Urban Distribution", "Power Generation, Transmission and Distribution", "Automation and Process Control", "Educational Technology", "Telecommunication", "Information Technology", "Food Production and Distribution", etc. These functions are more clearly defined and constitute more stable "modules" than the socio-technological systems of which they are facets. They constitute need categories which elicit the response of different technological options. Thinking in terms of these categories implies breaking out of the linearity of specific technological development lines, and keeping the view open towards a longer-range future. Education in the framework of these systemic functions in society will become ever more relevant, with industry increasingly adopting a corresponding organisational framework[2]. Apart from developing technological options, which come under the heading of these functions, these departments will emphasize systems analysis of

---

1. See the footnote for Part 2. The author's opinions are not necessarily those of the Institute.

2. Erich Jantsch, New Organisational Forms for Forecasting, *Technological Forecasting*, Vol. 1, No. 2 (Fall 1969).

the effects and side-effects of selecting specific technologies for satisfying needs in these areas, forecasting which will be more properly technological forecasting in its broad connotation, and assessment of the "systems effectiveness" of technologies in the context of societal systems.

— *Discipline-oriented departments* of a more familiar type, but with a somewhat different scope, and comparatively smaller and more sharply focused on the interdisciplinary potential ("valency") of the disciplines. These departments will be mainly set up in the basic scientific disciplines at the empirical level of the education/innovation system and in the structural sciences, including such new fields as computer science.

The three layers of organisational structure focus on the interdisciplinary co-ordination of the purposive/normative, normative/pragmatic/, and pragmatic/empirical levels of the education/innovation system. The accent here is on *linking pairs of systems levels* - in other words on *interdisciplinary organising principles and methods* - rather than on the substance, the accumulated knowledge at the systems levels. *Figure 2* shows schematically how the structures of the transdisciplinary university relate to the levels of the education/innovation systems. Such a university would enhance the internal dynamics, the "life" of the system and thus the selfrenewal of society.

Unlike present university structures, which focus to an excessive degree on knowledge *per se* and (in the technological disciplines) on "know-how", the function-oriented departments will emphasize "know-what" — the quality which Norbert Wiener already put clearly before "know-how" — and the systems design laboratories the dynamic "know-where-to", both of which are prerequisites for our ambitions of actively shaping our future. The discipline-oriented departments, on their side, will make a new and conscious approach to "know-why" rather than "know-how", emphasizing the investigation of basic potentials and limitations for the design of systems, in particular the "joint systems" of society and technology. This approach may be expected to give an entirely new focus to the life sciences in particular, which will then be concerned primarily with the feedback interactions between man and his environment.

The feedback interaction between the three types of structural units in the transdisciplinary university is sketched in *Table 2*. As these structures co-ordinate pairs of system levels in an interdisciplinary way, they are also co-ordinated in their work among themselves, with the systems design laboratories leading the co-ordination of function-oriented and discipline-oriented departments.

We may then envisage a university in which some students go through discipline and function-oriented departments only, while others go through all three types of structural units. As the latter proceed from undergraduate to graduate and doctoral work, they will shift the emphasis of their studies from discipline and function-oriented departments more and more to the systems design laboratories. At the same time they will get increasingly involved with purposeful work in technology or social ecology and actual socio-technological systems design and engineering, which will become a full-time (and paid) engagement during their doctoral work. Work phases and "absorptive" phases may alternate, with the need for theoretical learning being enhanced and guided by practical work. In essence, students will not go

Figure 2. TRANSDISCIPLINARY UNIVERSITY STRUCTURE

The three types of structural units focus on the interdisciplinary links between the four levels of the education/innovation system

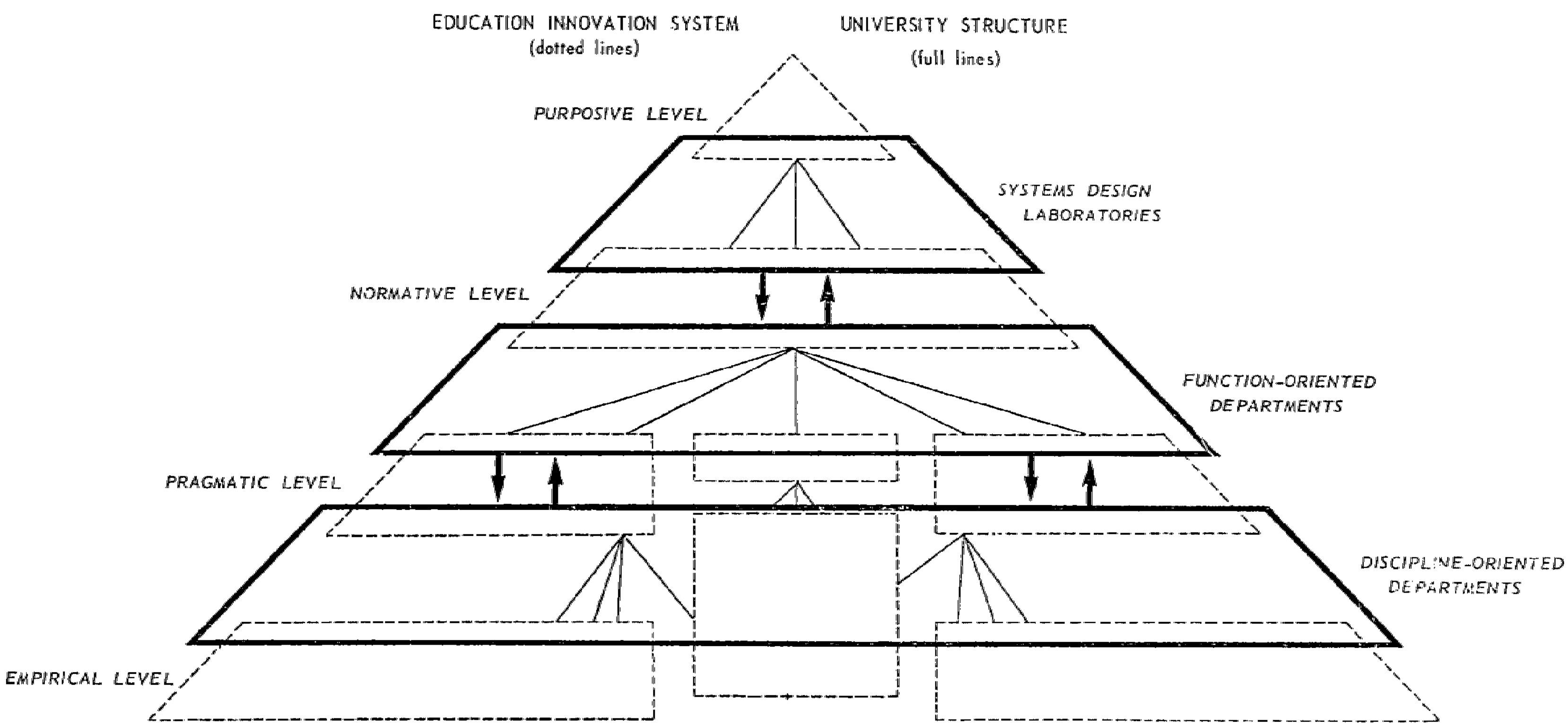


TABLE 2. THE PATTERN OF FOCAL ACTIVITI
All activities are horizontally integrated and vertica

	Education
Systems Design Laboratories	Socio-technological systems engineers
Function-Oriented Departments	Stationary engineers (oriented towards functi and missions of technology, rather than towa specific technologies or scientific/techni skills)
Discipline-Oriented Departments	Specialist-scientists

through these structural types sequentially but interact with them simultaneously during their studies.

Such a university will turn out people with a widely varying education, from specialist-scientists or mission and function-oriented scientists and engineers to full-scale socio-technological systems engineers. The systems design laboratories will also play an important role in the continuous education of professionals, who will probably come back to the university in much greater numbers than today.

One may believe that the outlined three-level structure will give the education function greatly increased flexibility in many respects — for specialized as well as broad (but not superficial) education, for changing tracks, for participation in various actual projects and in various qualities, for combining student and adult education, for stimulating leadership and professionalism, for education geared to various types of careers in the public and private sectors.

An important aspect concerns new dimensions in learning which may be opened up by the change from receiving training to doing useful work. With the university structure outlined here, education will take on more and more the form of selfeducation, and only part of it will occur with the help of "teachers". A student working in a systems design laboratory will be able to judge for himself what working and learning experience he needs from the function and discipline-oriented departments, which he will go back to part time. He will, to a relatively large extent, be able to work out his curriculum himself, and to set his own educational goals and priorities. Education will move away from the stereotypes of today to become increasingly self-education in an environment which provides an infinite variety of possibilities.

This is possible, because the student's work will be judged directly from his contribution to useful work. He may, therefore, graduate and obtain higher degrees without being examined by the rigours characteristic of the

THE TRANSDICIPLINARY UNIVERSITY

rdinated through feedback interaction

Research	Service
egrative planning and design for "joint tems" of society and technology	"Know-where-to" through inventive contributions to public policy planning and to the active development of new socio-technological system structures
ategic planning and development of alter- ives (including innovative technological earch) in areas defined by functions of tech- ogy in a socio-technological systems context	"Know-what" through providing strategic impulses to the development and introduction of technology into systems of society
search at the fundamental level, and develop- nt of theory	"Know-why" through clarification of the logic principles and concepts, as well as the basic potentials and limitations inherent in empirical science

university today. No grading system will be necessary to measure the development of his capabilities. He may not even write a thesis by himself, but make corresponding contributions to team work.

Providing academic careers for all three types of structural units will give immense freedom to the entrepreneurs, and may also change the traditional status system of the university. As a matter of fact, the university professor, as we know him today, may almost vanish, or become almost indistinguishable from the students and professionals, at least in the systems design laboratories and, to some extent, in the function-oriented departments. What today we call faculty members, may be the entrepreneurial leaders of the systems design laboratories tomorrow, and the through-flow of younger and older people would correspond to what is now identified as students progressing in their studies and professionals moving in and out of the university in their almost continuous education.

Viewed in the light of the research function of the university, the basic form of interaction among the three types of structural units will be a translation process in both directions between the dynamic characteristics of real and "invented" socio-technological systems, function and mission of technology, and contributions to them from the scientific disciplines. But the most important task in this process will be the formulation of socio-technological systems engineering requirements in terms of their technological mission and "building blocks". This task will fall primarily to the systems design laboratories.

It is obvious that the traditional concepts of "value-free" science and "neutral" technology will be completely dissolved in the systems approach, as the university proceeds to inter and transdisciplinarity. On the other hand, normative and psycho-social disciplines, such as law and sociology, will lose their abstract disciplinary identity and concepts to become aspects of social systems design. Through a transdisciplinary approach, the university will also maintain its flexibility for future situations in which there may be less emphasis on scientific/technical aspects of social systems design, and more on human and psycho-social development. Some people expect such a shift in emphasis to become significant before the end of the century. A shorter-range effect of the transdisciplinary university may be renewed "faith" in science and technology and a reversal of the current trend towards decreasing interest on the part of students in the scientific/technical side of the education system.

The generalised axiomatics of the transdisciplinary university, as it is currently shaping up in a variety of interdisciplinary experiments, develops around what Dubos calls the "science of humanity", the science of man's total living experience. The transdisciplinary approach having therein found its central theme, which may be understood as the new "universitas", it will be oriented towards humanity. It will give the university the flexibility to abandon linear organising principles, such as those underlying the current direction and momentum of technology and its supporting sciences.

The enhanced "know-what" will not strangle the freedom of education and research, but, on the contrary, will give it deeper meaning. The interaction between the three structural levels of the new university may, for the first time, lead to investigating and actively shaping science policy in a rational and systematic (because systemic) way, and to planning and *implementation in a decentralized way through the university,* at least to a considerable extent. This is what is called, in this paper, the role of the university as a political institution. It will not be easy for the university to maintain its vitality and continously renew itself in the erosive political process. For the first time, the university will expose itself to full public criticism, and may initially suffer from considerable shock in the sudden loss of its protection behind the faceless mask of "objective" science. The fundamental switch toward broad, horizontal thinking across established disciplines will inevitably lead to a transitory crisis period for the university which has developed excellence by penetrating deeply in sharply defined, more or less independently pursued disciplines. However, there does not seem to be any alternative if a rational, one might even say an ecological approach to science and technology is mandatory, as indeed it has to be so considered in the present situation.

One may also envisage an inter-university organisation, roughly of the type originally conceived of for the Institute of Defense Analysis (IDA), to become the "melting pot" and the centre for synthesis of a group of major universities. It would provide a "strategic antenna" oriented toward society's values as well as toward the future, and would maintain a dialogue with the educated public. It would force governments to formulate an overall policy and it would stimulate contributions from those universities backing the organisation. It would guide socio-technological systems design and engineering by giving it the proper framework.

The university will have to maintain close ties with many organisational elements of society, with government at all jurisdictional levels, with research institutes, and with industry. This will not be a passive connection, as it has been so far, but an active role which will also provide a new system of "checks and balances" for ideas and plans, whose discussion will be clarified and enriched by contributions from the actively engaged university. The university will stimulate and maintain the information flow in the government-industry-university triangle, and will interact actively within this triangle in planning for society at large. The systems design laboratories will, in many instances, lead this process by developing innovative design proposals. An economic basis will have to be provided for this type of interaction of the university, with the aim of eventually giving the university the possibility to earn its own income and thereby gain its independence.

Conceivably, the university will also provide methodological aid to both government and industry, possibly through broad horizontal institutes, resembling the "Institute for the Future" recently established in the United States whose first research centre is living in symbiosis with Wesleyan University.

The task of turning the university from a passive servant of various elements of society and of individual and even egoistic ambitions of the members of its community into an active institution participating in the process of planning for society implies profound changes in purpose and thought, as well as in institutional and individual behaviour. It will give the university freedom, dignity, and significance — qualities which have become distorted in a process in which the university is used, but is not expected and not permitted to participate actively. The thorny path to an inter and transdisciplinary university has been outlined in this paper as the way for the university to assume a new and active role in society.

Section 4

MATHEMATIC AND TRANSDICIPLINARITY

André LICHNEROWICZ
Collège de France, France

Through our universities, the training of men and the results obtained from their researches are broken up into disciplines whose fluctuating frontiers are sometimes clearly, sometimes roughly defined. But clearly, as presently used, the notion of disciplines depends simultaneously on several philosophical concepts belonging to different and often contradictory epochs, besides covering different functions attributed to the university. In a preparatory text for the Encyclopedia, Diderot makes a distinction between "science, art and history". To his mind, a science was broadly an effort of knowledge and explanation of a field of phenomena which was defined by that field and helped to define it. An art — we should say a technique — was a s of processes, more or less inspired by science, for construction and action. A history was a descriptive classification of the world, including both the physical universe (natural history) and the social universe. The science, art and history trio which is always unconsciously present should be joined by the "normative" disciplines (e.g., law or grammar in the traditional sense) in order to obtain the labels which still decorate the pediments of the university temples.

As Piaget has so well demonstrated, positivism has merely extended the definition of a science by the field of observable phenomena in which the latter is interested. It is against any truly theoretical enterprise and wishes to keep to observables, only aiming to connect them by numerical laws. The confused attempts at linear classification of the sciences which it inspires are the 19th-century equivalent of the medieval analyses of the "mirror of the

World". That was also the time when everyone believed that mathematicians reigned over quantity and dimension. But although positivism has too long been the explicit philosophy of many men of science, we now know nonetheless that it is not and has never been the implicit philosophy of the scientific enterprise itself, whose ambition is quite different. The so-called "positive" stage is in fact an infantile stage of science.

***

A discipline is now no longer a slow and cautious accumulation of facts and minor laws connecting them together, except in the initial stages. It consists first of all of methods and techniques, as well as an arsenal of concepts and the elaboration of a suitable discourse for translating its conquests ; still more, it is a *privileged viewpoint* over a large fraction of the world and is thereby very often *imperialistic* towards other competing disciplines. This was formerly the case with physics and is today the case with biology which, through ecology, aims to take pride of place in the study of all living systems, including those in which man takes part. Sociology — even Marxist sociology — does not relinquish to economics what it regards as its own province, and searches in vain to understand human geography. History — in the modern sense of the word — pretends to be an overall analysis and synthesis of civilisations, and no human activity over the last ten millennia can rightfully be foreign to it ; hence its difficulty in defining its status in relation to the social sciences.

This imperialistic impulse of one discipline is not unhealthy for the others ; it obliges them to receive, accept and modify points of view and to use concepts, methods and techniques that have come from elsewhere. It reflects the impossibility of a specific definition of fields of phenomena and, paradoxically enough, of the unity of the scientific process. The discipline which is too imperialistic is endangered if it ends up transforming its master words and master concepts into intellectual idols, whereby it may well lose its powers of renewal.

It is of course possible to make any subject such as mathematics, physics or biology, history, sociology, linguistics or economics indifferently the *queen of disciplines* and to claim that in the beginning was the living being, or language, or reasoning, or human society or the working of our minds. I might facetiously add that epistemology or the analysis of technico-social projects could be candidates for this pride of place. But such games are pointless. The overall *"savoir-faire"* which our science and our technology have really become does not allow for *one* inordinately privileged point of view which would only become congealed as a result.

***

Having thus put out a warning against a temptation, I shall immediately yield to it, as Piaget invites me to. What he calls deductive sciences — logic, mathematics in the usual sense of the word, and also information theory — I shall now baptise "*Mathematic*" because it all concords with the mathematical process and its ambition to build up a type of discourse "without background noise" which is coherent and compelling for others and able by its very form to prevent rejection of its content.

Logic may mean either the mathematical study of certain forms of algebra or what is also often called Metamathematic. But we have learnt with Gödel that mathematics is not only infinite downwards — this we have already known for some time — but also upwards and that it is pure convention which now and then makes us put up the sign "Mathematics country begins here". Recently, for specifically mathematical reasons with the appearance of the notion of category, the sign was moved upwards above the concept of sets.

Mathematics has been studying itself for a century and a half and has become aware of its real ambitions and the limits imposed on those ambitions ; it throws an aseptic light everywhere on the workings of our minds and on the conditions of communication, the essential point being as follows : any would-be unequivocal discourse without misunderstandings or background noise can only be a discourse subject to mathematical ascesis, i.e. in fact, a mathematical discourse. But the irony of mathematics should supplement this statement by the following : it is impossible to prove mathematically that mathematical discourse is really unequivocal. Anyone who studies contemporary mathematics' view of itself will observe three major features.

One is first struck, I think, by the *absence of a privileged rank for mathematical beings*. A set (or a category) is, I venture to say, a set of anything — numbers or functions certainly, but also a set of sentences in a language, of elementary tasks in a project or of exchanges within an economy. Various structures can be defined from these sets, the actual concept of structure lending itself easily to a technical definition which has no place here and is based on two fundamental operations concerning sets : taking the product of several sets, taking the set of the parts of a set. *Perfect dictionaries* can exist between sets, respecting or transporting structures, which leads us to the concept of *isomorphism* between structures.

At the same time, there is *no idolatry of the thing in itself*, no charisma, within the mathematical process. The mathematician always works to the nearest perfect dictionary and often unscrupulously identifies objects of different nature when a perfect dictionary or isomorphism assures him that he would only be saying the same thing twice in two different languages. Isomorphism takes the place of identity. Being is put between brackets and it is precisely this *non-ontological characteristic* which gives mathematics its power, its fidelity and its polyvalence. In truth, any fact can be regarded as mathematifiable so long as it submits to this singular treatment of isomorphism or rather exactly insofar as what we overlook in this way is not important to us. We can always weave a mathematical net with an arbitrarily close mesh but from which the ontological wave will necessarily flow away.

A third feature of contemporary mathematics is its *unity*. By making a common language and finding common elementary structures it has cast aside the old historical framework which would have broken it up into disciplines evolving in different ways. That is why we can speak of The Mathematic.

***

For the contemporary scientist, science as a whole is one, by right as in fact. Interdisciplinarity is not seen as a product of fashion but as a necessity for the overall success of research. We shall give a few examples of this.

Anyone who takes science and its unity seriously will regard it as an untearable fabric whose weft consists of the results of privileged analyses and experience with which we encompass reality, while the warp comes from the theoretical and therefore mathematical process.

Our mathematics operates here on two levels : it may be an auxiliary tool for almost all disciplines, used in particular for analysing reality either through information theory or through the statistics and probability approach. It can also make itself an *effective instrument of thought*. The asymptotic ambition of every scientist, whether avowed or not, is to prepare a *mathematical model* for predicting and dominating as wide a class of phenomena as possible with as wide an approximation as possible. Such a model is none other than a more or less rich structure. It is only when a model has been constructed that we consider that the apparent complexity has really been explained and straightened out. You can see how much I am in agreement with Piaget. I shall confine myself only to one or two reservations concerning the concept of structure in a not strictly mathematical sense and concerning the word causal, which I do not favour.

Introducing the concept of a model calls for one or two remarks : first of all, knowing how to put mathematics at one's service also involves not making it say more than it can and correctly throwing full light on the assumptions and approximations peculiar to each field. Assumptions which are too estranged from experience will, mathematically or not, only produce nonsense.

Furthermore, although experience may lead to certain structures being discarded and although concordance with experience is still the imperative condition to prove that we are not vainly theorizing about some imaginary world, in the last analysis the emergence of a new model does not depend on experience but on the imagination of a theorizing mind, since the royal game played by the scientist is only justified *a posteriori*. We are quite a long way from positivism. This was true of Newton as of Maxwell, of Einstein as of Pauli and of Walras as of von Neumann. Quantic field theory and an appreciable part of economics are waiting today for new sufficiently refined models.

Lastly, it is important not to yield to a temptation, as we have done too often, which is to *identify the model with reality*, e.g., to confuse the space of Euclidian geometry with the space in which physical phenomena take place. Such a model is the best reflection, with a certain degree of approximation, of all that we can seriously say today about such physical or economic phenomena. Tomorrow it will be included in a new, more satisfactory model but which we have no more reason for "believing to be true". We must not take to worshipping models.

I should like to quote a few special examples : an entire class of hydrodynamic phenomena is governed by the same formal equations as electrical phenomena. On the basis of this isomorphism, a species of "analogue computer" has been constructed which measures electrical effects and predicts hydrodynamic results numerically thus avoiding the need for expensive, unrefined experiments with small-scale hydraulic models.

Of the readymade mathematical theories, Hilbert's space theory, whose distant origins lie in vibration theory, were responsible, together with the theory of group representation, for elaborating our contemporary quantum mechanics and our theory of elementary particles. This was built up under the influence of Dirac and Wigner and comes from an algebraic idea which is as a whole simple, although the techniques involved are very detailed.

An abstract exchange theory has been built up which applies both to physical exchanges and to economic exchanges. Thus the economics of trade and thermodynamics have received a common framework in which prices and thermodynamic potentials are identified, together with function of satisfaction and entropy. A certain form of production economics with a fixed technology finds its counterpart in chemical kinetics.

This shows the interest of these polyvalent models with their variety of interpretations permitting an exchange of intuitions. Each interpretation represents a different mediation between our desire for rationality and the shock of a more or less refined reality. To some extent, it demonstrates by its very existence our relative clumsiness in mathematifying reality ; at the same time, it is a source of inspiration for our imaginations concurrently with the motivations peculiar to mathematics. It may well soon be possible to elaborate a type of "statistical economics" which is similar to appreciable parts of statistical mechanics and information theory. This might provide a common framework of thought for certain physical, economic and linguistic phenomena.

Elsewhere, the ethnologist Lévi-Strauss has found algebraic structures in the comparative study of systems of relationship through the various civilisations, which he has called structures of relationship, and these are actually structures in the mathematical sense of the word. But I must admit that when Lévi-Strauss wishes to bring in what he calls "myth structures", the concept of structure seems to me to be different and does not convince me as much. Nonetheless, these comparisons have opened up new paths of thought and structuralism shows some realisation by social science of the way in which a science is built up, the rest being "history" in the old sense of the word.

***

There are two theory complexes which reign in present-day thermodynamics as well as throughout a whole portion of economic and social realities and also throughout many organisational problems. One includes combination and graph theory and the other consists of convex programming (optimisation theory), games theory and control theory, both being made most effective by the use of computers. It is the second of these two complexes which concerns me here.

It began about 1930 with von Neumann's work on game theory and its application to economics, and continued with the researches of Kuhn and Tucker concerning optimisation, while more recently we have had the benefit of Pontryagin's general findings concerning the control of an evolving system. Thus, a magnificent instrument of understanding and action has been built up which is *transdisciplinary by its very nature.*

I should like to make two remarks in this connection : first, all the systems we envisage, whether they be physical, economic or social, undergo extensive phases of stability in their evolution, interrupted by shocks (due to sharp changes in liaison, technology, etc.) or periods of instability. This apparent regularity or stability corresponds to the predominant role played in their description by piece-wide *convex functions*, the frontiers of convexity corresponding to the appearance of the phenomena of instability or shock. This is the case in thermodynamics for entropy regarded as a function of extensive variables as well as for the economic functions describing the processes of trade or production (and this is the serious aspect of marginality) or for the information function, etc. This is what explains the role played by convex programming and optimisation.

At the same time, the game is the most serious thing in the world and we all play, or rather we can describe our actions in terms of play. The scientist plays with nature, the manager of a large firm, the authors of five-year plans and the town planners play with economic phenomena, and of course the military play. Many of these games are unfortunately variable coalition games which we are not yet equipped to tackle in any general way. We all play and we wish to elaborate strategies which in the light of our information at any given moment give us the maximum chance of a certain type of gain. Through convex programming, games and control, complex problems which are important for our actions and our life in society have found a unique framework for reflection and are beginning to be amenable to parallel methods where computers play a great role. Some limited problems have been completely solved : it has become impossible to administer stocks, a seaport or an airport and to organise vast projects made up of many elementary tasks without the help of what I shall call game theory in the widest sense and a computer, whether large or small. In other cases, which are most numerous, it is only the approaches which are suggested and these approaches obviously do not dictate solutions but indicate the coherent choices which are in fact possible and, *by simulation on simplified models,* make it possible to study predictions — naturally, short-term ones — based on different assumptions.

*
**

What conclusions should be drawn from this analysis ? Essentially, I think that theoretical activity is homogeneous throughout science and technology, independent of the fields in which it is practised. It is the development and adaptation of this theoretical activity which assume and impose transdisciplinarity. It is also the unique process of theory and experiment which leads us to understand and to act and which inspires "science and art", the powers acquired proving to be the guarantees of our understanding of phenomena and permitting us without any loss to question everything.

Present-day universities must train men who are both independent (if only to preserve their own creativeness and that of society) and capable of taking part in a complex collective activity — in what we shall call a *project.* I should like to sketch out roughly the outline of an education which endeavours to approach such a goal.

For the majority of any age-group, training should consist of three separate activities which take appreciably the same length of time :

1. Methods of expression and representation. Introduction to mathematics, covering: elementary data processing, algebraic structures, convex programming, elementary statistics and probability.
2. Know-how concerning one or (preferably) two fields of physical or social phenomena. Analysis of data, acquiring the main methods and techniques.
3. Participating in an interdisciplinary project, e.g, town-planning, preparing programmed teaching, project concerning an environment problem, functioning of a community, etc.

Our present university system throughout the world trains much too large a proportion of specialists in predetermined and therefore artificially limited disciplines, while a great many societal activities, such as the development of science itself, call for men who are capable both of much wider vision and of focusing in depth on new problems or projects reaching beyond the historical frontiers of disciplines. These are the sort of men we should be educating.

Section 5

THE EPISTEMOLOGY OF INTERDISCIPLINARY RELATIONSHIPS

Jean PIAGET
Faculté des Sciences de Genève, Switzerland

Following usual practice we should of course begin by defining our terminology, and in particular the possible distinctions to be made between interdisciplinary in the strict sense and neighbouring concepts such as multidisciplinary or transdisciplinary. But since definitions are relative to conceptualisations and these in turn are relative to the actual position of the problems, it seems useful to begin by discussing the latter, for they are complex and depend from the start on our interpretation of scientific activity.

1. First, we must distinguish between purely deductive sciences, that is to say, mathematics and logic, and experimental disciplines in the broad sense which are subject to factual verification. The first naturally have a particular independence and are thus in a special position as regards interdisciplinary relationships. We shall therefore come back to them later. The second give rise to the general problem on which the very meaning of interdisciplinarity seems to us to depend.

Insofar as the field of these sciences is restricted, as with positivism, to the analysis of observable facts alone and therefore to the description, measurement and inter-relating of phenomena, we merely discover a set of more or less general or particular functional laws. But as we refuse to seek causes or even modes of existence which might characterise the various substrata underlying the phenomena, we end up having to divide reality into a number of more or less separate zones or superimposed stages corresponding to well-defined fields of the various scientific disciplines. The clearest model of such a conception is the classification of the sciences drawn up by Auguste Comte, who grouped them in order of decreasing generality and increasing complexity. Thus, the elements studied by chemistry easily lend themselves to arithmetic enumeration and geometric description and obey the laws of physics, but they also have a number of specifically chemical characteristics (affinity, valence) which are considered irreducible to the former. The same applies to biology in relation to chemistry, or sociology in relation to biology. Any interdisciplinary research is therefore excluded in advance, for its very principle is con ary to that of natural boundaries separating the various categories of observables from each other. Nevertheless, modern theories based on electronic models of ionic valences or co-valences show well enough how subjective the boundaries between chemistry and physics are and how the search for casual explanations is essential to scientific activity and at the same time provides a source of interdisciplinary connections.

Hence the spectacular difference between modern conceptions of science and the positivist ideal. Since the initial approach is naturally the same, many think they are remaining faithful to its tenets-measuring phenomena, establishing laws, continuous checking with observables, etc. But the transition from experiment to the extremes of observation (relativist and microphysical mechanics) and the constantly increasing conquests of mathematical deduction have strengthened the need for causal explanation, which, moreover, never died out. Only, the novelty is that fulfilment of this need has managed to take a rather unexpected form, hardly foreseeable in the days of classical physics. Whereas the search for explanations for a long time remained limited to attempts at reduction, as if particular laws were justified once they were included in more general ones, or as if, in short, the complex or the higher body could forthwith be reduced to the lower (witness the numerous attempts made, even by Maxwell, to reduce electro-magnetism to mechanism), the development of mathematical constructions and the advance of experimental techniques have led to the fundamental discovery of structures[1]. It goes without saying that an elementary structure such as the group is explanatory, since it is a transformation system comprising invariables and thus ensures understanding at the simultaneous composition of production and conversation which forms causality. But from the viewpoint which concerns us here, that of interdisciplinary relationships, a structure has many other properties.

First of all, it introduces into reality a set of necessary connections, whereas the laws themselves are simply noted as factual data. It is true that the whole system of laws has often been presented as necessary and implying a general determinism. But here there is already the search for a system. Furthermore, so long as the parts of the system are not inter-related by causal transformations, i.e. by structures defined in detail, this necessity is still only a postulate.

Secondly, a structure extends beyond the boundary of phenomena. Only its manifestations are observable ; as a system, it is grasped only by deduction, therefore by connections not observable as such. This does not mean that it remains subjective since its transformations are attributed to reality. But as

1. Generally speaking, a structure is a transformation system presenting laws as a system independently of the properties of its parts and capable of a self-regulation which expresses the fact that the product of its compositions remains within the system. (See our book, *Le Structuralisme*, PUF 1969).

Hume showed decisively, sequences reduced to simple observable data are only regular successions without effective causality, whereas the transformations of a physical structure introduce, through the duality of production and conservation, a set of transmissions which are the sole basis of the causality but cannot be noted by themselves.

Thirdly, insofar as a structure extends beyond the observable, it leads to a profound change in our concept of reality. Far from having a monopoly on objectivity, observables become, in their divisions, relative to our organic tools (perceptions and actions) or recording and information-gathering techniques and, beneath the phenomena, it becomes necessary to invoke a dynamic substratum of operators and transformations. The consequences are obvious. We no longer have to divide reality into watertight compartiments or mere superimposed stages corresponding to the apparent boundaries of our scientific disciplines. On the contrary, we are compelled to look for interactions and common mechanisms. Interdisciplinarity becomes the prerequisite of progress in research, instead of being a luxury or bargain article. The comparatively recent popularity of attempts at interdisciplinarity therefore does not seem to be due to quirks of fashion nor (or not only) to social constraints imposing increasingly complex problems. It seems to result from an internal evolution of science under the dual influence of the need for explanation, and therefore the attempt to supplement mere laws by causal "models", and the increasingly "structural" nature (in the mathematical sense) of such models.

2. But there is more. An obvious consequence of the evolution that we have just described too briefly is that no science develops at one level only ; each comprises various levels of conceptualisation or structuralisation. Hence, each discipline sooner or later has to work out its own epistemology. But if the search for "structures" in the sense of underlying transformation systems is already a basic factor of interdisciplinarity, it is clear that any internal epistemology, aiming, in particular, at characterising existing relationships between observables and the models used in an science, will very soon be an integral part of the epistemology of the neighbouring sciences, not only because the epistemological problems are found everywhere but because the relationships between subject and object can only be discovered by comparative means (or, as we shall see under 4 below, by genetic methods).

While the ambition of modern "logical positivism" is to base "the unity of science" mainly on phenomenalist principles, it has already had to distinguish two quite different levels in each science, namely, the recording of observable data, on one hand, and their translation into logical mathematical formulae on the other, the latter merely forming a "language" which is itself tautological although adapted to the diversity of reality. Now, it can be seen at once that, even reduced to this far too simple duality, diversity of the level itself raises problems of interdisciplinary verification. Indeed, the statement that logic and mathematics function only as a language and do not play a part in conceptualisation or structuralisation is, first, a linguistic hypothesis which involves the relationships between signifiers and signified : and while Bloomfield was cheerfully prepared to leave to writers and theologians the old-fashioned belief that concepts correspond to words, Chomsky now once more subordinates language to thought. Secondly, it is a psychological hypothesis : in this field, however, the operations of logics and mathematics seem to pertain more to the general co-ordination of actions than to purely linguistic behaviour. Finally, such a statement raises serious difficulties as to the relationships between mathematics and physics for, if they go together so well, it is either because logic and mathematics are not tautological or because reality itself is so. The very existence of "structures" and the possibility of attributing them to the universe of physical transformations is sufficient to show that there is a double synthesis in this case and that the purely "linguistic" solution of this basic problem is in no way adequate.

This brings us back to the question which we left pending earlier. If logic and mathematics are entirely independent as regards their demonstration techniques and thus seem to escape from the necessities of interdisciplinarity, this is no longer the case when we pass from their internal procedures to their epistemology. There is first of all the well-known problem of their relationships with each other. These are highly instructive, for neither can be reduced to the other ; for instance, mathematics may be considered as a gradual extension of logic, but logic forms part of mathematics as a particular case of general algebra. This reciprocal assimilation can even serve to characterise interdisciplinarity.

As regards the epistemological relationships between the deductive sciences and other disciplines, there is the problem that the method of the deductive sciences is formal and formalisation is always the axiomatisation of earlier intuitive data even if these are then freely transcended through increasingly independent reflexive construction. Thus arithmetic was first based on "natural" numbers, geometry on elementary spatial intuitions, Aristotle's syllogistics on an awareness of reasoning in general thinking, etc.

This leads us to two types of interdisciplinary considerations. The first deals with the nature of these prescientific intuitions on which formalisation is based, and the second the place of logic in the system of sciences and the difficulties of any linear classification of the latter.

As regards the first of these two points, it could be argued that this question relates only to epistemology and does not concern the sciences themselves or their interdisciplinary relationships. But we should then fail to grasp the scope of a very topical subject of discussion whose significance is strictly an internal matter for scientific research. For example, the nature of elementary geometric intuitions resulting from the spatial properties of the objects, from the actions and operations of the subject or from both at the same time is not only a question of genetic psychology and epistemology but also of the relationships between physical and mathematical space. This relationship can be elucidated to a certain extent by psychogenetic analysis, just as the latter, of course, needs to be vitalised by physical and mathematical epistemologies. The latter have been renewed by the theories of relativity with their geometrisation of mechanics and with the contrast they have introduced between the space-time continuum specific to object space and the intemporal space of "pure" geometry. The discussion has revived in the last few years with the work of Misner and Wheeler on dyamogeometry resulting in a geometrisation of reality even more complete than that of Einstein, but which nevertheless maintains the duality of the temporal specific to the object and the formal intemporal. Thus it is not unreasonable to argue that any analysis of the epistemology of the deductive sciences themselves leads to interdisciplinary problems within specialised technical research.

This raises another problem which is related to the previous ones — the position of logic in the science system. From the standpoint of its formalisation and demonstration technique, logic is indeed based only on itself and has no interdisciplinary problem other than that of its relationship to mathematics. At first sight, therefore, it should be placed at the foundation of the science system. But as soon as we ask what it formalises, the situation changes. This problem can no longer be considered, as it was in the past, as purely ep. emological and thus outside the internal theories of logic : indeed since we know, through these theories themselves, the existence of limits of formalisation, it has become necessary to define the relationships between the latter and what exists beyond and consequently within its boundaries. To take this second point only, we again encounter the problem of structures. Under unproved propositions in the role of axioms and undefined concepts used to define others, we cannot find any state of even relative chaos or disorder, and without this formalisation itself cannot function. We thus discover structures which do not express the contents of consciousness or subjective evidence, but the already co-ordinated operations that the subject is capable of. Aristotle based his syllogistics on these and could have gone further if he had also discovered the structures of relations (the logic of relations as defined by Dr. Morgan in 1860). But then what is the nature of such structures ? Are they psychosociological, psychoneurological, biological or all three at the same time ? In any case they pertain to the nature of man, and in this context logic is therefore to some extent linked to the higher levels of the science system.

If true, this would seem to lead to two conclusions. First, that in the epistemology of even the most formal and deductive science interdisciplinary considerations arise. Second, these considerations seem to force us to consider the science system as non-linear, but turning on itself in an endless spiral, to say nothing of the numerous inter-connections among the terms. To be convinced of this, we need merely look at the numerous attempts to classify the sciences and the difficulties their authors have encountered in trying to fit logic into all the disciplines dependent upon it, but from which it must in turn derive the information required for its own epistemology.

3. This leads us to the human and social sciences, which raise a series of special problems as regards interdisciplinarity.

3.*a.* The first is the absence of hierarchies in these disciplines, as opposed to the partly asymmetrical dependences observed between the natural sciences. In fact, taking the experimental disciplines alone, chemistry is based more on physics than physics on chemistry, and biology more on physical chemistry than the reverse. It is true that such situations perhaps are temporary and we shall come back to the fact that genuine interdisciplinary relationships lead more or less necessarily to reciprocal services, but hierarchies do exist and are probably due to structural relationships. In the human sciences, while it is fairly easy to see that psychology frequently draws on neurophysiology and even general biology (particularly through ethology), it cannot be said that there is a hierarchy between psychology, linguistics, economics, demography, ethnology or sociology itself. It is true that pseudo-hierarchies have sometimes been sought, but as a result of imperialistic tendencies rather than on a basis of objective reasons. This was seen, for instance, in the days of Durkheim's sociology and can be found in certain supporters of dialectics, although they are philosophers rather than scientists.

R. Jakobson recently had similar hopes for linguistics, but while a strict distinction can be made between signifiers (the specific objects of the linguist's research) and what is signified, it is not clear that linguistics can be identified with information theory, even if it is hoped the latter can be turned into a science of science governing all biological and human disciplines (whereas it is the product of an intersection between them).

This absence of hierarchy, which theoretically should have promoted bilateral exchanges, has in fact retarded them instead, for lack of the obligatory hierarchial contacts which exist between the natural sciences. However, here as elsewhere, the progress of structuralism seems to be the main factor in increasing interdisciplinarity in recent times, as shown by the three following examples.

The first is the relationship between linguistics and psychology characterising the young discipline known as psycholinguistics. Linguistic structualism goes back to F. de Saussure, but in his doctrine it was mainly synchronic, invoking the "arbitrary" nature of the sign which makes the current meaning of the words relatively independent of their history. In the context of the psychogenesis of norms, however, particularly as regards the development of intelligence, the final stable forms are the product of progressive equilibration, so that there is a link between synchronic and diachronic factors rather than independence or constraint as in the case of sign systems. This has led to a rather systematic lack of contact between linguistics and psychology and even a deliberate playing down of the latter's possible role by F. de Saussure's disciples. However, the work of Harris and Chomsky on the creative aspect of language and on transformational grammars enabling speakers to construct continually new verbal combinations, shows that the connection between this new linguistic structuralism and psychogenetic research is becoming legitimate and interdisciplinary work ever more fruitful. With reference, for instance, to the already published work of H. Sinclair and the studies she is now directing at Geneva, we must confess that we have been increasingly surprised by the results obtained, which establish far more numerous and specific relationships between the development of language and the formation of mental operations than we would have dared to expect.

The second example deals with regulatory structures rather than systems of signs and operation structures. Such regulation appears, for instance, in problems of value and choice or decision-making as to the anticipated consequences of exchanges or strategies between players. Von Neumann and Morgenstern derived from it a method of economic analysis based on the so-called game theory or decision-making. This method has led to a series of psychoeconomic research studies forming a link between two disciplines hitherto too far apart (with the exception of the rather elementary psychological considerations which were sufficient for Pareto and the marginalists). Moreover, it has been possible to apply game theory to other sectors of psychology (perception, etc.).

The third example is of course the ethnographical structuralism of Cl. Lévi-Strauss, co-ordinating linguistic, juridical (family relation structures in quasi algebraical form) and economic structures in cultural anthropology, a discipline which has been virtually interdisciplinary from the start (although these potentialities had to be realised and not merely left at the multidisciplinary stage).

3.*b*. The human sciences raise a second general problem, namely their relationship with the natural sciences. Certain metaphysicians have tried to contrast them, but nothing much remains of their imagined antitheses except that the human sciences are far more complex, require much more decentring on the part of the subject of the research (since its object still consists of subjects), and therefore they lag behind the natural sciences. The main handicaps the human sciences have are in particular, the lack of units of measurement in many fields (except in economics and demography) and the difficulties of experimenting (except in psychology and psycholinguistics), but these are obstacles which are found in many natural sciences (for instance geology, and sometimes biology, as regards units of measurement ; and astronomy as regards experimentation, etc.) and they have in no way hindered their progress.

It is all the more striking to note the emergence of a number of interdisciplinary relationships between natural sciences and human sciences, and even two-way relationships since certain human science models have been used for physical analyses. Without going back to Darwin, who based his natural selection hypotheses on life in society, we can refer to the parallelism between "information" and the concepts of entropy or negative entropy emphasized in particular by L. Brillouin, and the physical applications of game theory.

3.*c*. But the essential link between the natural and human sciences is indisputably biology, so much so that psychology, which is to a large extent a biological discipline, is as often considered a natural science as a human science. Proof of this may be seen in the existence of animal psychology or ethology, which both zoologists and psychologists include in their respective fields. (This is legitimate in both cases and simply shows that the classification of sciences should provide for cases where activities intersect.)

Obviously, any profound psychological analysis whether it concerns perception, motivity, affectivity or even intelligence, must sooner or later refer to physiology, and we shall not be labouring the point. What is more often forgotten, however, is that the most general structures of the living organism, those of the self-regulating systems (since they govern even the mechanisms of hereditary transmission and are found at all levels of the organism) constitute the most explanatory models for the development of cognitive functions, and in particular of logical operations. Between the general processes of evolutive variation or equilibration of the resulting states and the basic factors in the development of rational knowledge, there is therefore a functional relationship, which is just beginning to be analysed.

One wonders therefore whether biology, as the link between the natural and human sciences, does not characterise a particular type of interdisciplinarity. This would not mean, of course, that the exchanges between biological information and the other forms of knowledge should be different in kind from already known links. But it would amount to saying that, while the applications of mathematics or logic to the various sciences follow the direction leading from subject to object, the lessons the human sciences learned from biology would flow in the opposite direction, from the object (for the organism remains subject to physical chemistry) to the subject, which would be consistent with the circular order of knowledge already indicated.

4. Organised life adds a fundamental characteristic to the peculiarity of

being the source of the acting and thinking subject, indissolubly linked with it. Namely, it has a progressive history and therefore provides the initial model for the "developments" that are found at all levels studied by human science. Biology likewise already implies consideration of a necessary link between structures and geneses. But if it is true that the structuralist view is a permanent motivating force in interdisciplinarity, should we not conclude the same will apply *a fortiori* to the genetic structuralisms common to biology and the human sciences ?

An obvious reason why the genetic approach promotes interdisciplinarity is that the very development of a genesis excludes any absolute beginning and therefore compels the researcher to link up the most distant levels, with all that this implies in the way of connections between the particular disciplines that might be used in studying these different levels. Thus within a single science with well-defined specialities, the study of development constantly compels us to establish links between sectors which initially have no contacts with one other. For example, in biology a fairly detailed analysis of ontogenesis necessarily calls for analyses of the synthesising powers of the genome, hereditary transmission, evolutive variation and of phylogenesis as a whole, without it ever being possible to speak of a "beginning" as such.

We here take another example which concerns us more closely, namely "genetic epistemology", and say at once that this reference to our own interests is not as immodest as it may appear, for it will serve above all to show what still remains to be accomplished. The purpose of these studies is to define the meaning of knowledge in terms of its method of construction. As knowledge is always incomplete and tends to develop by correction, addition or integration into a wider and more coherent system, we felt that a hitherto neglected analysis of the elementary stages would throw some light on the nature of such processes, on the assumption that the mode of accession would be the expression of the mode of constitution itself. Hence there was room for a series of experimental analyses on the formation of logical and mathematical structures, concepts or conservation, kinematic and dynamic concepts, theories of chance and probability, etc.

The first interdisciplinary problem which then arose was that of the relationships between psychology, used here as a method of approach, and epistemology as the research goal ; and numerous critics naturally foretold that we should be stuck in the first of these fields and never reach the second. Although it is easy, when considering a single stage (for example, adulthood), to dissociate psychological problems of functioning and epistemological problems of normative structures or subject-object relationships, the very sequence of stages constrains us constantly to define how the subject moves on from one piece of knowledge to another or from one norm (or lack of norm) to another, considered sooner or later as necessary. All epistemological questions are therefore inextricably linked with those of development, up to levels where the subject reasons in a logically valid manner and possibly attains some particular stage of rudimentary scientific thinking. This genetic analysis therefore forms only an extension of the historical-critical method on which it is incidentally based.

But while there is thus, from the outset, a connection between psychological experimentation and epistemological research, many other associations become necessary. First, of course, that of the logician, for if the transition from one stage to another marks an advance of knowledge, this is a process pertaining to normative validity as much as to factual sequence. It is therefore a question of formalising, as far as possible, the initial and terminal states, marking the gaps as well as the positive additions and comparing these semi-formulations of forms deriving from natural thinking with logically valid structures. Regarded as temporal and factual sequences, these transitions raise a problem of progressive equilibration and therefore of self-regulation, and cybernetics is needed to derive coherent models from them. There remains the nature of the concepts or operations studied and on this point it is essential to obtain the cooperation of specialists in the field concerned (mathematics, physics, etc.) and especially experts in the history of scientific thought in this particular field. Finally, as the structures involved or rather those of which the subject becomes conscious in very incomplete conceptualisations (for here again the structures transcend the observables) are translated by verbal expressions, the cooperation of psycholinguists is also needed in order to determine the connections between language and thought.

Having said this (and the wide range of interdisciplinary relationships needed for this kind of study is already apparent), let us go back to our problem of absolute beginning. In seeking to detect one or more stages in genesis, as we are doing here, we are being quite arbitrary, for the process continues uninterruptedly upwards and moreover has no assignable beginning. At the upper limit we generally stop between the ages of 12 and 15, for until then the child (from 4 to 11-12 years) is constantly creating and inventing most of his own concepts, whereas after this age he repeats lessons and is then integrated into the social current of modern thought. That is why the only valid complement of psychogenesis so far discovered is the history of science, but it is a necessary one.

At the other end, the situation is quite different. The structures studied at the level of representative thought almost all show sensory-motor roots earlier than language. Thus, the sources of logical operations are to be sought not in verbal syntax but much further back in general co-ordinations of action (interlocking action schemas, order of actions, connections, intersections, etc.) The genesis is therefore already very far back but what is the origin of such co-ordinations ? Reference to neurology then becomes essential and everyone knows the famous study McCullogh and Pitts made of the operators intervening in neuronic connections (synapses) and their isomorphism with propositional functors. This is not to say that logic is innate or preformed, for a substantial body of reflective abstractions and reconstructions at new levels are needed for the same propositional operations to function at the level of thought (about 11 to 12 years). But as potentialities to be achieved, these nerve tracts already show an organisation whose genesis still has to be traced, which is a question of general biology rather than psychogenesis. It is then clear how the impossibility of an absolute beginning leads here as elsewhere to linking up distant levels and, consequently, in this particular case, makes the union between psychogenesis and biogenesis indissoluble.

We may even go further, while awaiting that transdisciplinarity which we aspire to (see 5*c* below). One of the great mysteries of the relationships between the sciences is the surprising agreement of the purely deductive constructions peculiar to mathematics with the increasingly refined results of experimental physics (the comments on space in paragraph 2 are only a very limited example). But, from the genetic standpoint it seems impossible to explain this agreement by the very small part experience plays in the formation of logical and mathematical operations, although to refer to *a priori* frameworkers (group concepts etc.), like Poincaré or Hilbert, or to a pre-established harmony only postpones the problem. On the other hand if we refer simultaneously to the structures of the living organism and the self-regulating powers making it possible at each new stage to reconstruct and enlarge what has been drawn from previous stages, the link between reality and the logical and mathematical construction is established right within the organism because the latter is both a physical chemical object among others and the source of the activities of the subject. If this hypothesis is at all probable, nothing could give better proof that the outlook for genetics sooner or later must lead to interdisciplinary cooperation.

5. Lastly, if we wished to draw some conclusions on the nature of interdisciplinarity from the foregoing we should be prompted to distinguish three levels according to the interaction between their components.

5.*a*. The lower level might be called "multidisciplinary" and occurs when the solution to a problem makes it necessary to obtain information from two or more sciences or sectors of knowledge without the disciplines drawn on thereby being changed or enriched. This situation could be a first stage which would subsequently be transcended but would last a fairly long time. This is often observed when research teams are formed with an interdisciplinary objective and at first keep their discussions on the level of mutual and cumulative information but without any actual interactions. Child psychologists who call in other specialists know this kind of collective experience. The consultant will be delighted to tell about his speciality or to enlighten their ignorance and will listen politely to the psychogenetic results which are explained to him, but without finding them relevant to his own problems until a series of facts suggests a possible link with some former level of the history of his discipline and a preliminary exchange becomes possible. But there are whole fields where the multidisciplinary level cannot be transcended because of the persistent heterogeneity of the information used. This is the case, for instance, in geology, where in order to reconstitute the history and explain the formation of a mountain chain, a tectonician requires paleontological data and knowledge of mineralogy to determine the stages of the terrain. Now although such data are so essential to him that he has had to learn these disciplines himselfs, there is no feedback — in other words, tectonics as such will not explain the relationship of paleontological strains or the structure of minerals. Tectonic data certainly play a role in the metamorphism of rocks but cannot account, for instance, for the rotation group etc. which determines the form of the 32 possible varieties of crystalline structure.

5.*b*. We shall keep the term interdisciplinarity to designate the second level where cooperation among various disciplines or heterogeneous sectors in the same science lead to actual interactions, to a certain reciprocity of exchanges resulting in mutual enrichment. But the various possible types of interaction must then be analysed and classified and this is no easy task. Only if our initial hypothesis is correct and the fragmentation of science depends on the boundaries of the observables, while interdisciplinarity results from a search for structures deeper than phenomena and designed to explain them, we may suppose that the types of interdisciplinary interactions will conform to the various types of interstructural relationships, that is to say to forms of linking which, although numerous, are easily intelligible and even become deducible once the structures involved are known.

The simplest form of linking is isomorphism and we can already speak of fruitful interdisciplinary cooperation when specialists in two different fields realise that their analyses lead to similar structures, the data in one field possibly throwing light on the other. When, for instance, ethnographers use linguistic structuralism to decipher a series of myths, it is not a one-way process, for their analyses help to elucidate the symbolical character of the myths and therefore tend towards the constitution of the general semiology earnestly awaited by linguists.

But we must also distinguish two main categories of interstructural isomorphisms. There are those which can be discovered from interactions between two factual sciences, as shown in the previous example, which is one of many possible cases. But — and this is a far more general situation — there are also cases of isomorphism between a deductive or formal structure and a series of experimental facts, as in relationships between mathematics and physics or any of the other factual disciplines. There relationships, however, are at once so general and so specific that usually we do not talk of interdisciplinary relationships between mathematics and the science using them, since they are in fact essential working tools for the latter and even the only possible tool (including logic) for analysis and intelligibility. Nevertheless, we have to distinguish two different situations, of which we refer only to one, the more particular of the two. The general case is that in which logical and mathematical operations are simply "applied" to measure and describe a series of facts so that they lead to formulation of a system of laws. In this general case, there are naturally no interdisciplinary relationships but one-way services, even if sometimes the complexity of the facts brings the mathematician up against new problems which further his work by forcing him to make formulations hitherto unforeseen. But there is another case in which the physicist's work extends beyond formulating laws and therefore describing observables, and is directed towards the search for structures or explanatory models. Here the mathematician's operations and structures are no longer simply applied to reality but (as was said in paragraph 1 about causality) are "attributed" to it, as if the objects themselves were acting as operators and the structures pre-existed in reality before the deductive construction of the subject reconstituted them. It is then that we can speak of isomorphism or at least of correspondence between physical and mathematical structures. This results in the series of exchanges between theoretical and mathematical physics, analysed and distinguished so well by Lichnerowicz, as intermediate steps between experimental physics and pure mathematics. In this fascinating case, sometimes the mathematical structures were already constructed and prepared before use while the physical structures pre-existed naturally before being known; but sometimes the physical structures were discovered in an unexpected form, thus forcing the mathematician to reconstruct and reinvent until he achieved an adequate adaptation to reality. It follows that there are two interdisciplinary problems, one being epistemological, namely the equilibration between form and content up until isomorphism is reached, and the second being technical, involving the mutual enrichment which comes from interactions between two disciplines, one subject to verification by facts, and the other discerning the facts among the set of possibles and conferring necessity on them by virtue of this inclusion.

To come back to more particular cases, interdisciplinary relationships can lead to many other interactions, comparable, in principle, to the possible links between "structures". It is, of course, necessary to consider organisation of hierarchies, not merely in superimposed stages as with observables, but in interlocking structures comparable to the relationships between groups and sub-groups (as in the well-known "fundamental groups" of geometry leading from homeomorphics to displacements by way of projective groups, affinities and similarities). This is the type of hierarchy attained by interdisciplinary relationships between chemistry and physics and we may expect a similar integration of biology into the same hierarchy. Weisskopf has described the rapidly decreasing energy levels which characterise elementary particles, atomic nuclei, the organisation of atoms and molecules and finally that of macro-molecules capable of reproduction, this energy hierarchy thus placing the linkages studied by chemistry in a complete and coherent system of levels which, moreover, probably corresponds to how they were formed historically and cosmologically.

But alongside the interlocking hierarchies of structures and sub-structures which interdisciplinary research may lead to, other types of interaction must be distinguished, such as combinations or intersections between different structures. Combinations between separate sections of mathematics are quite usual as, for example, in the case of algebraic topology, which combines two Bourbaki "mother structures". But apart from the deductive rigour, similar situations are found in interactions between factual sciences. Psycholinguistics, already given as an example, comes into this category in connection with development, since the very object of this interdisciplinary research is the set of possible connections between linguistic structures and other structures of a different type, such as the operative systems of the mind.

Praxeology may be mentioned as an example of intersections since it is the study of the economic conditions of conduct in general. Certain economists have wished to reduce the whole of their discipline to this study, but it is now agreed that it is only one of the aspects of economic activity. It is however an aspect common to numerous fields, covering *inter alia* the controls described by P. Janet in the area of elementary feelings (effort and fatigue etc.) as well, of course, as the economy of the organism in its physiological functioning. It is perhaps the human praxeological experience (least effort for maximum result) which suggested to Maupertuis his physical principle of least possible action.

5.*c*. Finally, we may hope to see a higher stage succeeding the stage of interdisciplinary relationships. This would be "transdisciplinarity", which would not only cover interactions or reciprocities between specialised research projects, but would place these relationships within a total system without any firm boundaries between disciplines.

While this is still a dream, it does not seem to be unattainable and there are two considerations to justify it. The first is the failure of reductionism whenever an attempt has been made to reduce the higher to the lower (or vice versa) and the success of what one might call reciprocal assimilation. We have already noted this in relationships between logic and mathematics. Another equally commonplace example is provided by the relationships between mechanics and wave theory, ultimately co-ordinated in the form of wave mechanics. But we can expect similar processes in the still obscure areas of relationships between the living organism and physical chemical structures. Between premature reductions and vitalist anti-reductionism there is room for broader solutions in which knowledge of the vital will endow known physical or chemical structures with new properties and frontiers will be eliminated, revealing unexpected transformation systems.

Secondly, and perhaps this amounts to the same thing, it should be remembered, as Ch. Eug. Guye often emphasized, that our sciences are at present incomplete because they have purely phenomenalist boundaries. We know the physics of the inanimate but are not yet sufficiently familiar with that of a body involved in the process of living and still less that of the nervous system of an individual in the process of thinking, so that, as this physicist said, physics will become really "general" only after it has encompassed biology and even psychology. Of course, if this were possible, we should then be in full transdisciplinarity.

As for defining what such a concept should cover, it would obviously be a general theory of systems or structures including operative structures, regulatory structures and probabilist systems, and linking these various possibilities by means of regulated and definite transformations. But it is up to the mathematician to tell us more and Mr. Lichnerowicz will enlighten us on this future.

Chapter 2

CONCEPTUAL TOOLS FOR INTERDISCIPLINARITY : AN OPERATIONAL APPROACH

Léo Apostel
University of Ghent, Belgium

SUMMARY

In this paper, it is our aim to compare and evaluate several attempts to develop interdisciplinary research. These attempts have been made by the Movement for Unified Science (Wiener Kreis) ; by the Society for General Systems Research ; by the "Centre International d'Epistémologie Génétique" and related groups at Harvard and Stanford, by the application of general praxeology to the history of Science made by Häkän Törneböhm ; by various groups of scientists and philosophers in Eastern European countries, trying to apply general principles of dialectical materialism to specific fields of science and by considering in "hermeneutics" sciences as systems of symbols (Cassirer). We consider all these attempts fruitful, and we consider — and shall try to show — that none of them is completely successful as yet. We do not think that the future of interdisciplinary research stands or falls with any of these endeavours but we are of the opinion that if we did not have the possibility of showing these initial attempts of non-localised but general interaction, the problem of interdisciplinarity would not be sufficiently mature to be treated, in the present state of crisis and upheaval in general education, as an important, independent and crucial issue.

The author of this paper, an admirer of Bernal's "Social function of science", wanted to start from Bernal's point of view to unify theory and practice.

Bring together Bernal, Carnap, Piaget, Bertalanffy and Cassirer to see what happened — such might be the jocular motto of this paper. It starts from very practical considerations to relate practical problems to highly abstract questions. The reader will have to judge whether the attempt was successful. The paper is divided into the following parts :

A personal preliminary.

i) Science as an activity. Definition of a discipline as an undertaking. Various types of interdisciplinarity as various types of integration of activity within a common whole.

ii) Conditions for the optimalisation of science. Solved and unsolved problems. The present situation.

iii) Different types of interlanguages as optimalising techniques for scientific research. Their advantages and disadvantages.
iv) Application of operations research methods to the research system. Interdisciplinary research as a tool.
v) Conclusion on the educational system.
vi) Final remarks.

***

A PERSONAL PRELIMINARY

The author of this paper is a philosopher, specialising in formal yet philosophical logic. He felt both enthusiastic and uneasy about participating in this project. It seems perhaps the best introduction to the paper to present the reasons for this uneasiness, and the motives for the enthusiasm.

The project recommends certain measures to be taken in the organisation of education and of science. This can only be done on a scientific basis as a consequence of an optimalisation programme. Optimalising research and education, however, presupposes criteria of efficiency, a model of the education and research system, and a solution of the optimalisation problem for them. Not being an economist or a specialist of research administration, the author wondered whether he was at all able to contribute. He thought that he should learn a lot more about operations research than he knew before having the necessary competence to apply it to the optimalisation of R and D (research and development).

Yet he did not give up immediately. Why ? The author believes that his own discipline — logic and the theory of knowledge — can grow only if it contribute to the problem of the organisation and the optimalisation of research and education. Traditionally it is concerned with methods of acquiring new knowledge, with measuring the acceptability of new knowledge, with criteria to be satisfied by knowledge. The author, as an empiricist and a pragmatist does not believe that this concern with knowledge can be effective if it does not come into contact with the knowledge-producing process of the period. So logic and the theory of knowledge should, for their own sake, come into contact with operations research applied to research and development. The logician should change himself.

But, on the other hand, when the author looked into the problem of operations research applied to research and development, he discovered that its practitioners were confronted with traditional logical and epistemological problems (without always being aware of the fact). This must be explained somewhat more completely.

The efficiency of research projects (as of any project) is measured by comparing the cost of its input with the utility of its output. Let us then try to indicate what could be the input into a research project and the output from it.

Let the input into project P consist of :

1. Manpower in number of persons and working hours ;
2. space and buildings ;
3. instruments ;

4. energy ;
5. auxiliaries ;
6. working plans.

Let the output of project P be :

1. skills obtained through working at P (and possessed by a given number of persons) ;
2. mechanisms constructed ;
3. units of information of different types :
   a) observations made ;
   b) laws verified ;
   c) models or theories constructed.

Research work is the set of operations mapping the input into the output. The traditional epistemological problems present here are the following ones :

A. We must measure the utility of the various output items. An empiricist will value the laws and models only as tools relating the observations to each other ; a realist, on the contrary, will only evaluate the observations as tools to implement the models and laws. A method influenced by Kant will give highest priority to the skills acquired. Hence, the utilities will be different for the different outputs, according to different theories of knowledge. We may say more : even if we set the utilities equal to each other, we still have an underlying theory of knowledge.

B. The utility of the information acquired in the output rises with its newness, on one hand, and with its fecundity, on the other. This concept of "utility" has already been encountered in inductive logic by Carl Gustav Hempel who studied various definitions for "epistemic utility". The reader will see the difficulty if he asks himself for a moment what is to be named "new knowledge". It must be new in the sense that it was not derived either deductively nor inductively from other known information.

It must even be "new" in the sense that it could not have been either deductively or inductively derived easily from knowledge already in existence. So the canons of inductive and deductive derivation are presupposed in the very concept of "newness".

Once all this has been observed, it becomes obvious that either the logician or theoretician of knowledge must learn operations research and economics to apply his views (and test their adequacy) or else the economist and operations research specialist must learn logic and the theory of knowledge.

We are thus in the presence of the very difficult problem of the optimalisation of research and education. Within the general framework of this problem, we must examine the special function interdisciplinary research could play in view of this optimalisation. We feel very incompetent ; but we feel others are equally incompetent. So we have the right to make some steps in the direction mentioned, warning the reader that limitations in time and ability make this paper only a very provisional one.

Having thus come to our affirmative decision, and seeing ahead the difficult though promising research problem of how to bring together operations research on R and D and logic or epistemology, we again felt somewhat subdued when thinking about a second question : if this is the way we understand our task, how will other people understand it ? Does the image a philosopher of science has of his task coincide with the image other people have of his work ? Why were we asked to contribute ? It then became obvious that we were asked to contribute for the following reasons.

A. Within philosophy, a certain number of attempts have been made to unify science and to synthetise and integrate knowledge. Can they be used to give form to interdisciplinary research and education, or must they be discarded ? If these attempts are useless, what type of conceptual tools can be used to provide interdisciplinary education and to bring research projects together ?

B. The philosopher is traditionally the person who, for every activity, asks — what is its function ? what is its purpose ? does it have any ? If a student or a scientist asks this question, must he not be able to see the whole of human activity and the whole of the valuational system of his society, in order to localise his own action inside this totality, in order to see its "meaning" ?

We again accepted this challenge and saw that we had to connect these last two tasks to the first one. (All three parts of philosophy — epistemology, metaphysics, and the theory of values — were involved, even though at first we did not dare to notice it, in the technical, political and educational problems of optimalising R and D through interdisciplinary education and research.)

We came to the conclusion that two essentially different attitudes could be taken towards the problem of interdisciplinary research and education. The first approach is essentially an attempt of the global society to obtain complete control over the scientific educational group. The following argument is used : Science is applied in industry and technology in general, and it is consumed by those who learn it. The needs of the consumers (students, industrialists, and the population in general) should be the guidelines for both science producing and the education system. The second approach is the opposite one : Science is a dynamic attempt to mirror the laws of the real world. It must organise to defend itself and its existence against the attempts to subordinate it to external goals. In both these attitudes, however, the common feature was present of wanting to overcome the picture of science as it actually exists. The first group wants to organise science for external goals (by means of either socialist political convictions or a neo-capitalist cost-benefit analysis), while the second group wants to organise it for internal autonomous goals, in the face of the need to convince society to allow an independent experiment costing more and more and having more and more influence to continue.

A philosopher has to take an attitude towards this controversy, he cannot ignore it, so that we suddenly saw that, while others were perhaps unwilling to point out the political character of the problem, we had the responsibility to stress its existence.

Indeed, we have before us at least four different types of interdisciplinarity, and as many types of its rejection :

a) The classical capitalist manager, seeing the forum of science as a free market, where supply and demand, buying and selling occur in accordance with free-market mechanisms, wants monodisciplinary research for the same reason he wants a liberal economy, without any collective organisation in business — essentially because he favours individual production and consumption. His slogan is: organised science is the death of science. Furthermore, he believes that only competitive specialised science, and not the collaborative type, will be selective. This assertion is not meant as a statement about the content of consciousness of the manager mentioned (he is indifferent in these matters) but as a description of his actual behaviour.

b) The neo-capitalist manager, seeking to organise large units in a market that is either an oligopoly or a monopoly, wants to organise science for industry, or in the limit, science for consumption and production. Here interdisciplinarity will be accepted and demanded but as a means to increase productivity.

c) The socialist manager of a centrally direct economy wants to organise science as a whole and direct it towards the realisation of the total goal. If, however, a bureaucratic socialism is achieved, as is often the case, the bureaucracy in charge will essentially use science as a tool and will not tolerate its autonomous organisation. Strong status differences often occur, and a clearly authoritarian organisation of science will make for an organised, but not interdisciplinarian science.

d) The socialist manager of a non-bureaucratic society constantly breaking monopolies, continally mixing social groups, rotating persons from production to research and from research to production, or from one type of research to another, will try to realise a strongly interdisciplinary science. This fourth type of attitude is however not yet clearly established, and more or less utopian in nature.

For reasons not to be defended here, we favour the fourth attitude. The reader should be aware of this bias. Nevertheless, while recognising the political meaning of the undertaking we are engaged in (for the slogan "promotion of interdisciplinary research" is really equivalent to the phrase, "from unconscious to conscious research, from unorganised to organised research, from separated to global research, from isolated to connected research"), as scientists, we should understand that as long as there is no good model of a global society, the organisation of science for "the needs of the society" will not be feasible, as long as there is no efficient mechanism for learning the real needs of a population, it will not be easy to teach and search in the service of these needs, and as long as anthropology does not give us clear answers to questions about the motivation of actions, we will not know how much autonomy to grant the knowlege-gathering process.

This book has a heterogeneous rather than a homogeneous audience. For this reason, we want to study the problem of interdisciplinarity with tools that can be used by both a neo-capitalist and a socialist manager, by a manager-politician or manager-industrialist as well as by a manager-scientist. In the remainder of our paper we shall try to do this. But we want to point out that the development of such a neutral tool will not be an immediate success, and in the long run, will not solve the practical problem that concerns us here. In the long run one has to make a choice, and the choice between types of societies will also be a choice between types of science and education. That choice will never be an idyllic one. In both socialist and neo-capitalist economic systems, there is tension between the science producing group and the overall society, between the organisers who want the maximum amount of intercombinations and those who want the maximum isolation. These contradictions are present everywhere. Peace will never be achieved.

When we want to apply operations research to the problem of interdisciplinary research, we are not lured by the neo-capitalist spirit, for one can apply planning under socialism, and one can apply planning in the service of the search for pure basic knowledge. We think that our definition of a discipline, and our definition of the many types of interdisciplinarity, will serve the needs of this general planning approach.

Again, however, we want to end by warning the reader that we had a very difficult task and that the only way to be of service is to try to make a few strides forward and then to point how much still has to be done and in what direction to go.

Section 1. SCIENCE AS AN ACTIVITY

It is remarkable that in recent years the problem of the definition of a science, or a discipline, and the problem of the classification of the sciences has not attracted many students. As was stated before, we have to come back to this topic.

For our purpose, we have to be as concrete as possible. A science (for instance, biology) is the product of a *group* of people, in so far as they engage in certain *actions* (observation, experimentation, thinking) that lead to certain interactions, only possible by means of *communications* (articles, oral communications, books, including textbooks) geared primarily to the practitioners of the science themselves but also to the outside world. This activity is not called a science until it has the characteristic of *reproducing* itself from one generation to the next by means of a specific educational preparation. Moreover, a science is a *historic* and *dynamic* system, transforming itself in a given way.

Formally, to define a discipline, we thus need to indicate :

1. P : a group of persons ;
2. A : a set of actions, performed by these persons ;
3. I : a set of interactions or communications, among these persons and to other persons ;
4. E : a method of regenerating the set of persons by means of certain communications of an educational nature ;
5. L : a set of historic learning methods.

The quintuplet (P,A,I,E,L) is called one science, one discipline if the five sets satisfy certain restricting conditions. We are not interested here in developing a complete formal theory of this quintuplet, but we might exemplify the conditions by taking the following operational feature. Two documents belong to the same discipline if there are a sufficient number of cross references of these documents to one another or if both documents refer to a sufficient number of common sources. Two scientists are practitioners of the same science if :

a) they had not identical but sufficiently similar educations :
b) they are sufficiently often in interaction with each other ;
c) the type of action they perform is sufficiently similar ;

d) they belong to a sufficient number of common professional institutions.

It is sufficient to look at these definitions to see that they are ordinal definitions. The word "sufficiently" occurs in each of them, and this term is arbitrary. In order to remain objective, we have to avoid it and to say instead that "two persons A and B have a larger probability of being practitioners of the same science than two other persons C and D, if and only if their professional actions are more similar, their professional interactions more numerous, their preparation more similar and their preparatory actions more alike, and their publications more frequently referring to the same sources. We hope it is clear to the reader that the degree of unity of one science is not the same as that of another; and that the expression "practising the same discipline or the same science" does not have a single meaning.

We could perhaps be more explicit about the expressions "practising the same science" or "belonging to the same discipline" by elaborating the following picture: a scientist is to be seen as a system, receiving certain inputs, transforming these inputs in certain ways, producing certain outputs linked to other scientists by means of certain linguistic interactions, provided with certain learning mechanisms that gradually transform the methods of transformation and communication as a function of the results obtained, and that finally this set of learning mechanisms in interaction reproduces itself by means of educational procedures (once again not without causing certain modifications).

A discipline does not exist. A science does not exist. There are persons and groups practising the same science or the same discipline. Our main problem is:

- *a*) that the inputs to all members, or groups of members of the same discipline are certainly not identical;
- *b*) that the work they do is not the same;
- *c*) that the conceptual models or instruments they produce are not identical;
- *d*) that their interlanguage is not the same for all interlocutors; and
- *e*) that the pedagogical procedures are not identical either.

Yet before we say that two persons or groups "practise the same discipline" we must for all these aspects state certain relevant partial similarities. What is the maximal distance on any of these five dimensions that can separate two persons still considered to practise the same discipline?

That is the difficult question Heckhausen and Boisot started out to ask. In view of the questions hereby added to theirs, we finally see a discipline as a pentad, and we should therefore have axioms on the relationships among five elements before possessing the definition of a science. Their answers can thus not be final for us, even though their work is excellent preparation, and even though we cannot add much more than a suggestion: we think that all five mechanisms (observation, thinking, knowledge, transformation, communication and education) certainly ought to be means and ends, each one purpose and instrument for all of the other four processes. We think that for practitioners of the same discipline, the purpose of communication and more often than not of communicational interaction is the modification, both in the receiver and in the sender, of the knowledge producing process. Communication to members of other disciplines, or to the layman (high or low level popularisation) does not have this double purpose of modifying and being modified by the knowledge-producing processes of the other.

But it is important to stress that a single scientific community is not one homogeneous cluster. Within physics, cristallography and plasma physics, electromagnetism and astronomy, are well-defined subcommunities of workers. Within history, economic history and political history are the same (with cultural history to a certain limbo that perhaps already has a certain unity and stability in terms of journals, meetings, cross references, courses, but is not yet as clearly determined as the other two).

The science communities, then, are not homogeneous clusters : there are sub-sciences, and super-sciences. Again, it is not clear what is to be called a sub-science or a super-science : a sub-science of Romance philology is certainly the stylistics of Rumanian and the historical grammar of French, and a super-science is certainly either philology or linguistics. But what is the comparative degree of unity and interaction between practitioners of the same sub-science or super-science ?

An idealised version of the state of affairs would be :

1. the members of a sub-science receive the same education as the members of the science, plus a certain additional amount of information ;
2. the members of a super-science receive part of the common education of all the members of the science ;
3. the members of a sub-science read in common the same journals (or the same amount of equivalent journals) as the members of the super-science, plus certain more specialised publications.

In terms of institutions, one could say that the members of sub-sciences belong to sub-institutions of those institutions to which members of the science belong. But this version is an idealised one, since it is simply not true that the sub-science is merely the science plus something more, and that the super-science is merely a fragment of the science. In the first case, when something is added, something is subtracted ; in the second case when something is subtracted something is added and many things are also modified. If it is well understood that the concept of sub-science and super-science confronts us with many problems, it must also be well understood that, if sciences are not homogeneous clusters, the diameter of the clusters they form is not everywhere and always the same. It must perhaps also be concluded that sciences are historically limited enterprises—they have a life span, are born and die, depending on how profitable the performance of the collective task that is typical for them is. An acceptable "science of sciences" should be capable of indicating the "diameter" of a given science, that is, the average distance between publications considered as publications belonging to the same science, or the average distance between types of information or work or education belonging to the same science. This goal has not been reached at the present time. It is not clear what index of semantic distance one should use for documents. It is not even known how we should measure the distance between tasks. And since all these measures are unknown, it is not clear, for example, whether the "diameter" of the cluster called psychology is larger or smaller or equal to the diameter of the cluster called sociology.

The diameter of the clusters is not always the same, but the distance between clusters is not the same either. We must also take into account that the same person can practise several sciences (Helmheltz was a physiologist as well as a physicist, Pavlov was a neurologist as well a physiologist, and so on). We must have a definition that is both conceptual and operational of "practising a science" such that we can distinguish a man in his professional capacity in different disciplines. The situation is not simple : one man can belong to several disciplines, and one discipline can present different subdisciplines and even different subtasks, where the subtasks are not always subdisciplines. If we consider experimental and theoretical physics, we have an opposition in terms of the type of work done and the method used. If we consider solid state physics we have a distinction in terms of the object studied, whereas if we consider medicine we have a distinction in terms of the practical aims pursued ; preventive and curative, human and animal, individual and group medicine having widely different objectives and methods.

If there are various types of disciplines, of subdisciplines and of superdisciplines, there are also various types of interdisciplines. In other words, sciences, being collective enterprises working on specific materials, by means of specific instruments, pursuing specific aims and expressing themselves by specific communications can be brought to collaborate in various ways. The problem of intersciences is part of the problem of co-operation among the sciences.

It is important to stress that this problem can only be tackled if a thorough division of labour is introduced. Before 1800 it was not impossible for one person to know all the scientific information at mankind's disposal. In 1970 it is not even possible for one single person to know all the relevant information available in the discipline he is working in. This means a qualitative transformation. Only when the different problems became so complex that they had to be subdivided and that only a few individuals could know the information relevant to any given problem, did the problem of the integration of the sciences, of the collaboration of the sciences, become an actual, real issue.

In this section we have not yet considered the importance of collaboration among the sciences, nor the more or less useful forms of collaboration. We shall only do this later. We must ask the reader to be patient while we try once more to understand the conceptual issue.

There are sciences with composite names : biophysics, molecular biology, physical chemistry, social psychology, psycholinguistics, and so forth. If we consider only one important but not all-important aspect of a science, namely, its communication system, we can consider a science to be a language. Let us assume two sciences, L_1 and L_2. We consider that deduction and inductions can be performed within these two languages. Let us give the pompous name of "theorems" to the statements accepted as true in those two languages L_1 and L_2.

Collaboration on this linguistic level means simply using theorems of L_1 and of L_2 together. It could be the case that either by deduction or by induction, either by probability or by necessity, from the conjunction of a theorem of L_1 with a theorem of L_2, a consequence could be derived that would be new and true in either L_1 or in L_2. This is a first, weak, perhaps unimportant form of collaboration. Let us now strengthen this in various ways.

a) First we could consider more or less important statements, measuring the importance by means of the number of consequences following from the statements in question. We then ask that the statement in either L_1 or in L_2 that could be derived from the conjunction be important as well as new. The quality of "newness" is not a clear one, so that to be accurate, one should ask that the consequence under consideration not be derivable from theorems of one of the two languages taken in isolation.

b) We can ask that there be mutual fecundation. In both L_1 and L_2 the conjunction of theorems of L_1 and L_2 has new and important consequences, either inductively or deductively.

c) This interfecundation occurs, however, by means of the conjunction of arbitrary statements of L_1 and L_2. We could ask that more important, fundamental or axiomatic statements of both languages be conjoined, or we could divide the statements of both languages in subclasses and we could ask that statements from all subclasses be combined. The demand would then be that

1. from the conjunction of every basic theorem of L_1 with every other basic theorem of L_2, new and important theorems of L_1 and of L_2 be derived ;
2. from the conjunction of a theorem out of every subclass of the theorems of L_1, with a theorem out of every subclass of the theorems of L_2, new and important consequences in L_1 and L_2 be derived. This requirement is now a very strong one. We could weaken it by asking that interfecundation not occur continuously but only sometimes, or that newness in the syntactical sense not occur continuously but only sometimes, or that not every combination pair by pair yield consequences but merely more do than not. The reader can see many other weakenings.

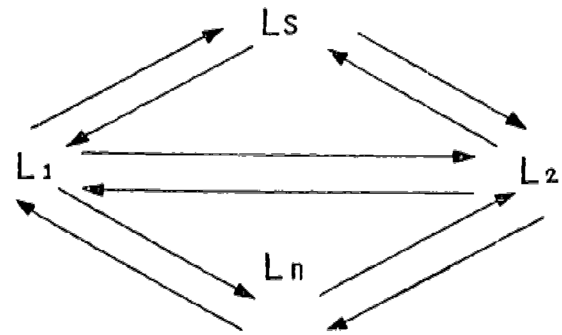
d) In the assumptions made above, we only considered conjunctions of pairs of theorems. We can now consider conjunctions of triads, quadruplets and so forth, the members of which are alternatively chosen either in L_1 and in L_2. Again we can ask that all these combinations yield new and/or important consequences both in L_1 and in L_2.

This variety of possibilities is not exhaustive, however. It could happen that from the conjunction of L_1 and L_2 theorems, statements might be derived that belong to a third language, or to a variety of languages. (Everything depends upon the criterion we use to decide if a proposition belongs to a language.) The maximum creativity would be present if the languages were not existent prior to their production by the linguistic interaction just described. Finally, it could happen that both theorems of L_1 and of L_2 might be derived from a third language that contains axioms and theorems made probable by conjunctions of theorems of L_1 and of L_2.

It thus becomes clear that we can have three fundamentally different situations :

a) interfecundation (L_1, L_2) ;
b) fecundation of Ln by the interaction of L_1 and L_2 ;
c) fecundation of L_1 and L_2 by means of a common abstract of L_1 and L_2.

In these three cases, represented in the drawing



all the weakenings and strengthenings that we considered when looking at interfecundation can again be present.

We considered until now the consequences of conjunctions of propositions of L_1 and L_2. We can, however, also consider the consequences of disjunctions $P_{L_1} \vee Q_{L_2}$, or of implications $P_{L_1} \rightarrow Q_{L_2}$. These types of interdisciplinarity can be combined with all forms of weakening and strengthening mentioned above.

The analysis presented up to now considers only two sciences. We can also consider sciences.

The main questions then become : when does an interscience become a science ? and how long does it preserve its status as interscience ?

Electromagnetism, as Marcel Boisot points out, was an interscience and became a science (a subscience of physics). This could occur because an Ls became strong enough :

a) to be a system in itself ;
b) to encompass completely L_1 and L_2 ;
c) and to have consequences outside L_1 and L_2.

An interscience will not supplant its integrated subsystems as long as it cannot deduce all of their consequences, or as long as it cannot reach the same level of systematic integration as L_1 and L_2 (formally, the system of conjunctions of pairs selected in L_1 and L_2 cannot be economically systematised), or as long as the interfecundation of $[L_1, (L_1, L_2)]$ and of $[L_2, (L_1\ L_2)]$ remains stronger or as strong as the interfecundation of L_1 and L_2.

The picture we have drawn is a static picture, as we announced at the outset. The really important forms of interdisciplinary research, however, are those in which the two mother disciplines are modified by means of the combination of theorems of two or more disciplines. This implies that new laws or facts are discovered that are incompatible with the earlier ones and thus compel us to change L_1 into L_1', and L_2 into L_2'. The strength of the modification is measured by the number of theorems of a given degree of complexity that will have to be asserted after having been denied.

This last remark shows that we cannot evaluate the effectiveness of interdisciplinary research within a theory of interconnections between language systems. We must raise the issue in the realm of the theory of modifications of language systems. Time, the dynamic feature, is essential here.

We have now had the occasion to discuss many forms of interdisciplinary fecundation with reference to only one feature of the scientific system : the communication apparatus. *But — and this point must be stressed — science as an enterprise is much more than a series of texts, articles or text-books.*

As we pointed out, it is a set of actions, of aims, of groups, of developments. We want now to emphasise that if we take a science as a set of actions, we come to possibilities similar to those mentioned earlier with reference to languages.

We gave a linguistic definition of interdisciplinarity. We must, however, also give an operational definition. An interdisciplinary paper is a paper that refers to at least two clusters (possibly more) of papers that do not refer to each other and that do not refer to the cluster of papers to which it itself belongs.

The more equally divided the data, techniques and models used, the more the paper is interdisciplinary. It is also more interdisciplinary, the larger the part of the paper that does not belong to the two (or more) external clusters to which it refers. A person is more interdisciplinary the more he produces interdisciplinary papers, or, if he does not produce papers in isolation, the more he belongs to groups that include practitioners of various disciplines. The degree of disciplinarity is then determined by the number of persons of each discipline and by the distance in the existent institutional framework of these disciplines from each other. This operational definition must be compared with the linguistic definitions, and it prepares the more general definition we shall give.

Let us finally take two sets of actions A_1 and A_2. Interfecundation will occur if co-ordinated (simultaneous or successive) performance of members of A_1 and of A_2 yields results bringing them closer to both the purposes of A_1 and of A_2. Co-ordination will mean performance upon the same or related material, by means of the same or related instruments and/or agents, making use of the intermediate products of both action series.

If we look upon scientific research as a pattern of action, it is clear that *the general problem of the division of labour is really at the core of the problem of interdisciplinary research.* There are two intrinsic limitations to the division of labour :

a) If it occurs, the subdivided tasks must be again related to each other. If not, their usefulness will disappear as in general their products will have to be recombined and the succession of completions of the subtasks will have to be planned accordingly. This co-ordination of the subtasks demands some planning agency that has insight into the global action.

b) If division of labour occurs, it should not be pushed too far. If the action units are so small as to be meaningless motions for those who have to perform them, the monotony of uninteresting and often precise work will counterbalance any gain in efficiency obtained by means of the subdivision.

We thus can see that, in general, division of labour should not be pushed so far as to make integration impossible or too difficult, and it should not be pushed so far as to make the actions humanly meaningless. Yet division of labour has to occur simply because the human mind cannot use too much information and thus must be brought into situations in which much information can be discarded as irrelevant.

The question thus becomes : what type of division of labour is efficient or even optimal for scientific research at given periods of its development? Are there historic situations in which a counter-agent to the trend towards division must be introduced? Is there even an ever-present need for introducing this counter-agent?

Having come to this problem, we see that our definition of a science as an enterprise in which languages occur only as means, and of interdisciplinarity as a specific method of collaboration of enterprises (a method of collaboration that is not uniquely determined but that has many forms, the multiplicity of which we have indicated by studying the interrelations between languages, and generalised to the interrelation between sets of actions) compels us to apply the economic and operational point of view to our problem. We have before us a problem of optimalisation of forms of co-operation. Only operations research can yield the necessary tools, if we want to tackle this problem scientifically.

Before coming to that, however, let us state the problem clearly. We are facing a set of clusters of activity, called sciences. The problem of interdisciplinary research and education cannot be used to wipe out the organisation of this cluster. Quite to the contrary, we want to consider all possible lines joining these clusters together. These lines are taken from the research point of view, using techniques, observations, models, languages of one science in the other science and inversely. Perhaps we should have two lines for every two clusters running in opposite directions.

To every line we want to attribute two coefficients: the cost of this collaboration, and the utility of this collaboration. This will yield us a number showing how profitable this collaboration is. Having done all this, we have to make a decision, for a given community, concerning what types of collaboration to stimulate, and what types of collaboration to slow down. The problem of research has to be done over a second time for education: what types of information coming from one science should be introduced into the preparation of persons going to perform other scientific or non-scientific activities. This picture is not even the whole of our problem, for we have to determine whether we cannot derive from our first map of clusters a second one, having other subdivisions yet built up by using information of the first, and we have to ask the question of the usefulness of pair by pair combination all over again.

But this is not the totality of the organisational problem of interdisciplinarity. We have also to draw a third map. Here we have as clusters all pairs of clusters of the first two maps, with the two profit-capacity values characteristic of their collaboration. We again have to draw all lines between those clusters and determine how profitable they are. Here also a hierarchical list must be prepared.

This process must go on until we reach the point of having only one cluster.

The reader should remember that this process must be run through both for research and education, and that the two processes are not independent.

The answer of the average scientist will doubtlessly be that this job can only be done by history itself. Combinations will occur when they are needed and disappear when they are not.

We consider this point of view to be basically wrong. Our thesis is that the necessary co-ordinations will not occur by chance interaction alone, and the rest of this paper is an attempt to prove this thesis. Useful interaction between sciences far apart in the institutional structure of a given period will not occur as often as they should to optimalise research and education, and moreover, higher order interactions (interactions between interactions) will not occur as often as they should. If this is true — and we warn the reader that the consequences of this thesis are far reaching — a general plan for the whole of interactions of any order must be prepared. Furthermore, it is absolutely crucial to recognise that the people able to prepare this plan must be prepared. Moreover, the institutional framework capable of making this plan effective must be prepared. What requirements can we impose upon the plan ? What are the intellectual problems we have to solve in order to organise research ?

If we accept the definition of science as a specific kind of enterprise, we have in this definition a new principle for the classification of science.

Man lives in a physical environment. He wants to protect himself against this environment by predicting it and by modifying it. We may call physics the primary system that undertakes this task. The distinction between physics and chemistry can perhaps be made in practical terms : physics is interested in undertaking those interactions that modify the external relations of the systems we work upon, whereas chemistry is interested in modifying their internal relations. (The transmutation of the elements is the paradigm of chemistry while the transportation of heavy loads or energies is the paradigm of physics.) But mankind as a group of agents also produces a number of relations between these agents. We again want to transform this group of relations in the service of our needs. The behavioural and social sciences would try to perform the tasks under discussion. Our view of science as an enterprise would make it important to develop sociology in interaction with social engineering, physics in interaction with physical engineering, psychology in interaction with pedagogy and psychotherapy.

If to know is to transform, to modify, to act upon, and not to model, to reproduce, and if we accept in the philosophy of science the point of view that has been for so long accepted in the arts, namely, that photography is not painting ; sound imitation is not music, then the aim of knowledge is a certain creation (as well as a creation of needs, and at the limit, creation of a new, or many new types of mankind), and the conception of science as an enterprise really comes into its own.

It also becomes clear at this point that this total creation can only function as a whole. The production of new internal relations in physical systems (chemistry and chemical technology), the production of new external relations between them (physics and engineering), the production of new types of producers (psychology and pedagogy) and the production of new types of relations between producers (sociology and politics) can only be efficiently undertaken if it is undertaken as a whole. Why ? Because new productions imply new producers and new producers new products ; because new external relations between products imply new relations within products, and new relations in and between producers.

Let us take an example : history can be defined as a preparation for politics (let us pray here for the indulgence of both historians and politicians), the study of the irreversible transformations of groups of producers. But chemistry also studies within the objects to be modified and produced irreversible transformations between producers (and in the world of objects some objects play the role of producers of other transformations).

So it is natural to have a standing working group on the relations between history and chemistry. (The reader should understand that we take this example, suggested by Asa Briggs, because it does not come naturally to mind, and because it can only be organised if one has understood the overall picture of science that we are defending here.)

However, wouldn't the study of another irreversible development, namely evolution or cosmogony, be just as interesting for historians as the study of chemical reactions, and isn't the study of historical developments equally fruitful for evolutionary biologists and for cosmogonists ? From a speculative standpoint, it certainly is and perhaps even more so. But in chemistry we intervene, just as we do in history. From our point of view, where knowledge is action, the interdisciplinary teams history-chemistry should receive priority over the interdisciplinary teams of evolutionary biologists, cosmogonists and historians, but all of them should exist. To take another example : aren't a group and a polymer structurally similar even if the forces drawing them together are very different ? But are our actions and our action instruments also similar in both cases ? One thing is certain : so few forces exist in the universe that a diversity of forces cannot justify a complete separation of efforts.

The reader should be cautioned that science as an enterprise could also be defined as an activity having as its aim the construction of models (basic science) or the transformation of its object (applied science). In both cases the economic and operational point of view could still be applied and in both cases the problem of how to define the efficiency of research and education could be discussed. How can they be optimalised ? How can interdisciplinary research be used to contribute to this optimalisation ? How can the probable effectiveness of certain types of interdisciplinarity be evaluated in comparison with the effectiveness of other types of interdisciplinarity ?

In the section on the application of operations research to science and education, we are going to show as many models as possible of the problem of choosing between monodisciplinary and interdisciplinary research. We cannot solve the problem but we can show how it can be transformed into many other ones, that are in principle solvable, because they are analogous to problems already solved.

Here we only wanted to show that our definition of "discipline" implies a certain classification of the sciences and that the problem of interdisciplinary research is related to the problem of the classification of the sciences.

We shall first try to draw a picture of the relevant variables of present day science and technology, using historical data, and bearing in mind our main argument that a study of spontaneous development shows that a qualitative re-organisation of research and education is needed, but that the same spontaneous development cannot bring this re-organisation about.

Section 2. THE PRESENT SITUATION IN RESEARCH

1. Science is growing according to an exponential function. The growth of science can be measured by the number of articles published every year, or it can be measured by scientific manpower. Since 1700 the growth rate is constant. Both papers and men have doubled in number every 15 years. (De Solla Price, p. 8.) This rate of increase is faster than the rate of increase of the

total population (p. 14). "Every doubling of the population has produced least three doublings of the number of scientists".

Let us ask what is the relevance of this fact for our problem. First, number of scientific projects will increase even faster then the number scientists. If this is the case then it is more and more improbable that projects can be executed. In that case, selection criteria must be found a applied, and methods for modifying unexecuted projects must be examin These methods must take into account the impact of executing or neglecti the proposed projects on technology and the economy in general, and other accepted projects in particular. Therefore, it is necessary for the guidi agency to have a total map of the interrelations between the several ongoi projects. Moreover it is useful to interiorise into every practising scientist map of these interrelations so that he channels his energies in the direction acceptable projects, not losing time and energy in proposing and defendi unacceptable ones.

A second consequence, it seems to us, is the fact that the proportion extant science that every single scientist has at his disposal is diminishi every generation. This makes communication between scientists more a more difficult, and weakens their social strength, diminishing the probabil of collective action, except in regard to their claims on the national budget.

2. Deductively we can say that either the total population will becor scientists, at the limit, or that the growth of science will decrease and that t exponential curve will become a logistic one. De Solla Price choos the second extrapolation and examines what happens to other exponentia growing phenomena that go into logistic growth. On p. 31 Price tells u "Clearly there will be rapidly increasing concern over those problems manpower, literature and expenditure that demand solution reorganisation. Further, such changes that are successful will lead to a fre escalation of rapid adaptation and growth.

"Changes not efficient or radical enough to cause such an offshoot w lead to a hunting, producing violent fluctuations". This prediction implies th science will not continue its uncontrolled growth but that attempts towar organisation of the process will be made. These attempts imply knowledg vastly more important than that now available, about the interrelations of t various disciplines. Science can only be organised as a total system, so th scientific organisation implies the application of the systems approach to t totality of scientific research and education.

Another conjecture may be made : if the growth impulse continues and the number of producers and the number of products (articles) cannot b increased (saturation level), then it seems probable that the intensity ar variety of interpenetration of production forms will increase and that mo information will be included in every communication, i.e. the level generality and inclusiveness of every article will have to increase also. Whe these two conjectures are combined, we can state that :

a) uncontrolled science will be followed by organised science ;
b) the closer to the saturation point the system gets, the closer to uni it will arrive.

3. Price finds a version of the Zipf law true for scientific research — th number of authors publishing exactly n papers is a function of n. This show

how inefficient scientific production is. Most of those who participate in it have low production rates. The Zipf law is also applicable to the amount of use made of scientific papers. A few papers are quoted very often, but most papers are quoted very rarely. This again shows low efficiency, since the energy spent in writing most papers is largely lost. The consequence is a strong, dictatorial organisation of the whole and an immense loss of energy. According to the Pareto law for the distribution of income the distribution of intellectual production seems to be between $1/n$ and $1/n^2$. In order to increase the efficiency of the expenditure in education for the formation of science producers, either the inverse square distribution should be destroyed and greater equality in production insured by psychological measures — and then the question is entirely open as to what these might be — or, by means of grouping and organising low producers among each other and with high producers, their output rate should be increased. The latter measure seems to have more chance of success than the first, because it is easier to influence social structures than psychological ones.

It ought to be stressed that Price should not be held reponsible for the conclusion just drawn. He himself seems to consider unequal distribution of productivity as a natural phenomenon that cannot be overcome. (See pp. 56 and 57.)

However, if it can be proved that a more equal distribution of productivity will not decrease the productivity of the high producers (and we have not seen arguments to that effect), a clear case can be made for a more flattened distribution.

Science as it stands is characterised by big inertia (creation of new centres is slow) and strong resistance to change as the effect of the strong authority of those in charge. If now the distribution were more democratic, the resistance would be less, and this resistance would be further decreased if authorities in very different fields were compelled to co-operate. They would be compelled to learn continuously from each other, and thus less authoritarian modes of organisation would necessarily come about. It is not from humanitarian values that we recommend the socialisation of the giants and the collectivisation of the dwarfs, but in the interests of the efficiency of the overall process.

It will again be obvious that if this point if view is adopted, it will not come about spontaneously but only through organisational measures taken by the whole scientific community, for there is strong resistance to giving up power and vested interests.

Another symptom of the low efficiency of research is the large amount of overlapping papers. The most illustrious form of this illness is the frequency of multiplex discoveries. Price, on pp. 66-69, using Merton and Barber, makes this point very clearly. Science thus cannot be left to itself. It functions poorly. This state of affairs is more deplorable the larger scientific production becomes. It is now clear that the present talk about the information explosion, that makes all channels of communication pour out so much information that use can no longer be made of it, implies the necessity for reducing the amount of information circulating in the scientific system. This means introducing redundancies ; this again means communicating upon a much higher level of generality and abstraction, and reducing by these means the amount of communications to be decoded by any possible receiver. This is one method to decrease the number and length of communications any science producer must digest. There is another and complementary measure. It is possible when for the competent production of any given paper, m papers have to be read and when this number is too high for any given individual, to get together r individuals that taken together can manage the necessary amount. These groups will have a better change to scan the whole relevant field if their participants are not replicas of each other but rather are divergent. Being divergent the groups must include either scientific translators who are capable of understanding the different languages of the group, or else each member of the group must be trained in such a way that he can learn very different languages. This means that he must receive an education in scientific method and basic science that enables him to go easily from one subtask to another.

Price, pp. 87-88, quotes a fact that is very important in this respect : "the proportion of multi-author papers has accelerated steadily and powerfully, and it is now so large that if it continues at the present rate, by 1980 the single author paper will be extinct. It is even more impressive that three author papers are accelerating more rapidly than two author papers, four author more rapidly than three author and so on" (p. 89). This is doubtlessly a symptom of the phenomenon we just described.

5. A final fact is that the cost of science has been increasing as the square of the number of scientists" (Price, p.92). Science, attracting more and more people, in the more advanced countries (USSR, USA) now consuming 3 per cent of the gross national product[1], seems to demand more and more in order to make the next increase in manpower and in discovery. The reasons for this are perhaps manifold : competition increases, so that more inducements have to be offered ; economic relevance increases, so higher wages are due ; the difficulty of finding facts increases the more facts we know ; more important instruments have to be used. Something like a law of diminishing returns seems to hold in science also. This fact again makes organised science necessary. And now we come to the final argument in favour of interdisciplinary research : studies on scientific creativity have shown that the most creative person is the one able to bring unexpected ideas together. If this is true, then, as the cost of science is rising, the productivity of scientific thought (this means personal creativity) must be increased, and so the possibility of associating widely different levels has to be encouraged. But in as far as more and more organisation has to be imposed upon the scientific community, one must organise for the unexpected, and organising for the unexpected means organising interdisciplinary research systematically, bringing together seemingly completely unconnected ideas from fields very wide apart.

6. If then a sizeable portion of the national income is to be spent on science (a new phenomenon), the expenditures cannot be made haphazardly. How should we allocate our scarce resources so as to optimalise research activities ? We shall present different criteria with the following ideas in mind.

---

1. Let us state, as a side remark, that we are not impressed. It seems very suspicious to us that this *low* investment comes under such close scrutiny and provokes such amazement or admiration. This reaction is the expression of a value judgment for which we want to know the origin !

A. These criteria can be applied only if interdisciplinary research that is not in existence is institutionalised and developed.

B. The same criteria give high priorities to interdisciplinary research.

Alvin Weinberg, in his much quoted article, "Criteria for Scientific Choice", gives both internal and external criteria for the selection of scientific projects.

He applies three external criteria : scientific merit, technological merit, social merit.

The first criterion, scientific merit, in the formulation he gives to it, leads us immediately to the problem of interdisciplinarity. On page 28 he states "that field has the most scientific merit which contributes most heavily to and illuminates most brightly its neighbouring scientific disciplines". Why does he come to this formulation ? In his own view the reason is philosophical : reality exists as a whole : science seeks the knowledge of this whole ; every subdivision of labour is artificial with reference to this whole and so those projects that overcome most deeply these artificial subdivisions are to be preferred.

We are in complete agreement with this argument. It has, however, the unhappy defect of not convincing administrators and dedicated specialists. So we have to look for another justification of this criterion. In order to find one, we have to analyse more deeply the nature of scientific activity. Scientific activity has two aspects : it is production, on one hand, and consumption on the other. Finding knowledge and learning about new facts, even though nothing is done with them is rewarding in itself if, as most psychologists declare, curiosity and searching activities are basic needs of men. So we have to evaluate the consumption value of a piece of research. On the other hand, we have to judge the production value. One research project will have more production value than another in the following two circumstances :

a) the research project A will make more probable than B future research in the same field ;

b) the research project A will, more than B, produce and help other research in other fields.

The first criterion is more difficult to apply than the second one, since more prognostical elements have to be introduced. So we fall back upon the second criterion. The second criterion does nothing more than develop the Leontief matrix for scientific disciplines. One states for every discipline A and for every discipline B what R yields to B and what B yields to A, and one prefers the development of the discipline whose total yield to other disciplines is maximal. The second criterion, as we said, is easier to apply than the first criterion. Moreover, if we use it to evaluate the production value of a given piece of research, then more constraints, more data are introduced in the problem than if we restrict ourselves to merit evaluations taking only a limited field into account.

Later we shall come back to the difficulties we see in applying this criterion, but at the present moment we only want to make two points ;

a) Even though Weinberg limits himself to "neighbouring disciplines", we can claim that we should have to construct the Leontief matrix for the whole of the scientific field. This, however, implies really important interdisciplinary research that has to be repeated at fixed intervals and thus constitutes in itself an argument for interdisciplinarity. The concept of vicinity or neighbourhood for scientific disciplines is not clear enough, and not stable enough. Even though we might try to construct a distance measure between sciences, and weigh the contributions of one science to another by the distances between both, it remains an open problem if a contribution to a discipline at large distance should be more or less evaluated.

b) We thus can already come to the conclusion that the criterion can only be applied in as far as interdisciplinary research has been carried out. But it is also obvious that the criterion will give priority to interdisciplinary research over monodisciplinary research.

One important point is not introduced by Weinberg. We should not only evaluate the present or past input of a field into other fields, but also the future input over a certain period of time. How can this forecast be made ?

The second Weinberg criterion is a technological one : "once we have decided that a certain technological end is worthwhile, we must support the research that is necessary to achieve that end" (p. 26).

Again, technology is a man-machine system in a physico-biological environment. It is the totality of that environment that has to be shaped by human activity. This entails that it is only possible to come to a motivated decision about technological desirability after considering the organisation of the total man-environment system. In other words, once again psychology and sociology, physics, geology and biology are needed to carry out the evaluation.

As the development of environmental studies and of landscape shaping or urbanism show, technological projects that modify the whole environment will certainly be preferable, at least in economically advanced societies, where the society becomes really one of the forces that determine the environment as a whole. The third criterion, that of social merit, is perhaps the most difficult but also the most important one to apply. It is here very difficult to discover the value systems of the different societies in which the scientific research is to be done. We defend, however, the following opinion, again using Weinberg's data : the research that makes the largest number of societies co-operate with each other and that within each society makes the largest number of subgroups having divergent valuation co-operate with each other has to be preferred.

Applying this criterion implies examining the impact of research done in physics or mathematics on social values. Only very strongly interdisciplinary research can make it possible to apply this criterion. If the Weinberg version is chosen (an option that derives from the fact that no valid scientific reasons for any valuational system are at present known), then we have to prefer the type of research that would serve the widest variety of needs and valuations. Once again, this can only be, in the first case, interdisciplinary research.

The Weinberg criteria, however, cannot be taken as intrinsically valid. They have to be derived from a more fundamental analysis of scientific activity. This analysis can either be based on economics, or can point towards certain general features or reality.

From the standpoint of economics, let us consider that at a given moment in time the decision-makers of a society have before them a series of research projects for which they have to set the order of priority.

As in the case of any economic calculation, they must first of all evaluate the cost of the research (we shall come back to this feature later on) and the profit to be derived from the research in question. They must also estimate the probability of total or partial success of the research, and the probable date by which these total or partial successes will be achieved.

If all these estimates are available for all projects to be judged, a criterion for the decision can be adopted. Naturally, the alternative expected to yield the greatest utility at a given point in time would be chosen.

If the decision about scientific research is to be inserted in a general decision about the economic framework of the group, the cost and profit must be calculated for a given number of production possibilities and a hierarchy must be determined in view of these decisions.

Basic science is a means of influencing applied science or technological knowledge, whereas technological knowledge is a means of influencing actual production. This made Bernal say that fundamental science produces a change in the change of production. It means that basic science is akin to a second derivative in a transformation process. So to see which technological research is needed, one must decide which production process input costs are to be decreased, which technology productivity is to be increased, and which outputs of the process are to have their usefulness increased. Research then has to be undertaken on exactly these points. Meanwhile, for these various economically advantageous research projects, various types of basic research have to be undertaken. It is obvious that the type of basic research needed in the largest number of technological projects must get priority, and it is equally obvious that the technological research most urgently needed in the largest number of production process improvements should get priority. Once again it emerges that research into the interrelationship of all fields must have been undertaken if this criterion is to be applied. The problem is not as easily solved as this explanation would suggest, so that there also has to be research for education as well as production for research. The cybernetic feedback cycle is here of the utmost importance : every part of the economic system and of the sociopolitical system of the society is to be used in the service of every other part. How much research for educational purposes should be undertaken, and what type of research should it be and how should it be linked with the educational process itself ?

We have an easy answer here, in that nothing should be done by complex and costly mechanisms that can be done by simpler and less costly systems.

This is a simple application of the rule that the instruments available should be used to the utmost of their possibilities. If this is true, man, being the most complex and costly mechanism at our disposal, should not be used to perform information-storing activities as erudition and learning factual data, or to make simple and repetitive calculations. Computing equipment, tools of the automation of science, should be used for these purposes. This implies that essentially one should learn how to learn, one should do research on research, and man should become skilled in high level methods.

These high level methods are not tied down to specific regions of observation and their full generality can be grasped only if they are applied in widely different fields. The research undertaken for education should also be intensified and strengthened, its passivity should be reduced for economic reasons, and the slogan "education through research" should become a reality. These qualitative remarks, however, are very far from yielding an answer to the basic questions of what proportion of research should be taken for educational purposes, and how much of it should go for varying degrees of interdisciplinarity ?

The scientific problem of organising research thus contains decisions about both investment (science produces instruments of production) and consumption (science is a given type of consumption).

We cannot offer a rigorous solution to the problem, because too many measurement problems are involved, and too much feedback among the various sectors of the technology, of the economy and of the science need to be considered.

Suffice it to say, a general forecast of the future state of the whole economy is needed in order to determine which science should be developed for the future community. General research upon the interaction of the technology, economy and science is needed to organise research rationally. Only an institute for the science of science, created with an essentially interdisciplinary nature, can handle these projects, however much they are, in view of Prince's results, of vital importance and needed to implement Weinberg's criteria. We cannot solve our problem. We can only indicate the data that we might need for its solution. The possibility of gathering these data only exists when our programme is realised.

As far as education is concerned, we can now deal with a very important proposition. Method and problem-centred education seems to derive directly from the demand to increase the productivity of education for research. This method and problem centred education seems essentially interdisciplinary in nature.

The need for interdisciplinary research (IR) will even be clearer if we understand that not only must existing projects be ordered in a certain order of priority, but a cut-off point must also be decided upon, beyond which no project may be allocated funds, or the opposite case, all project allocations must be reduced so as to allow each project proposed to receive a sufficient amount of help for work to begin. Next, the question also arises whether an adequate study of the history of science and of the present scientific and technological situation does not lead one to the conclusion that social stimulation must be applied to induce scientists to undertake projects they did not themselves propose. When the organisation of science is not only selective but also active, it becomes imperative for decisions to be based on a global picture of science. The following abstract formulation could be given to our questions. Let a problem be a triad : initial stage, possible transformations, desirable final stage $< I, T_1, F > = P_1$.

Let a problem be characterised by the time it is worked upon, the degree of solution it has received, the number of people working upon it.

Let there be n problems : $P_1 \ldots\ldots P_n$. Let us suppose that a ranking order is found determining the priority of the problems. We could consider the following rules of thumb :

1. If $P_1 \ldots P_n$ are progressing very fast, apply their transformations $T_{1i} \ldots T_{ni}$ to all other Initial states. Do this more, the more
   a) $P_1 \ldots P_n$ have high priority, and
   b) $P_s \ldots P_r$ are progressing slowly.
2. If P_1 is progressing fast, and P_n slowly, combine for at least one such pair :

$<I_1 \cup I_n, T_1 \cup T_n, F_1 \cup F_n>$

3. If n projects go slowly, r fast, look for
   a) common structure isomorphism or homomorphism
   b) common elements, between the fast and slow ones, and combine where sufficient communality is found, with priority for :
      i) common elements ;
      ii) isomorphism ;
      iii) homomorphism.

All these rules of thumb are reasonable. Many of them are incompatible. No theory deducing them exists as far we know. This is our aim.

Only one specific type of organisation of research, namely, research of an interdisciplinary type, can give such information.

The present situation of research is also mirrored in scientific policy.

It seems important for us to point out that the Interministerial Conference on the scientific policy of European States, held in 1970 at UNESCO, defined the virtues and shortcomings of R and D systems in such a fashion that operations research can and should be applied, and that interdisciplinary research has a clear and high priority.

As is suitable, proceedings of the conference define on p. 83 the productivity of an R and D system. The inputs are taken to be time, personnel and material resources ; the outputs are not defined but are optimalised for all variations of the three input variables. The productivity of one R and D system A is considered to be higher than the productivity of a system B if for each input unit added there is a larger increment in output. Granted, the definition is disputable, but we are already sharpening the formulation more than was done in the original document. We are mainly interested in the factors that it is stated determine scientific productivity :

a) the scientific worth of the researchers and research units ;
b) the adaptability of the system ;
c) the amplitude of the effort spent upon given projects (average effort, maximum and minimum effort, distribution of effort) ;
d) the adequacy of the communication channels within the system, and the use made of them ;
e) the administrative capacity of the R and D groups.

We want to defend the view that, on a presystematic and prescientific level, the factors of productivity mentioned plead in most cases for a large amount of IR.

a) The scientific value of a worker or of a working group depends crucially upon the depth of the problems they tackle and upon the scope they give to them. The larger and the more precise the contexts or research become, the more the individual or group excels. The amount of interdisciplinary research is not the only indicator, but it is a crucial one.
b) The adaptability of the system will increase with an increased amount of IR. This point has already been made.
c) The relation between effort amplitudes (dispersion and average) will only be controlled by strong IR relations. Otherwise extremely lopsided R and D systems could occur, or even extremely diffuse ones that would not reach the level of production of knowledge.

d) The communications between projects and institutions depend upon the existence of sufficiently precise and general (sometimes contradictory demands) interlanguages.

e) The administrative capacity of R and D groups depends upon the development of an adequate "science of science" that can only come into existence through the strong interaction of administration sciences, operations research, logic, methodology and the history of science.

The document defines, moreover, general criteria for an efficient R and D system considered as a whole.

An efficient R and D system is one that, in the present and foreseeable future, can meet the demands of the social groups that develop it, as well as its own demands. The social group has in general a development strategy for the whole society. The type of global strategy adopted will determine what type of adaptation of R and D will be demanded. It is naturally impossible to prove that *for any possible national strategy, a high amount of IR will be optimal.* No general solution is presently known for the problem of determining what amount and type of IR is possible or desirable for any social or economical strategy that a community might adopt.

Nevertheless, certain general remarks are in order. The R and D must adapt itself to the global system, and yet must preserve its autonomy. This demands a good knowledge of the global system, its future, the R and D system itself, its future, as well as knowledge of the consequences of any modification of the R and D system on all these variables.

We claim that a sufficiently high amount of IR is a prerequisite of this adaptation.

Perhaps we might say that if the strategy of increasing and redistributing the Gross National Product is chosen, there will be a larger amount of IR needed, provided there is to be a strong relationship between the rate of increase and the type of redistribution, than if there is to be an absolute priority for either the rate of increase (to be maximalised at all costs) or for the redistribution. A subtle steering problem (it can be conjectured and should be proved) seems to demand more IR research than the two simpler ones. One may also assert that if the strategy chosen calls for developing new production types rather than improving existent production, the amount of basic research and of IR must be higher than if the opposite choice is made. Analogous remarks can be made for long-range strategies in contrast to short-range ones, or for strategies with very strong and immediate practical use for basic findings in applied regions compared with strategies with admission of lags on this last point.

The difficulty involved is that there are so many feedbacks. The motives for R and D are modified by R and D and so the system changes its own criteria for optimalisation. The same can be said for the degree and kind of interaction between basic and applied research. The unification of both by means of basic research on all forms of applied research, and of applied research on the execution of all basic research seems to be a requirement stemming from an awareness of the feedbacks involved. This implies that the optimalisation problem of R and D is a sequential problem.

Let us also mention a particular type of feedback, namely, the degree of institutional and spatial concentration, and the average density of projects, which are factors favouring IR while the degree of dispersion works against it.

This feedback could also be denied, and the degree of isolation of certain types of research could perhaps be considered to foster an interdisciplinary point of view on data that have to be obtained in unfamiliar ways because of the very restrictions mentioned. More research is needed here.

A perfunctory study of the type of criteria used by present authorities to evaluate research projects hence seems to lead to certain conclusions in favour of IR that can be made in all social and economical situations, and to other remarks in favour of it that can be made if and only if certain general developmental strategies are adopted.

As a final point in this section of the paper, it should be indicated that Burton Dean's book, *"Operations Research in Research and Development"*, includes a chapter on "Proposals on Strengthening the United States Technology" that allows us once again to see that in the present prescientific state of the art, there are intuitively reached criteria of efficiency that plead for IR.

Ellis Johnson mentions the following critical problems :

a) The increased rate of development produces a high degree of instability in consumer products, production methods, and weapons systems. How should the intellectual problems produced by this high degree of instability be solved ?

b) "The effect of a large number of technical alternatives imposes a greatly increased need to consider the interrelations within the overall system" (p. 15).

c) There is an imbalance between basis, applied and developmental research. Too lengthy development periods are combined with too fast new discoveries.

d) Great areas of R and D are neglected that require the integration of basic and applied research (p. 16). Multicustomer-multidisciplinary problems are mentioned.

Our answer is simple : the four problems mentioned all seem to demand a higher amount of IR. For

(*a*) accelerated evolution demands schooling in more fundamental operations, for routine information decays too fast. The large number of alternatives in (*b*) demands strong IR to evaluate the interrelationships. Next, the coordination of the three research levels in (*c*) demands an increase of IR.

The last problem is already formulated as a problem due to the lack of IR (on p. 31 we read, "the failures involve primarily multi-department, multi-industry and multi-industry areas... of an interdisciplinary nature").

We have now come to the same conclusions on the basis of four different sources that are not primarily theoretical but on the contrary rather factual :

a) On the basis of the present development of science, as described by de Solla Price, we can predict a high priority for IR.

b) On the basis of the authoritative proposal for priority choices on scientific projects, made by Alvin Weinberg, we reach the same conclusion.

c) By analysing the concepts used by the UNESCO Symposium on Scientific Policy, we draw the same conclusion.

d) A short perusal of the American technological situation in 1961 gives us analogous results.

In order to verify the strength of our conclusions, let us try to develop an argumentation against interdisciplinary research and education.

1. The cost of interdisciplinary research and education is high for the following reasons :

a) Either the research is done by one person and then this person has to learn many new skills he did not possess before, which takes a lot of time, although his learning is not highly effective, or else the research is done by a group that needs a long period of internal acculturation before teamwork can be achieved.

b) The uncertainty of returns is even greater for interdisciplinary research than for monodisciplinary research, because the relative newness of the undertaking does not allow the organisation to make predictions on the basis of earlier similar projects.

2. In general, it seems to be sound economics not to encourage complex combinations of enterprises under the following conditions :

a) If the scientific potential is low or if the technological and economic potential is low. Countries concentrating on eliminating major social evils or overcoming major economic bottlenecks seem to be primarily so advised.

b) If the potential is high but if the organisational skills are low, or if interscientific competition is high, or if some extremely costly but highly rewarding scientific projects demand the immediate involvement of a sizeable portion of the scientific labour force.

These conditions would certainly not favour interdisciplinary research. But when analysed, they yield some interesting answers.

a) The counter arguments start from the scientist as we know him, burdened with a large number of facts and laws. They do not apply to the man who is primarily schooled in the fundamentals of his discipline and has afterwards applied these fundamentals very intensively in a few divergent and demanding research projects. Such a person is accustomed to appearing temporarily incompetent before other temporarily incompetent persons, for the purpose of learning new skills. Hence the first argument, about the high cost of interdisciplinary work, becomes a defence of interdisciplinary work.

b) The unpredictability of interdisciplinary research can only exist if there is no general plan for interdisciplinary activities, and if there is no large body of experience about them accessible in analysed form. If there were a department for the scientific organisation of scientific research that would collect these data, this argument could not be used either.

c) For underdeveloped countries, even though we recognise the strength of the argument against interdisciplinarity, we must take note of the fact that technological and scientific development must go forward in continuous contact with the entire culture that is not yet as fragmented, segmented and in a sense, dissected as the cultures of the so-called technologically advanced, countries are.

Developing research in contact with the total world view could yield a strong argument in favour of systematic, rather than haphazard, interdisciplinarity.

Section 3. CONCEPTUAL SYSTEMS FOR INTERDISCIPLINARY RESEARCH

We have studied various types of linguistic interdisciplinarity in section II of this paper. Let us concentrate our attention by simply focusing on one of the cases examined, that in which a theorem of L_1 combined with a theorem of L_2 yields new theorems both in L_1 and in L_2.

It should not be forgotten that we consider a science to be an enterprise receiving certain observational data as input, performing work of induction and deduction, yielding theorems and systems of laws, controlled by the motivating energy of driving problems, communicating to other more or less similar systems, reproducing itself by means of much formal and informal education, and transforming itself by given heuristic strategies.

Let us now quite ahistorically ask what would a manager do who had to promote interdisciplinary contacts between workers in different fields.

We think that he would have various ideas, evaluating afterwards their relative effectiveness.

1. He could try to develop a general theory of the type of inputs received by scientific systems, and of the type of instruments and eventual registration procedures. It would then be important for him to stress the differences, but also to develop the input classification in such a way that various new types, not yet existing, could be discovered in the empty parts of the table. Familiarising every scientist with every type of observation instrument or procedure, and familiarising every scientist with the theory of observation in general and of observation procedure in particular would be the educational measure related to this idea.

When looking through the literature, in a much less practical spirit and working under empiricist or epistemological influences, he would then find Wiener Kreis and the later "Movement for the Unity of Science", proposed to develop a "language of observation" — starting from the "inputs" — in terms of which all other scientific terms would be defined, completely or partially.

Our manager would be indifferent towards the epistemological points of view, and would be rather disappointed that such an observational language yielding a common foundation for all disciplines had not really been developed, but would conclude that at least the idea had fundamental importance and should be taken up again. The activities of the sciences, he would decide, should be tied together by means of a transformation of their inputs, brought about by their comparison and by operations of abstraction applied to the contents of these inputs.

2. The input of a science is thus transformed by means of a sequence of internal or external actions (classification, measuring, ordering, regularisation, systematisation, and so forth). This is a type of work. If we had a general theory of action, we could again link together the different types of sciences as different types of action. Tadeusz Kotarbinski has framed a general praxeology that he intends to be such a theory of action. Hakan Tornebohm

has described various sciences in a praxeological fashion, also using their history. In general, the history of the activities that make up a science should be used to describe its general features. Again, comparative studies of these action systems, relating each of them to the others, could yield an inter-language. The Kiev school of thought, animated by Bobrow and inspired by Bernal's works, tends towards a similar "Science of Sciences".

3. Science also has an output: a model of the region it studies. The manager in charge of interdisciplinary research would also look upon these models as objects, related to each other in certain ways. This means that he would treat them as systems, different from each other in their ways of integration, centralisation, and delineation. The problem of interdisciplinary research would become the study of the types of integration that would result if one model were inserted into another, or if certain relations of one model were inserted into another, or if a system of systems were built up. The "Society for Systems Research", which has already published 17 annual Yearbooks would bring a preparation to this task.

Again, with some hope and some disappointment, the manager in question would see that there is no ready-made body of systems theory or of praxeology, only the beginning of one, albeit a very promising beginning.

4. Finally knowledge-producing systems communicate with each other, and they produce languages. Integration could involve a study of comparisons and translation of each of these languages into the others. The movement now generally called "hermeneutics" seeks to study systems of symbols and brings them into close relationship. This could be a tool for interdisciplinary research borrowed from the humanities, whereas the other methods (the science and language of observation, general praxeology, theory of systems) come from physics, economics, ethics, biology or mathematics. Tools for unification on this level could be found in the work of Cassirer, Gadamer and Ricœur, as well as in that of the mature Wittgenstein and Austin.

It would also be possible to study the axiomatised skeletons of the actual languages used in science communication. Their general syntax and semantics should certainly be studied in order to see how new combinations of axiomatics could be produced.

5. Last but not least, science-producing systems reproduce themselves and are modified by doing so. This process can be studied microscopically (the transmission and reproducing from generation to generation) or macroscopically (the transformation over many generations). The microscopic problem has been studied precisely from the interdisciplinary angle by Jean Piaget, whose work certainly provides the only existing basis for interdisciplinary education. From the macroscopical point of view, the beginnings of the history of science are at our disposal; and these beginnings have at their side at least one set of hypotheses about the development laws of scientific history, namely, dialectical materialism. The manager would see that the hard facts of historical development and the general laws of dialectical development and the general laws of dialectical development have not yet been sufficiently related to each other. He could also see that the microscopic and the macroscopic data are yet to be related, but it is again obvious that this fifth aspect of all disciplines or scientific systems should be used to promote interdisciplinary research.

The manager in charge of interdisciplinary research could not approve of rejecting any of these conceptual tools: neither dialectical materialism rejecting logical empiricism, nor general syntax and semantics rejecting hermeneutics, nor hermeneutics rejecting general systems theory. The purpose here is not to promote a world view, but to use ideologies from the past as tools for the future.

Finally, it would become apparent that the five conceptual systems just mentioned, whose unavoidability can readily be deduced from the very definition of "discipline" we used, cannot be the only conceptual tools for synthesis integration.

After all, the science-producing systems are composed of human beings. The needs of human beings are the fundamental criteria for any human action. All of us shy away from this platitude, because as scientists we are aware that we know very little about the needs of human beings and societies, though we know enough to be aware that they are variable, modifiable and contradictory, and as managers or politicians we are aware that very few objective statements can be made about them.

However, as Berger's research has shown, one of the fundamental needs of human beings is relating to others, and arriving at some self-evaluation by means of evaluating their own place in the totality of human activities. Studying the motivational structure of humans and the type of motivations that lead to mono and interdisciplinarity should certainly be an important tool in interdisciplinary research. The desire for security, for property, for territoriality, for fast effectiveness all make for mono-disciplinarity; the desire for community, for participation, for meaningfulness in life and for adventure make for interdisciplinarity. None of these desires can be abandoned, but they can perhaps be combined in ways yet to be thought out by the applied psychologist. Finally, systematic general anthropology, to use a solemn word, applied to the activity of science-producing, will have to be brought in, modestly while the science is yet in its beginning, but decisively, because the energy driving the intellectual action comes from the human needs.

It is this author's prejudice to be convinced that a scientist should be modelled on a learning automaton, that a discipline is simply a set of interrelated learning automata, and that the problem of the optimalisation of interdisciplinary research is that of optimalising connections between sets of learning automata, connections that have to be built in such a way that they produce a new system that is again a learning automaton.

It is perhaps interesting to state that all six conceptual tools for interdisciplinary research will show a certain justified imperialism.

a) Collaboration by developing an input theory will lead to the conviction that the other four elements of the discipline can finally only be described in relation to input.

b) Collaboration to develop a theory of work and work interaction will show all the other elements—input, output, communication and reproduction—as types of work.

c) Collaboration on an output study will show up in all the other elements types of systems which are studied as systems.

d) Developmental studies, whether psychogenetic or historical, will show the stages of growth and transformation of the science-producing process.

e) Finally, all the stages are types of information transmission, and their interrelations should be studied as a type of information transmission.

It is our conviction that all these statements are true although none of them has yet been proven. None of the five projects has really been executed or is even in an advanced stage, and different priorities have to be given to them in various stages of scientific development.

The conceptual tools of scientific integration cannot judge themselves ; only the scientific study of research and development and of its optimalisation is the final judge. This statement perhaps may be contested by many scientists and integrationists, but the aim of this paper was to make clear our conviction and counter their arguments.

A last remark about the function of two extremely important tools of interdisciplinary research, computer science and mathematics can be made.

Many readers will perhaps be astonished not to see them mentioned in a list of the conceptual tools of interdisciplinary research. We are certainly convinced that insufficient knowledge of mathematics in biology and in the humanities is one of the major obstacles preventing interdisciplinary research and education, in that one basic tool is absent. We are also convinced that widespread use of computers will compel scientists to analyse their thinking processes sufficiently to make them see the possibility of new comparisons and co-operation. But neither mathematics nor the computer is in itself a tool for overcoming differences, or for creating new combinations. Computer science is characterised by a large number of programming languages and a large number of compilers translating these programming languages into computer languages. The problem of combining and unifying programming languages is precisely the same as that of combining and unifying the different sciences. Moreover, "mechanical mathematics", as Hao Wang likes to call it, is only in its very beginning. Furthermore, mathematics itself in principle has the possibility of expressing any structure. It is interesting to select certain types of divergent structures in order to combine them in new ways, and to combine in new ways the different processes of mathematisation, mathematisation, after all, being only one stage in the overall process of scientific work. We are convinced that the general use of mathematics and computers, as well as the unification of classical and mechanical mathematics, and the unification within mathematics of the divergent fields, should and will occur, and should and will constitute a major instrument of interdisciplinary research. But these formal sciences do not, by their own tools and dynamics, capture the divergencies and the integrations of materially different fields. That is the reason why we did not mention them among the conceptual tools of interdisciplinary research.

This remark can be clarified in the following way. André Lichnerowicz's "polyvalent models" (systems of equations that can be isomorphically applied, for instance, in economics and thermodynamics) would certainly constitute very important working material for the general theory of systems. This theory, however, would try to develop a general typology and classification of such models, would initiate a systematic search for them as well as have to develop an strategy for such a search, and would try to understand what types of interactions between subsystems were responsible for isomorphic equations, while also trying to look for weaker analogies than isomorphisms (homomorphisms or probabilistic homomorphisms or qualitative analogies) and again to classify and explain them. The typically "interdisciplinary" activity would only start after the important discovery of the existence of polyvalent models. And this typical interdisciplinary activity, while using mathematics all the time, would presumably not belong to mathematics.

Moreover, as a logician, the author should be allowed to mention that after Goedel's incompleteness results, after Göedel's and Cohen's independence proofs in set theory, and after the failure to unify mathematics, sensed, when it was seen that neither the *"Principia mathematicae"* nor set theory could be the foundation of the total science, that the problem of dynamic interdisciplinarity, not of a closed integrated system of mathematics, is as alive in this field as, for instance, in geography.

The priority we gave in our paper to operations research should not lead the reader into the belief that we underestimate the conceptual problem. On the contrary, this section of the paper exists to assert that the general problems of how to optimise research, and how to optimise education, must be supplemented by the more particular problem : once a given amount of interdisciplinary research and education is decided upon as being useful, how should it be optimalised by concentration upon input, output, transformation, communication or development integration ?

The author hopes that he has, by this presentation, shown the exact role present-day philosophy has to play in the organisation of science and education. The stakes are high, for if the managers of science do not see this point, the attempts described will disappear (not dramatically, but by not reproducing themselves, as life wants it), the integrational effort will be weakened, and it will again be necessary to regenerate, in many different contexts, these same interlanguages obscured once already by lack of insight.

Section 4. OPERATIONS RESEARCH APPLIED TO RESEARCH AND DEVELOPMENT

Among the many handbooks in "Operations Research" we have selected a recent one, *Fundamentals of Operations Research,* by Russell L. Ackoff, and Maurice W. Sasieni (Wiley and Sons, 1968), to skim through and try to apply its methods to the research and education situation.

We shall try to show that the more intensively studied problems of operations research can be translated into problems about research and development.

1. THE ALLOCATION PROBLEM

The allocation problem presupposes a list of jobs and a list of resources. The resources are to be allocated to the jobs in such a way that total costs are minimised or the total returns maximised. Such an allocation problem can be described by means of a matrix of the following form :

	Job 1	Job 2	Job n
Resource 1	1_1	1_2	1n
Resource 2	2_1	2_2	2n
Resource r	r_1	r_2	rn

If we want to apply the allocation idea in research and development, the jobs can be different research problems and the resources various types of work performed by scientists and technicians (observation, deduction, induction, model building, experimentation, etc. can be among them). In as far as problems and work types are clearly defined units, this presentation can be accepted. However, we have before us one of the most difficult allocation problems imaginable.

i) The allocations of resources to jobs are dependent upon each other in the organisation of research and development.

ii) The problem is most probably not linear : the cost of allocating n units of a given resource x to a problem j, is certainly different from n times the cost of allocating one unit of the resource x to problem j. We believe this to be so because to express the work acceleration due to the increasing difficulty of the task and due to the rigidity and fatigue effects, a complex function of these costs rather than a linear one, seems the only function acceptable.

iii) The resources available, the amounts of the resources needed and the costs of allocation of a given resource to a given research problem are not completely known.

iv) The jobs are not completely defined (the problems are only completely defined when they are solved), so instead we have to think about fuzzy sets of jobs.

v) The problem is not a balanced one, in that the resources are usually not sufficient to perform all the tasks mentioned and certain jobs cannot be done.

We can only justify mentioning the allocation problem here if we can show that it has relevance to the problem of interdisciplinarity. Interdisciplinarity is introduced by one of the following three methods :

a) by introducing jobs in the matrix that are reciprocally dependent upon each other (different problems that presuppose each other's partial solution) ;

b) by manipulating the jobs and by considering complex matrices, whose constituents are simple matrices and the jobs of which are combinations of the jobs of the others ;

c) by manipulating the resources and by assigning the same resource to a multiplicity of jobs.

It must be emphasised, moreover, that the problem is a dynamic one, the allocations made in one period of time being dependent upon the allocation made in another period of time.

It is perhaps interesting to stress that one of the earliest problems of operations research, the transportation problem, a subcase of the allocation problem, can also be used as a model for the difficulties of IR.

Let us assume there be n production units (= sciences), with their products known. Let the cost of furnishing one product of one science (in terms of observation, concepts, law, etc.) for use in another science, also be known (the cost, in principle, of learning to apply the information). What production units could then with maximal utility furnish a product to what other production units ?

2. The Inventory Problem

A second type of problem is the inventory problem. A given production unit (= science) needs to have available a certain amount of production goods (again meaning observations, models, computational procedures, laws, etc.) that are not in constant use. How large should the inventory be, as a function of the frequency of the demand for the goods in question and as a function of the cost of storage and depreciation ? This inventory problem can also be used to calculate the number of scientists or technicians, not immediately useful in obtaining the solution of the problems of the science in question, and yet who are at the disposal of this science. This reserve corps is in a sense the group that will speculate and deviate from known roads.

The problem of interdisciplinarity is related to the problem of inventory in the sense that the more varied the inventory has to be, the more sudden and unexpected demands are and the more severe the penalty for shortages or the cost of charge in science production rates (see Ackoff, p. 176). The more varied the inventory of a given science has to be, the more interdisciplinary its practitioners will become.

It is perhaps interesting to state that the problem of cost and frequency of review of the goods available determines the problem of the frequency of foundational studies, systematising activities within the given discipline. A purely logical activity is thereby related to a purely economical parameter. Both the quantity of goods available, and the best timing for delivery have to be sought after. In general, there are n goods about which inventorial decisions have to be taken, and this will certainly be the case if we want to model one feature of the interdisciplinary programme by means of the inventory problem. The most difficult situation possible crops up again :

- *a)* the demand for given types of knowing and know-how is not at a fixed, known rate ;
- *b)* the time of producing lacking items is neither zero nor known exactly if not zero ;
- *c)* the production of needed goods is not instantaneous ;
- *d)* a certain type and amount of shortages is permitted. Multi-level and multi-item problems are the ones most clearly related to the question of interdisciplinarity.

3. The Replacement Problem

A third problem is the problem of replacement, maintenance and reliability. This problem is applicable to the organisation of research and development on many levels. First of all, given observations and theoretical generalisations lose strength and reliability though continued use, because the new facts and structures discovered make them obsolete sooner or later. The process of maintenance or replacement in a sense corresponds to the inductive modification of the theorem structure of a science. Secondly, the science uses instruments and mechanisms, and the replacement and maintenance problem in its most classical version can be applied to them. Finally, one could consider that in the R and D situation the productive units are scientists, and the replacement and maintenance problem then refers to their replacement by schooling and other types of formal and informal education.

As the maintenance problem can be found in the district of R and D, the problem of interdisciplinarity can likewise be found to be related to the maintenance problem.

It is obvious that the more relations established between the production elements (considered as information units, or as mechanism, or as agents), the less the probability that eliminating one course of action will make action in general impossible. Precisely this fact was pointed out by Ackoff, on p. 219 of his book. The multiplication of the relations is the exact aim pursued by interdisciplinary research.

We now come to a fourth classical type of problem, the queue problems.

4. The Queue Problem

Creating a model of interdisciplinarity in the queuing problem would imply the study of the multichannel case. Customers (= problems) could arrive at n service stations (= specialised scientists). One could introduce a post-screening procedure where several lines are brought together, or one could introduce a diversification of service stations, or of customers, or a linking of stations and customers, the time taken and service granted at point p becoming a function of time taken and service granted at other points.

Russell Ackoff mentions (on p. 263 of his book) queue problems that model rather well our own situation :

a) queue systems with priority rules (this is certainly the situation in research) ;
b) queues in tandem where the output from one queue becomes the input of another ;
c) circular queues ;
d) multicounter problems with different service rates.

We thought that the critical variables of service time for problems, rate of arrival of problems, and waiting time for the solution of problems, were sufficiently important to draw the reader's attention to the queuing model as a tool in the organisation of research and development.

5. The Sequencing and Co-ordination Problem

Perhaps even more impressive is the usefulness of tools introduced for sequencing and co-ordination problems.

The first type concerns the selection of a queue discipline which in queuing problems is taken as given or fixed.

The second type of problem entails projects that consist of tasks that must be performed in a specified sequence. These problems involve determining how much effort should be put into the performance of each task and when to schedule it... (p. 275).

This last co-ordination problem becomes applicable to the interdisciplinary question in the following way : when n tasks, transforming x into x_j have to be performed T_1 (x_1x_2), T_n (x_nx_n), what amount of effort and what time priority should be given to various combinations of such tasks ? Among the combinations which could be considered are : $t(x_ix_j, x_k)$ of $t(x_ix_jx_k)$ or $T(X_iX_j)$ (where X are classes of x), or $T(x_ix_j)$ (where T are classes of t), these classes eventually having interrelated members. We ask the reader not to immediately withdraw his attention when in works on O.R. he does not right away encounter the problem of efforts and priorities to be given to combinations of tasks, as a function of the efforts and priorities given to the tasks themselves. The problem of co-ordination is itself already crucial in the organisation of science and if we look for the data needed for its solution, we see that these data are only available as the result of intense interdisciplinary research. For instance among the measures of performance in the sequencing problem are the following :

1. minimising total elapsed time when n jobs (= research projects) are to be done between the first and last completed problem.
2. minimising time of completion minus due time (a variable depending either on technical requirements or on the priorities of other problems whose solution depends upon this one)
3. minimising the maximum of 2
4. minimising in process inventory cost.

We know that for r problems, s facilities and arbitrary dependencies cannot solve the problem. But it is obvious that these measures cannot be calculated for the totality of R and D if a large multiplicity of data on the interrelationships of types of R and D is not known. (By the way, while measures 1 and 2 are only applicable as a result of a complete and painstaking inventory, measure 3 requires minimising the cost of this inventory and thus the amount of interdisciplinary research on the relations between problems. A compromise is needed, although we don't know just what it should be.)

The co-ordination problem demands :

1. A well-defined collection of tasks that are to be completed before the project they are a part of is completed. It should be emphasised that this well-defined collection is redefined as science goes along for R and D, but at any given moment, if an optimalisation of R and D is to be carried out, there should be a provisional image of this collection.
2. The tasks can be started and completed independently within a specified sequence. This represents the subdivision of the total task of science at moment m in n dependent units. In general, we have to consider a multiplicity of subdivisions for any moment.
3. The tasks are ordered in the sense that for each task we know which tasks precede it and which awaits completion. (Again an approximation of this situation has to exist if science is to be organised.)

Both PERT and critical time method are interesting but insufficient to solve the optimalisation of research. CPM does not introduce undeterministic situations (the typical case for R and D) and PERT does not manipulate times by means of resource shiftings. Perhaps the critical reader will ask why we mention these techniques if they cannot be used ?

The point is that all the data needed for task time minimalisation for given total costs must likewise be known in order to decide upon the desirability or undesirability of IR, and more data besides. But certainly at least as much. How much and which ones we cannot say, but : *In order to judge the desirability or undesirability of given amounts and forms of IR, a* *large amount of a given type of IR, not yet carried out, must be done. The few remarks about sequencing and co-ordination problems we have made indicate what type of IR is needed.*

We should like to point out two more partial models for interdisciplinary research.

6. Game Theory and IR

Let us consider a science as a game (in simplified form, a game against nature, more realistically, against other scientists). Let us consider that there is the possibility to participate simultaneously in n different games, or to combine in various ways n different games—for instance, combining players, combining information, combining utilities, combining possibilities of moves. There would be a game on games: when is multiple participation or combination advisable in the meta-game ?

7. Network Theory and IR

Let us consider a science as a network: the links are the problems, the nodes are stable states of knowledge, and directions as much as costs (= valuations) are indicated. Let us consider the minimal path problem, as a minimal cost problem. Again there are combinations of networks possible (networks sharing nodes or links), and the combination improving the optimal solution of the minimal route of minimal cost problem is sought.

It is obvious that these two last suggestions are again models for interdisciplinarity, and that we cannot *solve* the problems here; it is once more painfully clear that if we ever want to adopt a policy IR *rationally* we will have to gather the *IR information* needed to solve these problems. We want to finish this section of our paper with the description of the most adequate models of the IR we can think of.

OR has studied search problems. We can consider sciences as types of search, and combinations of sciences as combinations of types of search. What methods can we use to optimalise search strategies ?

Finally science is model building, optimalising science is optimalising model building.

IR is the building of certain types of models. How must we evaluate this building of IR models in the course of the optimalisation of model building in general ?

8. The Optimalisation of Search

Formally, we can consider a search as an action, intended to select a given subset of a set, as the result of observing chosen elements of that set in view of performing certain actions upon the selected subset. We can consider the cost of observations and procedures (number of observations, kind of observations, number and type of inductions and deductions), and the cost of errors. We may have the aim of minimising the sum of these costs, considering various types of errors due to the observer, the object observed, the interaction, and various types of utilities sought after, as well as minimising costs to be paid, as a function of the number of observations, of diversity, of length, of means used, etc. The general problem of optimalisation of search is not solved. But when we have to study IR, we look for situations in which the combination of searches has an optimalising effect ? What can we understand by the combination of searches ? We can look simultaneously for different selected subsets or use simultaneously different types of measures, or combine different strategies of search, or search in a space of n + m dimensions, instead of in spaces of n and m dimensions. All these possibilities have to be considered, but as we stated, we cannot hope at the present time, in the absence of a general solution for the single search problem, to have even a partial solution for the combined search problem. We are happy enough to show that IR is moving in this direction and to point towards certain common sense convictions in the field :

a) A mixture of strategies is sometimes optimal, and this mixture can be an IR.

b) For a variable heterogeneous or strongly unknown environment, it should not be too difficult to show that an organisation of combined searches with maximal internal variability is preferable, and this organisation is precisely the one we want to promote.

9. The Optimalisation of Model Building

A decision problem can be formalised as follows : a certain number of variables is controlled ; a certain number of variables is uncontrolled ; a certain result depends both upon the controlled and upon the uncontrolled variables. A performance measure indicates the function of the results one wants to maximise. If a rational organisation of research is possible, even decisions about the acceptance become available. We cannot scientifically prove that in certain cases interdisciplinary model building would be a help in optimalising model building. It is however suggested to look into the many meanings that IMB could have. It could mean introducing more heterogeneous variables, or agglomerating the model building for n systems into the model building for one (presumably with consecutive aggregation of variables and greater simplification of relations), or combining various information-gathering procedures.

The reason why we mention model building is that, from a very general point of view, the creation of specialised sciences is a move towards constructing a total model for the whole universe, to be used to obtain total control over it. This is a well-known move : the construction of multiple models when the system to be controlled is too complex (Ackoff, pp. 84-85). But there are also situations in which rejecting hypotheses can be inserted into an action model of thinking. The difference between basic and applied research is not fundamental : two different action types are concerned, but they are both action terms. A model of the system upon which the performance value depends is the selection of a series of variables, of relations between these variables, of modifications of their values, and of laws relating the outcome. U to be controlled and the uncontrolled model variables : U = f(XY). The model either takes fewer variables than the real systems, or aggregates the variables, or simplifies them, or takes fewer relations or simplifies the relations. The degree of simplification depends upon the number of data available, the succession in which they are obtained, and the type of aim involved. Optimalising model building for arbitrary systems, information-gathering possibilities and tasks to be executed, has not yet been defined, and no such theory is available. Again no theory countermoves have to be executed.

The problem of the amount and type of IR to be done is one of deciding in which situations replacing multiple models by global ones is optimal. No theory exists on this topic, as far as we know. But we observe with satisfaction that the problem of IR can be rediscovered in this context.

We can at least, on the basis of pre-scientific information, foresee the following situations.

1. Systems $S_1 \dots S_n$ exist. Their internal structure is best shown in interactions S_iS_j in which disequilibria are caused and in which tendencies to constitute super-systems originate. But these interactions can only be studied in the combination of models.
2. Systems $S_1 \dots S_n$ have to be controlled. But the performance measure depends upon complex functions of all systems $f_1(S_1 \dots S_n) \dots f_n(S_1 \dots S_n)$ and not upon $f_1(S_i)$, of $f_r(S_j)$. Again this problem can only be solved by IR.

These two situations however, are not described accurately nor is it shown what type of model building would be optimal in them, nor is it clear in how many other situations IR would yield optimal model building.

We have now shown a sufficient negative and a positive result. The positive one is that operations research comes naturally to the evaluation of interdisciplinary research[1].

Section 5. EDUCATIONAL CONCLUSION

The reader would be right to feel disappointed if he discovered that his interest in the problem of education was to be frustrated by hearing only information about research and none about education. It is certainly true that we cannot solve the general problem of optimalisation of the educational system. In the OECD publication dedicated to this task it becomes clear that work on optimalising curricula, as a function of the demand of the society for n persons of given qualifications, and as a function of the offer of the student body to yield r persons of general different specialisations, has not yet been sufficiently advanced and we cannot begin here such a study in which the concept of an "interdisciplinary curriculum" would have to be formally defined, and in which partitioning of tasks of a society into professions, the type of qualifications asked for professions and

1. We want to point out that the work done by Peter Norden, "Internal Dynamics of Research and Development Projects", (Management Sciences Congress, 1960 pp. 187-205) and "Resource Usage and Network Planning Techniques" (Dean, in Ellis *op. cit* (pp. 149-169) seems to us highly interesting, because it treats the problem of the rational organisation of R and D on a higher scientific level than any other articles we know of. Norden considers the problem of finding a law for the development of research projects which should indicate how they evolve new operations, new operators, new objects operated upon, new spending rates of time or/and energy. If a general form for this law could be found we would then, for different hypotheses concerning the possibilities of returning operators or products to given operation points, try to find what amount of recombination of either operators, operations or objects would be expected or would be optimal at any given stage of a given project. This would certainly be a way to approach the problem of interdisciplinarity.

how much the supply and demand of labour can be altered would have to be taken into account.

Hence, it is our assertion that the extremely important problem of education optimalisation has not yet been sufficently developed to make it possible at the present moment to apply in this area the techniques developed for our particular difficulty. However, we can already come to a firm conclusion on the basis of one fundamental pedagogical postulate: preparation for the so-called "intellectual profession" can only occur through guided and planned real research. This implies that preparation for research can only be obtained through research.

This involves rejecting the classical concept of a school or university. Although this postulate cannot be defended or clarified here, we are convinced of its truth. The only true education is self-education, and the only directiveness one has to exert as an educator in the educational process is to orient students in certain directions and to furnish certain research tools.

If this postulate is accepted, we come to a further conclusion: if lots of research has to be interdisciplinary— this is what we tried in many ways above to demonstrate is probable—then lots of education must be interdisciplinary as well.

This conclusion naturally does not concern those (and they are the majority in any educational system) who do not plan to devote their lives to research.

Should their education be interdisciplinary and in what sense? If once more we argued here in favour of the need for studying the structure of the professions in our society and the motivational structure of our youth, and if we had to prove that the professions were evolving towards demanding more general and less specialised skills while the motivations were also developing in the direction of being satisfied only by less specialised activities, we would have to abandon our task, because at this late point in this paper, we cannot start two such important investigations. Let us only hope that they will be done somewhere else.

We again can only answer by introducing a second huge social postulate: in all sectors of work in our society, work must be more and more accompanied by, and even partly supplanted by, research on various features of this work. We cannot prove this to be true, but we believe it to be so, because tasks are becoming more and more complex, shortlived and high-ordered (one could mention Colin Clark in this context). If this social postulate is true, in as far as we have proved that R and D must contain a large amount of IR, we have obviously also proved that every type of education should contain a large amount of IR.

To summarise: by means of two postulates, one pedagogical and one social in nature, we come to the conclusion that solving the IR problem in the field of research would also solve it in the field of education.

We have shown some ways to prepare to solve the IR problem. This is the most natural moment to leave the topic and to refer the reader to the paper by Briggs and Michaud which will describe concrete methods for interdisciplinary teaching.

Final Remarks

We find ourselves at the point in history where:

1. Every science becomes an inter-science, and
2. Research becomes self-aware, and tends to guide itself.

We have to act surrounded by the combined effects of these fission, fusion and self-regulating phenomena.

These are, according to us, the reasons that justify the preoccupations of the editorial community of this book.

We wish to thank our colleague and friend, Mr. A. Comhaire, without whose advice this paper could not have been written in its present form.

PART III

PROBLEMS AND SOLUTIONS

This part was written jointly by Asa BRIGGS, Vice-Chancellor, University of Sussex (United Kingdom) and Guy MICHAUD, professeur, Directeur du Centre d'Etudes et de Civilisations, University of Paris X (France).

SUMMARY

PROBLEMS AND SOLUTIONS

To transform the University, we obviously cannot wait until "a science of science" or even a "science or the University" crops up. The two-fold process of change in the university as an institution and in scientific knowledge is under way whether we like it or not, and it is gathering speed before our very eyes. Interdisciplinarity, it can be observed, lies at the meeting point of these twe currents, and is the direct consequence of them, so that it emerges as one of the key elements in any solution to the crisis in the University.

It is therefore important to define the problem clearly right away, both in terms of what exists at the present time and in terms of what may appear to be desirable. Indeed, unlike most businesses, the University is not working for the immediate present, but for the middle-range future. It must thus strive to *predict* and meet future needs. For this purpose, we need to begin by defining as clearly as possible the goals and requirements for its growth within an evolving society.

On the other hand, we must not lose track of reality, especially the wide diversity among current-day institutions, in which Universities of varying ages coexist, with their rich histories and traditions. Some of them, however, seem little by little to be growing rigid, while others are changing rapidly, and a whole slew of new institutions are coming into being and seeking their identity within broadly diverse societies based on different philosophical, religious and ideological conceptions, as well as on different levels of economic development.

It is therefore only when we are dealing with the concrete situation of the University face to face with many, diverse problems that we may attempt to work out and suggest an array of solutions and possible models, albeit not a single solution. These solutions must be looked at first from the standpoints of structures, course offerings and teaching methods, before we can suggest various kinds of models which may fit the requirements defined beforehand.

Chapter 1

PERSPECTIVES

Section 1. CONTEXT AND CHALLENGE

Since the term "university" covers a wide range of institutions, in consequence attitudes towards interdisciplinarity and transdisciplinarity must be related to very different kinds of context. Universities may be considered historically in terms of foundation, development, changing size, curicula, organisation and orientation, or as elements in "educational systems", themselves sub-systems of society.

Whichever approach is followed, problems of interpretation very quickly emerge, particularly in relation to present trends. Historically there have been distinct periods of university history, each withs own preoccupations, but it is generally accepted today that during the present and still unfinished period of university history, universities in all parts of the world, whether old, middleaged or new, are facing common challenges.

The term "crisis" had universal currency, even though the apprehension of "crisis" and the approach to it varies not only from country to country but from commentator to commentator. There is no shortage either of prophets or of reformers. The challenges may be explained in part by the great growth of student numbers during the last twenty years, by the increasing share of national resources devoted to higher education, and by the increasing preoccupation of governments in the problems of provision, including the provision of research and, not least, of *new* universities. Nonetheless, the challenges involve issues — and decisions — about quality as much as about quantity. They demand in every country a willingness both to examine or to re-examine past assumptions and to plot further strategies. Many different variables must be taken into account and there must be a sense of perspective which encompasses the future as well as the past.

The difficulties in using "systems" terminology spring from the differences on the one hand between the language of sociologists and educational analysis and on the other hand that of both historians and those directly employed in the government and administration of universities. This is because it is only very recently that in many countries, including Britain and the United States, that there has been any strong sense of an "educational system". While traditions have been crystallised, decisions have been decentralised. Intermittent, sometimes haphazard, growth in Britain and fertile, sometimes over lush, proliferation in the United States have produced, as in the very different context of Japan, a highly varie ated university pattern. In Britain, in particular, there has been more sense of hierarchy than of either "system" or "network". Yet there had long been a recognition in these countries, stronger perhaps than that to be found in the old universities of continental Europe, that universities are not enclaves in society with special privileges, but, as Talcott Parsons has put it, "part of the wider, on-going society, dependent on it for support, and, in some cases, responsible to it".

Historical Experience

Turning in more detail first to the historical approach, it is possible to identify "families" of universities, with the family pattern being shared across national frontiers. There are several examples of non-European institutions of higher education tracing their descent back into the distant past, but, as Sir Eric Ashby has pointed out, "the remarkable fact is that among the lines of descent of higher learning one, and only one, has adapted itself to modern civilisation and, by a process of natural selection among social institutions, has displaced other lines of descent. The successful survivor descends from the medieval university of Europe.

The European university emerged as a distinct type in the twelfth century when groups of students and masters gathered together in a number of scattered places and organised themselves into corporations. Even at this early date, there was variety within the family — Bologna, for example, was a federation of student communities, Paris a corporation of masters. Yet in all universities the same questions (and answers) and the same methods of teaching were to be found, and the fact that universities were more than local institutions, subject to local pressures, was enshrined in the close links with each university had with the Papacy in Rome. The university rested on a conviction that there was an essential and universal unity of knowledge and, through Christianity, that faith was the highest order of knowledge. The conception of the unity of knowledge influenced the pattern both of organisation and of teaching.

Tracing the subsequent line of descent in the most general terms is not difficult. A greater differentiation both of university curriculum and of external orientation followed the intellectual, social and political changes of the fifteenth and sixteenth centuries. Universities everywhere continued to concentrate on preparing their scholars for the profesions of the law, medicine and theology, but their role as corporations inevitably became entangled in the history of their own societies. At the same time, new modes of enquiry, particularly in the sciences, developed a momentum of their own ouside as well as inside the universities. Rival or parallel institutions emerged, some of them livelier and more effective, and during the eighteenth century, in particular, there was widespread recognition of the limitations of traditional universities as agencies either for transmitting existing knowledge or for advancing new knowledge. Yet the conception of "unity of knowledge" survived the growth of new geographical units, the challenge to faith, the confrontation of different religious systems and the rise of science.

There was a further differentiation in the nineteenth century, when academic specialisation and professionalisation developed along new lines. By the end of that century, indeed, not only had new "subjects' 'been carved out in university curricula and new universities been created in many coutries, but the differences between different countries had been widened in an age of nationalism. Common to most countries were increasing (in some cases total) freedom of universities from ecclesiastical control and patronage, the emergence of an academic "profession", specialisation of learning by "subjects", and the introduction of new courses, methods of teaching and forms of examination. The notion of "unity of knowledge" was difficult, if not impossible, to maintain in this setting, although was not until the last decades of the century that specialisation by discipline hardened in the humanities as well as in both the increasingly differentiated natural and social sciences. The conception of the *advancement* of knowledge was fundamental to the nineteenth-century university, not least when there was strong professional interest, as in medical education. The hero of the medical faculty, was not the "good physician" but the innovator in the medical sciences. This bias was obviously true in the case of all the natural sciences and applied in the arts and the social sciences also. Knowledge, it was felt, had a "threshold", and judgement *between* universities came to rest on the sense of there being specialised peer groups in each "discipline" able to recognise and appreciate the significance of the work of the real "pioneers".

So much was common. Yet for all the cross currents — and they were many between, for example, Germany and France or Germany, Britain and the United States — there were marked differences in ethos and organisation between the French, German, English and American "systems". In Britain itself, there was such a contrast in approach between Scotland and England, particularly during the early years of the century, that an influential young writer wrote confidently that he regarded "the academical institutions of England and Scotland as things specifically distinct... I please myself in thinking that the two institutions have different object... That each system might borrow something with advantage from the other is very possible, but I respect both of them too much to be fond of hasty and rash experiments". Broadly speaking the differences between universities in the French, German, British and American contexts pivoted on four points :

1. selection procedures ;
2. the degree of independence from central or local government of particular university institutions ;
3. the extent to which universities through colleges or through "non-academic" activities were deliberately involved in "socialising" procedures in relation to their undergraduates, forming their "characters" as well as their "minds" ; and
4. modes of teaching as influencing or as reflected in faculty/student ratios.

Recent Trends

It is not easy to generalise about these four points, each of which had a direct bearing on the nineteenth-century approaches ot both university teaching and research. Yet it is perhaps easier to generalise about the more recent period in university history even though inherited patterns of difference persist and when new university instituations are created they are permitted markedly different degrees of freedom to innovate and resources to do so.

Most of the experiment in universities has come about in the most recent phases of university history when universities have opened themselves up to a far wider cross-section of the community socially, when there have been remarkably high rates of growth (in non-European countries as well as in Europe), when the rôle of universities as centres of innovation has been widely recognised, and when, particularly, during the last three years there has been a "student movement" directly concerning itself with the objectives and functions of universities. Although some university development may have been "hasty and rash" and some has certainly involved "mimicry", much has entailed fundamental re-thinking. Increasingly the thinking has been "internationalised", and in this new setting nineteenth-century experience has been sifted, probed and re-evaluated. The limits to the value of "specialisation" both in academic and in social terms have been stated. In academic terms it has become clear that at the "threshold" of knowledge (in the social and biological sciences, for instance) inter-disciplinary approaches are often essential and that in regular teaching situations (not least in the humanities) it is valuable at least to relate disciplines to each other and to note where their methods and conclusions diverge and overlap. Some of these questions are taken up in Chapter III. In social terms the "problems" of contemporary society require interdisciplinary handling, the demand for graduates cannot be stated simply in terms of the demand for particular categories of specialists ("judgement" is needed it is often said, and "flexibility" more than "expertise"), and undergraduates themselves, coming from a wider social range than ever before are increasingly dissatisfied with the nineteenth-century specialised curriculum. There are pressures both from above and from below. There is increasing recognition, moreover, that in an age of rapid social change undergraduates are "being prepared" for quite different circumstances from those of the fleeting present.

So much is common in this century, when in trying to evaluate and to plan ahead it is increasingly useful to turn from particular institutions, each located within a particular educational "system", to the "systems" aspects of universities as a whole. Insofar as the academic sytem is a differentiated sub-system of society, it remains in complex ways interdependent with it. The community provides funds, and as the necessary amount of financial assistance increases it wishes to ensure that the funds are spent as economically as possible. It also supports research, a mounting commitment in many countries, but one posing difficult questions about academic freedom and direction. Finally it has its own assessments, vague or sophisticated, of "national need", as expressed, for example, in manpower projections. In each case long term views are necessary. Undergraduates fulfill their social needs long after they leave universities : the impact of research can only be assessed after time lags associated with application and further development.

For the modern community, therefore, the university is a pivotal institution. It can no longer be thought of adequately as an institution producing, distributing and consuming existing "knowledge"—either in "ivory tower" or in "factory" terms. It is concerned with creating, criticising and diffusing a new culture, and as the next part of this chapter shows, and, there are various "feedbacks" from and into society. Questions of disciplinarity, pluri-disciplinarity, inter-disciplinarity and trans-disciplinarity are all central questions in relation to this world of continuing change which requires not education once and for all but continuing education both to understand and to direct it.

VECTORS OF CHANGE

Whatever patterns emerge or, more positively, are planned, it is certain that changes in society are imposing on universities, often dramatically, sometimes through confrontation and breakdown, a number of new dimensions or vectors. Four vectors can be distinguished from each other, although in practice they are all interrelated. First, there is a *space vector*. In a society where the most important problems exist at world level, the university must be thought of as an essentially international — and not as a local — institution. This will effect both teaching and research. The comparative material in Chapter V of the third section of this book deals with experiments in particular countries, all of which have far more than a local interest and signifcance. Pooling of experience is perhaps more valuable than model-building, although unfortunately the experience so far is scattered and limited and thought always has to be given to genuinely new models. Second, there is a *time vector*. In a society in full spate of change, where model-building and forecasting are essential tools of control, both the short-term future when decisions must be taken and the long-term future when results become apparent, universities must concern themselves with the future. Third, there is a *demographic vector*, the vector which has most concerned governments. In a society where the trend towards the democratisation of higher education or in some cases "mass education" (usually against a background of population growth) presses on universities as institutions, the old forms and content of university education are no longer necessarily appropriate. New universities have a strategic significance in this context, although not all of them have taken advantage of it. Older universities, however well adapted to the needs and conceptions of the past, have been subjected to severe strains and at times and in particular places to conflict and disintegrated.

Fourth, there is a *knowledge vector*, as the first part of this book has demonstrated. Change in the pursuit of intellectual enquiry itself and in the modes of intellectual discourse have rendered obsolete the organisation of universities into vertical structures corresponding to the idea of "subjects" or "disciplines' and "faculties" or "departments", independent, self-determining and sometimes segregated. However intellectually alive some "traditional" universities may be their form of organisation inhibits them from changing their strategies in the light of all the relevant considerations.

These changes also challenge the very contents of teaching appearing in the courses which professors are usually satisfied to rehash year after year, and further, call into question the methods which are more conducive to handing down codified knowledge than stimulating the ability of students to discover and create knowledge in continuous progess.

These new dimensions are the way in which the University of today is being challenged by society, and it can rise to the occasion only by undergoing drastic changes. It has seemed to us that Interdisciplinarity should play a decisive role in this transformation.

Section 2. PROBLEMS

The introduction and expansion of interdisciplinarity as factors of change in the Universities comes up against many obstacles today and raises problems which are all the more difficult to solve since, as we have just observed, there are a great many different kinds of institutions of higher learning. But even before we look towards solutions, which will in any event have to be tailored for each individual case, we need to consider the main problems which may be put briefly under three headings: institutional problems, psychological problems, and material and administrative problems.

INSTITUTIONAL PROBLEMS

The model on which the Universities in most countries, especially in Europe, are still based today existed before the great changes that have occurred in scientific procedure, population structures and society itself. The purposes it served have practically never been reviewed and re-defined. It is still essentially based on:

— splitting up and grouping of disciplines as in a school or "Faculty" system which no longer corresponds to the present state of science and thereby thwarts its development;
— limited, relatively homogeneous recruitment, since it consisted almost exclusively of young people with middleclass backgrounds who received a classical education, whereas the University is tending to become an institution for the masses with enormous differences between individual students' basic culture and conceptual capacity;
— the needs of a society with a relatively stable structure, offering a range of well-determined occupations, each demanding a certain amount of clearly catalogued knowledge, whereas in a rapidly evolving world where science and technology as well as the relations between individuals and groups are constantly changing, the very notion of an occupation and therefore of preparation for a trade is gowing increasingly inaccurate.

This model had produced higher educational institutions that vary greatly in structure and operation but which can be grouped approximately in three categories according to their aims:

1. Schools emphasizing a liberal arts education, as was for a long time the case with the Schools or Faculties of Arts and Letter and also usually with the Schools of Law and Science. Based on a certain concept of humanism, in either a "classical" or a "modern version", the very notion of a liberal arts education, it must be agreed is now practically meaningless. It has been wrecked by the exigencies of specialisation and is now more and more torn between the temptations of impossible, Promethean all-encompassing learning and the risk of spreading superficial knowledge too thin, so that it usually boils down to the worst kind of multidisciplinarity. So it is that all forms of broadly-based, general studies programmes have fallen into disrepute.
2. In point of fact, most of these schools nowaday stress teaching specific subjects. But by their makeup, they are already sharply partitioned off into departments, Chairs and Institutes that are usually unaware of each other's existence, and tend to be yet more fragmented as a result of increasing specialisation, which ends up with the institution falling apart at the seams, for monodisciplinarity

itself has no further meaning and no longer meets the needs of science or society.

3. Schools which stress vocational training, mainly including the Schools of Medicine and Pharmacy, the State Engineering Schools and to a certain extent Law Schools. They are generally set up along fairly rigid lines and the least that can be said is that they are very slow to adjust to new developments in knowledge or social needs. This group also includes Schools of Education and Teacher Training Colleges, which in some countries have taken over in this field from the faltering Schools of Arts and Science. They are, however, rather isolated in the University structure, so how could they properly do their job of training teachers ? The majority of institutions of higher learning suffer nowadays from the serious ills of lacking precise objectives, and being overly subdivided and poorly adjusted to social needs. Even though the model on which they are still based has proved obsolete, structural patterns are holding on almost everywhere, which is incidentally a proof that the University, even when beset by hardening of the arteries, is still very much alive. The example of France is significant in this respect, where under the guise of the "pluri-disciplinarity" written into the Orientation Act, the separate groups are, paradoxically enough drifting further apart and the old bastions are more even closely guarded. It is therefore a problem of institutional surgery— how can new organs capable of changing the whole organism be transplanted into the patient without killing him ?

It is reasonable to suppose that the recently created Universities do not come up against these difficulties. That is true, but they come up against others. It is often probably easier to create new structures than to change old ones ; in any case it is necessary to invent a new model for this purpose. The experiences this book gives an account of show how difficult it is, at the present time, to establish such a model, since we do not know the requirements of science and the needs of the society of tomorrow, and they also confirm just how weighty old habits and out-worn models are. This phenomenon is particularly striking in the case of the young Universities created in developing countries, which have to meet entirely different, and fresh needs and which raise problems that can hardly be solved within the framework of the traditional disciplines as they are usually split up. Almost everywhere, the European model in one form or another was followed probably for lack of a better one, and for psychological more than for institutional reasons.

Psychological Problems

As these various examples clearly show, it is more difficult to change a way of thinking than an institution. The introduction of interdisciplinarity in particular, comes up against incomprehension and resistance stemming not only from teachers, as one might have expected, but from students and from society in general.

Granted that few teachers seem thus far to have understood how important are the stakes involved. They have been trained in generally hard and fast disciplines, have been teaching for some years with this same framework and usually pursue rather narrowly specialised research so that they find it hard to imagine how interdisciplinarity could be anything other than a shot in the dark or mere dilettantism. Thus they allow themselves to be caught in the trap which modern-day science sets, that while specialisation is indeed necessary, this is in order to reach beyond it. Part II showed what kind of dialectic should be established between disciplines and interdisciplinarity. But the problems implied by such an approach and the price to be paid for it must be clearly stated. There is a problem of distortion between the levels of development reached by the various disciplines. While any interdisciplinarity worthy of the name, we have pointed out, involves some amount of formalising, the disciplines involved must have reached that level, or at least their practitioners must be aware of the necessity of reaching it. How is this done and what price is paid ? Another problem is very well illustrated, for example, by the present state of history, which under pressure, particularly from structuralism, has had to move beyond the stage of erudition based on critical analysis of documents and the search for sequential causality in order to rebuild synchronous structures. Can it do so, however, without giving up its own calling, unless, as some people are now suggesting, it comes up with concepts of recurrent situations and diachronic structures and thereby unites with anthropology, sociology and mathematics in a fertile interdisciplinarity ? Last but not least, a third problem among many is how and to what extent, assuming such conversions are possible in the field of research, are they going to be translated into terms of education and teaching methods ?

All of this — and we should like to stress this point — postulates a profound change in attitudes, both for individuals and for groups, and consequently it raises the difficult issue of teacher training. Interdisciplinarity is first and foremost a state of mind requiring each person to have an attitude that combines humility with openmindedness and curiosity, a willingness to engage in dialogue and, hence, the capacity for assimilation and synthesis. Furthermore, it is a discipline in the ethical sense of the word and demands from the start that the representatives of different sciences accept teamwork and the necessity of searching together for a common language. It is no cause for surprise that teachers who have been accustomed since childhood to individualistic behaviour and studying rather isolated "subjects" don't readily accept the idea of changing over so completely and after years of practice based on handing down a certain type of knowledge — which they may often quite rightly have regarded as appropriate and efficient — and sometimes overhauling completely the contents, spirit and methods they use in teaching. What is true for the majority of tenured professors is also true for a good many junior faculty members, who have fixed habits and prefer the easier alternative of not displeasing the "boss" and risking their career on what seems to be a mere adventure, and thereby bolt down the system from one generation to the next. So this raises the major issue of teacher training, which we shall return to later.

The students might at least have been expected to be the best champions of interdisciplinarity. Experience has unfortunately proved that this is not so, at least for the moment and in most cases. A good many of them have the vague sense that the institution needs changing, both as regards its methods and contents and the structure itself, and the winds of revolution which caught them up in 1968 in many countries substantiate this. But once again, the "silent masses" have settled habits, a lack of information, structural inertia, a secret anxiety about the morrow and a fear of the unknown which have induced them to acept the return to the *status quo ante*. The real protestors, who are obviously only a small minority, are mostly convinced that the University cannot be changed without first changing society, and they are convinced that the traditional disiplines and the methods of transmitting knowledge are obsolete, this is obviously not the front on which they have decided to fight. Finally, there are others who take the opposite view, that society can or must be changed by first changing the University and who endeavour to find practical solutions. But what information do they have available to get through this narrow gate ? Where can they find an overall view of recent changes in the spirit of science and its new requirements, especially as far as interdisciplinarity is concerned ? Can they really be expected to have clearer ideas on this issue than their own teachers ? They must first be persuaded that the relevance to life which they are demanding of our Universities comes about through interdisciplinarity, that it is only through interdisciplinarity that the real problems arising in our times can be tackled and perhaps solved, and lastly, that interdisciplinarity is a prerequisite for the development of those new job possibilities which student are quite rightly particularly concerned with.

But to what extent have those very persons who control the entrance to occupations—business men, administrators and managers of organisations of all kinds—actually realised how swiftly changes are taking place in all fields and what the consequences are for vocational training ? Very few of them, specially in Europe, seem thus far to be aware that a wide range of skills will become much more necessary and valued than a particular store of knowledge attested to by a diploma but which will soon be out of date. The idea of anticipating the future, even though it now enters into any effective vocational training, is all too often still foreign to public opinion in general and even to the minds of the political leaders and many reformers. In these circumstances, how can the advent of interdisciplinarity avoid coming up against many obstacles ?

MATERIAL PROBLEMS

Among these obstacles, the difficulties in obtaining proper facilities should not be underestimated. Some of these stem from the organisation of space and others from the organisation of time, both being in any wase more or less closely related.

The organisation of University space is often the result of improvisation, chance circumstances or external constraints and rarely the result of a concerted plan. Thus we frequently find, especially in France, that "Faculties" are scattered in the four corners of a city, making the least attempt at "pluridisciplinarity" practically imposible. It may even happen that a single department, because of an increase in enrolment or because of new equipment is forced to accept new premises which are often spread wide apart. These are no doubt extreme cases and temporary situations but they often go on for some time and undermine the institution from the inside. The formula of the campus adopted long ago in the United States and in other countries, which is tending to spread among the newly created Universities, is obviously much more conducive to expanding interdisciplinary activities. But even then the advantages may be merely apparent. The size of some campuses and the way in which the disciplines are distributed on them make some kinds of connections perfectly illusory. A fifteen — or twenty-minute walk is sufficient to discourage even the most willing of students, especially when, as is generally the case, their time tables do not allow them enough interval between classes. Moreover, the layout of even the most modern Universities are rarely based on an interdisciplinary model for the simple reason that such a model does not as yet exist, except in the mind of a select few.

Similar problems can be found on a smaller scale. Whether in the context of teaching or research, the practice of interdisciplinarity demands a new arrangement of space to facilitate meetings and work in small groups as well as individual contact between teachers and students. How many of even very recent Universities, which are equipped with many large lecture halls housing the latest improvements, suffer from a manifest dearth of small work rooms or offices for the junior faculty or even for the senior professors ! It is high time that public opinion and government officials realised that increased university stafing must be accompanied by more work space and equipment and that such facilities must be designed and distributed in accord with the needs of teaching and scientific kwowledge.

Such a new economics of space cannot be separated from a new economics of time. The length and difficulty of transportation, as we have just pointed out, represent a considerable obstacle to expanding interdisciplinary relationships. There are yet other obstacles. The need to get both the faculty and the student body to join in running the University tends to absorb a good share of the activity and time of at least some of them and therefore obliges them to confine themselves to the bare requirements of their discipline. It is hence essential that everything be done to lighten their load (administrative facilities, office staff, etc.) and allow them to devote themselves to the necessary innovations. It is also essential that administrators themselves be informed of the importance of these innovations and of the resources required to implement them.

These are some of the problems raised by the University upheavals. Before we look at ways of solving them, we should carefully redefine the aims and functions of an institution which is tending to play a growing role in our society.

Section 3. AIMS AND FUNCTIONS

We must repeat that we are not attempting here to put the University in a long-term perspective but only to endeavour, on the basis of the present situation, to define the main objectives on which agreement could probably be easily reached and which could guide the transformation of the University and indicate its short- and medium-term functions. A very general "model" will therefore be proposed which will have to be "qualified" in order to adapt it to the special situations described above. Furthermore, if a superficial choice is to be avoided, such a model must necessarily cover under the title of a University the whole of what is generally accepted as higher education, on the understanding that the latter cannot be dissociated from the other levels of education except for the purpose of making a clearer presentation.

First of all, summing up the present situation in a few words, we can say it has the combined characteristics of a confusion of aims and functions, an anarchically complex and disorderly structure and also an anachronistic pattern of subdivisions.

There is a confusion of aims and functions. The same course is often given to prepare students for a profession and for research, and it is difficult to see whether the University is more concerned with piling up learning, dispensing knowledge or educating men.

The structures are anarchically complex. In most countries, higher education consists of a mosaic of schools set up during the course of successive generations and which suit a wide variety of requirements that are often out of date.

The pattern of subdivisions is such that the system is still almost everywhere based on disciplines which serve as a framework within which ever increasing amounts of information are handed down indiscriminately to students who are checked by examinations that also reflect this pattern of subdivisions.

The most urgent tasks are therefore to break down the partitions and build a new structure, and even more important, to clearly redefine purposes. Interdisciplinarity has a major part to play in this endeavour.

Overall Objectives

The essential cause of the crisis in the University is its increasing ill-adjustment to a rapidly changing society. The first objective is therefore to re-establish contact between town and gown. Any ambiguity in this connection must be dispelled at the outset. While the University should be in the service of society and must consequently fit into it more fully, this certainly does not mean that it has to follow in society's wake. A society groping its way needs an agency to lead and control it, and only the University seems capable nowadays of taking on this dual role, provided, however, that it keeps its proper distance and while developing closer ties with society, avoids any dependence on government officials or economic powers.

In short, the University must be given, in new forms of course, the spiritual power it once held and which enabled it for long to have the leavening influence on the development of civilisation. As the place where research is associated with training the managerial class of society, the University must now take on that *overall cybernetic function* in the absence of which the social patterns emerging would be subject to distortion, permanent crises and conflict, and exposed to the arbitrary decisions of a small minority.

In other words, it should in the future be regarded as the educational institution par excellence, as a true pilot institution working as both the driving force and regulation of society, where cultural political, economic and social models will be elaborated and subjected to review, and where the men who are going to put them into practice will be trained. In view of the ever closer ties between these various fields, it is evident that this overall primordial function can only be performed by an institution of a resolutely interdisciplinary nature. It is no less evident that how trustworthy such an institution is and how much credit it enjoys will depend above all on the clarity, flexibility and effectiveness of the model which it sets for itself.

Searching for a Model

This model could in fact be loosely based on the cybernetic model, distinguishing two kinds of input: the flow of students and the flow of information. The overall function of the University is therefore itself divided between the two functions of "processing" this information and "processing" the students in order to obtain an output of men and women who, as responsible agents and citizens, are not only able to find their place in society but can organise and control it in the light of the choices they made based on the models they get through information that is itself transformed into scientific knowledge. Thus, there are at least four closely knit functions of equal importance : providing information, liberal arts education, research and vocational training.

Information and Training

The function of information is the University's memory. The effectiveness of the other functions depends upon it ; hence the extreme importance of libraries and documentation centre. But printed books and written documents are now only a part of information which is increasingly transmitted through the mass-media and in audio-visual form. The "Universities memory" must therefore have new dimensions and this raises investment, reception and filing problems as well as that of selection. Documentation is multidisciplinary by definition, multinational by necessity and multiform as a result of its development, and is indeed beginning to assume monstrous proportions. The age of the ewalth of knowledge is thus being succeeded by the age of the economy of knowledge. The documentalist librarian must become an information agent, i.e., first a data processor. Using new technology, he must help the student, and even the teacher and research worker who are wrestling daily with a mass of information which is more and more difficult to master or even detect, to make a pertinent choice both at introductory orientation level and at the level of more exhaustive research and anquiry. He must not only be a guide but an educator. In order to steer others effectively through this maze, he must be able to get himself oriented and to grasp the relationship between disciplines. This assumes an interdisciplinary background.

Information thus necessarily leads to training. Monodisciplinary teaching or a multidisciplinary University could if need be confine themselves to transmitting information. The development of interdisciplinary knowledge and practice requires all information to be accompanied by adequate training at all levels.

General Education

The expression "general education" may be taken as referring to the undergraduate level, which has the two functions of guidance and initiation.

When they enter higher education, many new students think that they already know where they are headed. Apart from those — in fact very few in number — whose vocation comes out during adolescence and is confirmed during the first few terms of university study, many have chosen a discipline or School without knowing what lies in store for them because of family heritage, a chance circumstance, skimpy information, the image they have of a particular profession or quite simply because it seemed the easy way out. Many students, after a string of setbacks, will decide that they were wrong and after one or perhaps two years will try something else. The consequences of excessive subdivisions and premature specialisation are discouragement, maladjustment and a university which is not very profitable.

General education, properly understood, should avoid such a waste of effort. It is not of course a matter of patching up a sort of "cultural background" programme by learning a smattering of everything, which could only lead to encyclopaedic or ameteurish knowledge, but of enabling each individual to find and fulfill himself and, for this purpose, to "understand" the world so that he can determine what place he will soon have in it, with full knowledge of the facts. This general education should therefore cover a wide range of overlapping disciplines. It should be based on the study of a few problems demanding different approaches and should be a tough and exacting school. In other words, it should be made up of an introduction to the true scientific spirit as it is defined today, and should equip the student with the indispensable conceptual tools, especialy an introduction to the logical and mathematical language applied to the various disciplines studied. This introduction therefore involves a certain measure of "transdisciplinarity"', as this term was defined in earlier chapters, and insofar as it can prepare students' minds for a certain unity of knowledge.

It would also be a good idea to lay stress at the same time on the student's introduction to the methods of a specific discipline in order to get the student ready to specalise without any further to-do.

Teaching and Research

Liberal arts education leads right to scientific tr ining, which is usually divided into two stages, the first being teaching and second research. In a rational pattern, these two stages would correspond respectively to what in France are called the second and third cycles, that is, the upper undergraduate and beginning graduate student years and they involve quite separate if not opposite university functions. Thus, the demands of teaching frequently do not allow a professor much time for research, and the requirements of research are not really compatible with those of teaching.

However, this is apparently a false dilemma. First of all, from the student's standpoint ; teaching and research at all levels are fundamentally complementary activities for both pedagogical and scientific reasons. One elementary truth in teaching is that one only learns and properly understands what one has the impression of discovering on one's own. The art of teaching is above all the art of getting pupils to discover things for themselves. There is of course the basic knowledge which must be learnt in each discipline ; but even this will only bear fruit if the student has really assimilated it by learning how to transform it into practice, when he needs it to solve problems. But most problems are interdisciplinary. For this reason any specialised training, from a strictly pedagogical point of view, must necessarily refer constantly to other disciplines. This is so from a scientific point of view too, advances in knowledge are now tending to blur more and more the boundaries that have been used to divide up learning, both in the social sciences and in the so-called exact sciences. And the ever increasingly rapid progress, in part based on the interdisciplinary approach, tends continually to call accepted knowledge into question.

Scientific honesty and the demands of teaching therefore require the teacher to communicate as soon as possible to his students a sense of progress and of the relativity of all knowledge. While teaching, he instills in the student thought patterns conducive to research. As a well-known formula puts it, the essential thing is for the student to "learn how to learn" and, still more, to least in a pluridisciplinary form from the early undergraduate years on, is

This introduction to research, which should be present in germinal, at least a pluridisciplinary form from the early undergraduate years on, is developed during the undergraduate major, as the student specialises, following a progamme which whenever necessary calls freely upon interdisciplinary procedure, and becomes genuine research at the graduate school level.

It happens research will play a growing role in the Universities as they become aware of their essential objectives. If it is agreed that they should be an agency to innovate and check on things in society, they will both produce knowledge and create fresh, regulating models. Research cannot therefore be allowed to develop in separate independent centres even if such independence seems sometimes conducive to its development. But since such expansion tends to demand that scientists use an interdisciplinary and even transdisciplinary approach, research acts as a unit which must be organised and orchestrated and where everyone should have his place. The University must not seem to be the country cousin. It should on the contrary be the home of scientific research which will be based on its new requirements and will inspire society's future leaders.

Just as there must be no gap between research and teaching, there should not be any between basic research and applied research. Science can afford less and less to be cut off from its applications. It is these applications which, by the complexity and increasing size of the problems they have to solve, advance science along the road of interdisciplinarity and constantly create new crossroad-sciences, such as cybernetics, computer science or the environmental sciences. Future research workers should be trained in this spirit and be accustomed to work in teams, as this is an obvious prerequisite for any interdisciplinary research.

Vocational Training

Science, as we said, cannot be separated from its applications. Doctors are well aware of this and so are lawyers and economists and many others who practice or are preparing for professons other than that of research worker. Vocational training must always be regarded as one of the University's jobs, one that is essential in some cases and relatively secondary in others. There is in any case no competition nor gap between them, and general training and vocational training form a continuum, just like vocational training and research. The study of medicine is the best proof of this, and the close ties existing almost everywhere between medical schools and hospitals should serve as an example.

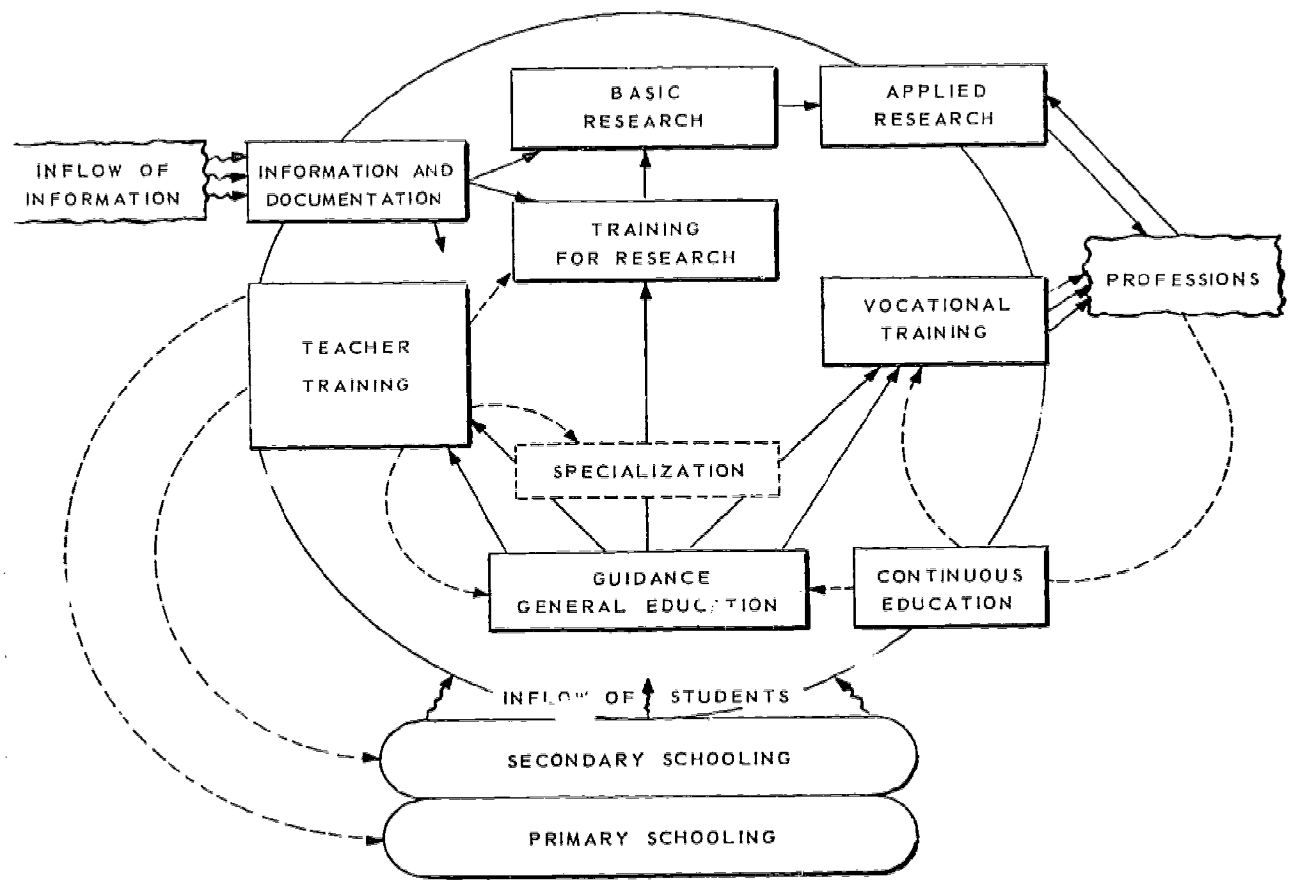
To be sure, training given within the University itself cannot help being academic. It is vital for this to be backed up by practical training at any early stage of the game. Hence there is a need for rather lengthy introductory and on-the-job advanced apprenticeships in government departments, private firms or organisations of all kinds, according to the case. As a preparation for life and a trade, such apprenticeships alternate with university study and not only make students better motivated to study, but by bringing them into contact with real problems should persuade them of the need for genuine interdisciplinary training. This is the first step along the road to true continuing education.

It is certain that presentday society is indeed developing in the direction of both diversifying requirements and jobs for any one profession and allowing greater job mobility. This means that the vocational training developed at the University must have, in addition to sound specialisation, a measure of all-round preparation and the ability to a. st to new situations and accept continuous "retraining". Such a background can only be built by resolutely interdisciplinary teaching, which will enable it to continue to develop through all the phases of life.

The University can no longer be an ivory tower or a hideout. Whether from the standpoint of information or research, of liberal arts education or vocational training, it must become a place engaged in constant comunication with society, a house which one does not leave forever after obtaining some sort of passport but a home one readily returns to, both to get to the sources of knowledge and to help in building and running a society which is forever changing.

In order to carry out its many functions and develop the necessary connections between them, the University must acquire a flexible structure, redefine its curricula and methods, and last but not least, train its own staff better than it is doing nowadays.

CHART SHOWING THE OPERATING FUNCTIONS OF THE UNIVERSITY



Chapter 2

STRUCTURES

Section 1. PATTERNS OF HIGHER EDUCATION

NATIONAL PATTERNS

There is great diversity in national patterns of higher education. In part this diversity reflects differences of historical experience ; in part, however, it also reflects different approaches to what are often common social and educational challenges irrespective of national boundaries. It is only during recent years that the patterns have been studied comparatively in "systems" terms with any real analysis of the main quantitative variables and of the basic relationships between primary, secondary and higher education. In the meantime, the patterns are changing rapidly as a result of the operation both of academic and social forces. In almost every country discussions are still proceeding about what future patterns, short-term or long-term, should be. Where "reforms" have already been carried through on paper — sometimes through Acts of Parliament — the struggle for implementation is proceeding. Any discussions, if they are to produce useful results, should go well beyond the immediate exigencies of policymaking or administration. If the issues raised in the last chapter are to be handled with the necessary imagination and vigour, there must be both the most profound questioning and the most audacious experiment.

QUANTITATIVE VARIABLES

It is not difficult to identify the main quantitative variables relevant to policy making, even though it is seldom easy to produce all the essential statistics. What are the numbers involved in higher education as a proportion of the age group ? In other words, how far is higher education thought of as an *élite* or a *mass* activity ? How many students are part-timers and how many of them full-time ? What is the normal duration of study and the age limits within which it takes place ? What is the through-put of the system, i.e. how many students who enrol complete their courses within the conditions as set ? How many students are involved in post-experience or continuing education ? What proportion is devoted to the provision of research, and is this proportion related to the provision of teaching ? How will each of these quantities change in the future ?

The available answers to some of these questions about past quantities are set out in the Report of OECD's Education Committee, *The Development of Higher Education, 1950-67,* although the Report ends before the most dramatic and significant recent events in university history in Germany and the United States as well as France. The difficulties in interpreting the statistics are not shirked. Thus, it is pointed out, for example, that in the American and Japanese systems, the concept of post-secondary or higher education covers what in most European countries constitutes the last year of secondary schoolstudy. This difference obviously has bearings on the kind of university courses which can or should be provided, disciplinary, multi-disciplinary or inter-disciplinary. So, too, of course, does the structure and duration of degree courses themselves and the relationship between first and higher degrees.

The Report is not concerned with research as such, where the statistical materials are both more scanty and more difficult to compare and to interpret, but it examines those pressures within contemporary society which influence both the demand for university graduates (and their aspirations) on the one hand and research needs on the other. Emphasis is rightly placed throughout on the *dynamics* of higher education systems. This involves thinking and planning in terms of rates and flows and feedbacks. The dynamics of the recent period of growth in university numbers are examined in detail, but it is also explained clearly why in order to understand what is happening at any moment of time in university history it is the "flows" which must be studied. The number of university students enrolled in any given year depends upon the intensity of entrance flows in the course of the years t, t-1, t-2... t-n, on the theoretical duration of studies, and on the retention rates of the system from admission to graduation. These last two variables are directly dependent on the structure of national systems and both obviously influence the opportunities for and the difficulties in the way of introducing multi- and interdisciplinary curricula.

As the flow of students through a higher education system increases — and in some countries including Canada, Greece, Norway, Sweden, Turkey and Yugoslavia, it more than tripled between 1950 and 1967—three points become quickly apparent. First, *many of the students themselves neither wish to follow the single-discipline-based university courses of the past nor are they always qualified to do so in terms of ability as well as of motivation.* Second, the growth in the number of members of an age group attending universities means thath university students have become an increasingly *heterogeneous* (if at the same time more articulate and more highly organised) group in terms of inclinations, talents and home backgrounds as well as in their occupational destinations. Anxieties on the part of students about both the socially formative and the socially critical role of the university have consequently increased. Thirdly, society, through its institutions, does not seek or require a continually increasing input of specialised graduates of the conventional kind : although "social needs' have tended to be expressed vaguely in a period when both business and the professions are uncertain about the qualities they expect from their new entrants, emphasis is being placed less on transmitted specialised knowledge, with accepted standards, and more on educational processes designed to develop "flexibility", "adaptability" and "judgment".

All these points emphasize the need *not only for a review of university structures and curricula but for greater guidance* to students about what is and what is not available to them. It also sharpens the case for greater participation by students in the affairs of their universities. At the same time, the increasing pressure on national resources for higher education in all countries — a pressure which will increase further during the 1970s — means that the content of higher education cannot be treated as a "luxury" product. The claims of cost-effectiveness alone direct attention also both to structures and to curricula.

Macro-structures

Against this common background there have been, of course, many differences of response. There is obviously no single blue-print. Three structural questions relating to national systems as a whole have been raised, with none of them being settled. First, should new university institutions be created or should innovation as well as expansion be left to the existing units of the system ? Second, should moves be made to widen the range or network of institutions concerned with higher education, building up or bringing in some which are not thought of as universities ? Third, should all institutions of higher education be concerned, as the university of the past century set out to be, with research as well as with teaching ? Indeed, should all universities in present circumstances be so concerned ? Could there not be a distinction between universities which are special "centres of excellence" and the rest ?

Old and New Universities

The first question has been tackled in very different ways, nor has it always been tackled by the same country in the same way over very short periods of time. Throughout the world there has been a great increase in the number of new university institutions since 1950, although more of them have been attached in various ways (through tutelage and affiliation, if not through incorporation) to existing institutions than have been born free : some, like Linköping in Sweden, have subsequently become independent. In most countries, new universities have been treated as incremental to existing systems, and weight of expansion has been borne by existing institutions if only because of the time lag between producing the initial plans of a new university and actually bringing it into existence.

The prospects of innovation are usually more favourable in new institutions than in old ones, although even in a new institution a precondition of moving naturally and willingly from discipline-based to multi- and interdisciplinary studies is a group of faculty members committed to change and possessing the necessary academic and psychological qualities to carry out the change effectively. If such a group is lacking, a new university will not necessarily be an innovating university. Some new universities, indeed, have not considered that it was their resposibility or privilege to innovate, and in many of the new countries which have introduced university institutions for the first time in their history, at least during the early stages of university growth more emphasis has usually been placed (often for reasons outside the control of the new institutions themselves) on imitation rather than on innovation.

The British example is an interesting one. The decision to create seven new universities was taken before the Robbins Committee recommended a sharp increase in the total number of university places. Sussex was announced in 1959 and launched in 1961 : York, East Anglia, Essex, Kent, Warwick (at Coventry) and Lancaster followed. For each of the new universities an Academic Planning Committee was constituted to decide what subjects initially should be taught, to draft a charter and to select a Vice-Chancellor. Once appointed, the Vice-Chancellor and the new academic faculty took over, although the Academic Planning Committee remained in existence for the first few years of the life of each University. Each Academic Planning Committee and each new academic faculty was free to develop the structure and curriculum of the new university as it wished subject to the general oversight of the University Grants Committee which is responsible in Britain for the allocation to individual universities of the global sum set aside by the Government on a quinquennial basis for university expenditures. Many of the Academic Planning Committees were active sponsors of a more varied pattern of university courses with greater emphasis on inter-disciplinary studies. So, too, was the University Grants Committee itself which saw the significance of expansion in qualitative as well as quantitative terms. Each of the new universities quickly established its own identity and each developed on distinctive lines. Some were more innovatory than others, but all were in a position to innovate. Undoubtedly the existence of powerful Academic Planning Committees was an important element in the process of innovation. The same procedure was followed when a new university was created later for Scotland—Stirling. It was not followed in the case of the Colleges of Advanced Technology which were also promoted to full university status in the late 1960s, and in consequence perhaps there was less initial emphasis on changes of structure in these institutions than in the new universities.

One new university in Britain or a group of new universities attached to existing institutions would have been incremental to the "system": seven, later eight, obviously affected its dynamics and gave a considerable impetus to change in structures and courses in the existing universities, old and middle-aged. The national "debate" about structures was enlivened in consequence and it had further international ramifications. From the start the new universities offered first and higher (doctoral) degrees in a wide range of subjects. There were none of the problems which have arisen in some countries about the relative status of degrees in "experimental" universities as compared with other universities or the relationship between university courses of a conventional kind and "fringe" courses. The fact that the new universities had to operate within the same financial "norms" as the existing universities was in itself an incentive to change, for, as Professor Martin Trow has pointed out, "in a system in which material differences are slight, it is the promise of contributing to bold and creative innovations in higher education, and of sharing in the intellectual excitement of such a venture, that attracts talented people."

In the United States. where the distribution of resources varies considerably from State to State and where there is often no equivalent to the planning apparatus to be found in Britain, expansion has taken place not so much through the creation of new universities as by the development within existing State University systems — and some of them are increasingly "co-ordinated" — of new campusses with varying degrees of independence. In some of these, like Green Bay, Wisconsin, described in greater detail in Chapter V, a new pattern could be evolved different from that at the other university campus at Madison. In California a whole cluster of new university institutions was created, each with a separate internal structure and curriculum : there was scope, indeed, for substantial initiative in each scattered campus, and some of the new university institutions are as different from each other as the new universities in Britain. The same degree of initiative was permitted also in Ontario, Canada, where a new university, like York, was able to develop a quite different structure from that of other new instituions, and in Australia where, for example, Monash and La Trobe in the State of Victoria set out quite deliberately to develop on contrasting lines.

In countries where traditionally there has been a more monolithic conception of the University, experiment has tended to be confined, until recently, to specially designated institutions and the dynamics of change have not been expressed so decisively in chain reactions throughout the whole system. It has been necessary, in consequence, to seek to introduce general reforms of the whole system at the same time. The introduction and implementation of such general reforms has involved a different kind of debate from that in Britain, the United States, Canada and Australia. At the same time, it is clear that on the basis, for example, of the French *Loi d'Orientation* of 1968 there is scope for a wide span of responses, conservative and radical : there is also scope for substantial differences of interpretation. The *Loi d'Orientation* does not deal with "Inter-disciplinarity" as such : whether it produces significant qualitative changes will depend on the way in which the U.E.Rs in different institutions respond to and interpret their particular tasks in the light of the general reform. The twin concepts of "corporateness" and "autonomy" will be tested in practice, but if there is to be a recognition of the need for variety within a range of corporation and autonomous institutions, there will have to be a less rigid attitude both to teaching and learning structures and to the degree qualifications ultimately conferred upon students .It is within this context that the French debate about disciplinarity, multi-disciplinarity and inter-disciplinarity still proceeds.

Universities and other Institutions of Higher Education

The answer to the second question depends on different attitudes (often they are inherited rather than closely reasoned in relation to present and future circumstances) towards the unity and diversity of the higher educational system as a whole. In many countries highly specialised work (for example, for teachers, social workers and technologists) has been carried out in non-university institutions where just because of the limitation of range in a few cases, it has been possible to experiment with pluri-disciplinary and to a lesser extent inter-disciplinary curricula. Courses have been less subject to tight control by professors of "established" disciplines than would be the case in universities.

What has bedevilled the development of these other institutions in most countries has been the inability to conceive of the higher education system in terms of a "network" of related institutions. Instead there has been a strong sense of hierarchy with, for example, the *grandes écoles* in France being conceived of as "superior" institutions (with highly competitive access) and in complete contrast the "Colleges of Technology" in Britain (with very open access) as "inferior" institutions. In most countries the argument for a greater variety of institutions as well as for a greater variety within the university sector has been advanced increasingly in recent years, and new institutions have been created in many countries, including the UITs in France (in 1966) and the Polytechnics in Britain (in 1970). These institutions should be able to develop pluri- and inter-disciplinary courses of a different kind from those offered in universities. They can also be of varying durations and relate work in the classroom to work outside.

Yet if recent argument in most countries has involved acceptance of the need for diversification, it has also involved (in countries with systems as different as those in France, Britain and the United States) a geater stress on the need for "unity in diversity". Students should be free, is argued, to move from one institution in higher education to another, with institutional transfers being made as easy as possible. The "structures" should not stand in the way. To imphasize the importance of unity within the system moves were made in Germany during the late 1960s towards "comprehensive'" universities, moves which would have been inconceivable during any earlier period of German university history. The "comprehensive" university is designed to merge hitherto independent units, like the need within the system for technical universities, colleges of education, colleges of art and other specialised institutions within one single framework.

In considering the prospects for multi- and inter-disciplinary studies in different countries, it remains necessary, therefore, to consider those particular structural questions in each country which bear on past and projected relationships between universities and other institutions of higher education. Within this international context the United States, in terms of its size and resources as well as of its history and culture, merits special attention in itself. Above all, it has a very wide range of highly developing and still developing institutional types — community colleges, private or public; comprehensive colleges, private or public, some of them operating mainly at the State level, where local needs may be very specifically identified, others of them national and international in orientation, some of them sub-systems of great complexity, with units or clusters of units managed with substantial degrees of independence, a few of them powerful research centres attracting, recently precariously, the great bulk of Federal funds for research; institutes geared to technology but often with extended curricula, some not concerned at all with teaching, many problem-orientated in such a way that they must necessarily be inter-disciplinary or trans-disciplinary in character; and a formidable infrastructure, private and public, of further education of various kinds.

The United States is important, however, for two further reasons. First, its different institutions already provide an immense range of multi-disciplinary curricula, with students in most cases being allowed a wide range of choice according to their individual preferences. Second, there is a high degree of mobility, particularly at the end of undergraduate education. Questions concerning the range of courses and the methods of choice generated an American debate about "general" and "specialised" education long before the debate about disciplinary, multi- and inter-disciplinary education began in post-War Europe, and a number of projects produced during this protracted debate and publications arising out of it still have direct relevance to current discussion in other countries.

The mobility between institutions is itself associated with degrees of specialisation. Undergraduate programmes in most American colleges and universities begin with course requirements in "general" education, pluridisciplinary in character, permitting wide individual choice and backed by professional counselling. Later courses involve more work in specialised fields ,again, however, not necessarily in one single field. It is often only at the graduate level that full specialisation starts, frequently at a different institutuon with attractive research facilities. The Graduate School is a key element in the American higher education system.

Some colleges and universities have extended concepts of mobility in a different sense, insisting, like Antioch, on relating university studies to "life" through work programmes outside the College ambiance, or extending the scope and scale of study-abroad programmes. In both cases the kind of education aimed at involved more than the acquisition of knowledge in a particular or even a group of related disciplines. It is perhaps significant that this kind of education, which involves a substantial access to resources, has been strongest in the private sector, a sector which is small or absent in many countries. There has also been a marked tendency in America in recent years to challenge the view, habitually accepted even in the United States, that the rationale of universities is the pursuit of "cognitive learning", and "fringe" activities concerned with the "affective aspects" of learning — most of which never existed in European universities — have been deliberately brought in some cases from the fringe to the centre.

TEACHING AND RESEARCH

American experience may prove to be more distinctive in character than was once thought. In every country there is a particular approach to the organisation and creation of institutions of higher education other than universities. Whether or to what extent all such institutions — even all universities — should be research as well as teaching institutions is an open question in most countries, as is the question of erecting institutions exclusively devoted to research. Both these questions have economic and political aspects. Yet they also have important bearings on the future of interdisciplinary studies.

Much research is by its nature inter-disciplinary since the solution of particular problems requires a combination of disciplines. This has become abundantly apparent in such diverse "fields" as the life sciences (for example, in the discovery of DNA), development economics (when dealing with particular cases involves teams of economists, sociologists, psychologists, historians, geographers and technical specialists) and the humanities (where the borderlands between, for example, history and literature or linguistics and experimental psychology, have provided some of the most fascinating territories for exploration). At the frontiers knowledge stubbornly refuses to fit into traditional compartments.

Research should have a feedback on teaching—and in some kinds of undergraduate work in new fields (often of great interest to students today), the insights of research workers in teams are already being communicated in inter-disciplinary from to students in the early stages of their university education. The outlines of knowledge are not yet always "firm", and the very lack of firmness is part of the attraction to the student as well as to the researcher. Some of the pedagogical problems — and opportunities — implicit in this situation are dealt with in a later section.

In the meantime, while the structures should not be too rigid, attention should be paid to the closer integration of research and teaching in the interests both of faculty and students. How this can best be achieved depends on the internal structure of the university, although the financial parameters depend on national policies. They will be considered alongside other dates relating to comparative costs, the use of buildings and equipment and the specialisation of functions of different institutions in terms both of available manpower and national priorities.

Section 2. IN ꝛNAL STRUCTURES

The internal organisation of universities has been studied far more seriously in recent years than ever before as universities have grown in size and have been subjected to sharp internal and external pressures.

There are two main varieties of universities—the unitary and the federal. Within the federal pattern the different units may have different degrees of autonomy and different functional relationships with the rest: some units, indeed, may be of a specialised kind, dealing with one category or level of students. Within the unitary university pattern there are always smaller units than the university itself. In some "traditional" universities "colleges" exist, in some cases residential as well as academic units, in the case of the Oxford and Cambridge colleges with independent sources of finance. In most universities which were created in the nineteenth and the twentieth century there are academic divisions into "departments", each deparment having in charge of it a professor or group of professors and being concerned with an identifiable academic "subject" or "discipline", sub-discipline or, more rarely, group of disciplines. In some countries there has also been a fundamental distinction between "departments" and "institutes", the two working in parallel, sometimes with separate budgets, the latter mainly concerned with research.

The term "faculty" is used in different ways in different countries, even sometimes in the same country, but in most countries there has been a separation of the university into different "faculties", for example, in arts and sciences of law and medicine, each with its own dean. Usually the faculties have had their own government, and in France before the Loi d'Orientation of 1968 and in Italy it is the faculties which have wielded the greatest academic power, sometimes reducing universities to groups of faculties. The faculty groupings have often been pluri-disciplinary, but they have seldom been concerned with inter-disciplinary experiments in teaching.

Dissatisfaction with aspects of these different patterns of sub-division has long been expressed, and in few cases have traditional" relationships remained stable. During the nineteeth century, for example, the position of colleges in collegiate universities was transformed as a result of the increased specialisation of knowledge, the appointment of university professors in far greater numbers, and the building of science laboratories open to students from the whole university. During the twentieth century there have been many critics of "departmentalism". According to a former Director of the London School of Economics, "departmental organisation often reaches a condition of monstrous hypertrophy, falsifying the academic map, and bringing about the herding of teachers into pens surrounded by fences." Duplication and dispersal of effort, lack of planning and coordination, rivalry and occasionally open conflict, boundary disputes and far from splendid isolation have often been in evidence. Given the rapid growth of some British and American universities in recent years, several departments in large universities have become bigger than whole faculties in smaller universities. They have naturally compared themselves with departments in the same discipline in other universities at least as much as they have concerned themselves with their positioning in their own university. The result has been a fragmentation of the conception of the university as a whole. Methods of departmental finance, administration and decision making have varied so much, however, from the authoritarian to the democratic, that it is not easy to generalise. And it is equally difficult to generalise about more recent changes in structure designed to check departmentalism. In several of the new British universities, for example, "schools" have been set up, headed by deans, which are bigger than departments and which constitute, through their composition and government, pluri-disciplinary units. Yet some of them are little more than super-departments with the deans super-professors, and the dividing walls separating them from other schools are thick. In only a few of them have inter-disciplinary activities taken root. Already the term "school" encompasses a wide span of organisations with different powers.

Generalisation is equally difficult in France, where the Loi d'Orientation had as one of its guiding principles the abolition of the faculties and the creation of UERs*. The faculties were said to have had too much independent power and their educational outlook was criticised on the grounds that it was compartmentalised and fundamentally conservative. The picture of what is happening as the Law is implemented is far from clear, although some faculties seem simply to have re-named themselves UERs with no change of function or style. The change in structure — as in the case of the British change from departments to schools — is only meaningful if new policies are pursued. As it is, the UER, like the department, can too easily be conceived of in a vertical and closed manner. If progress is to be made in developing inter-disciplinary work horizontal structures must be created. Moreover there is a further danger if some UERs devote themselves solely to research and others to teaching, thereby inhibiting reciprocal interchanges between the two.

It is unlikely that in existing universities, as distinct from new ones, that "departmental" or limited UER type structures will easily or quickly disappear. For inter-disciplinary work to flourish the following minimum structural pre-conditions are, nonetheless, necessary :

a) the university as a whole must be felt to exist as a corporate unit and it must be in a postion to develop its own global strategy. It must be prepared not only to encourage and support inter-disciplinary work within departments and UERs but to make central planning decisions which make possible the introduction of inter-disciplinary work across the dividing lines of its subsidiary units ;

b) within the subordinate units there must be discussion of and preparation for inter-disciplinary programmes. Faculty must, if need be, be specially appointed to teach such programmes. In big faculties, like science and humanities, organisation into mono-disciplinary departments presents the minimum of disadvantages from the teaching standpoint provided that there is frequent consultation at all levels and coordinating machinery to organise

* Unités d'Enseignement et de Recherche.

new courses, particularly preliminary courses for the first years of study ;

c) the whole budget of the university must not be carved out between the subsidiary units unless there is specific provision for the introduction of inter-disciplinary work ;

d) there must be a regular review of all inter-disciplinary work actually being carried out. If university structures are changed, this does not imply that all difficulties have been solved and all opportunities taken. Given the future changes which are bound to take place both in the organisation of knowledge and in the shape of society, it is essential that universities shall have efficient mechanisms for change ;

e) minimum obstacles should be placed in the path of individual ministries by central authorities in the way of achieving experiment. It is interesting to note in this connection that the British system, where each university awards its own degrees (as in the United States) and is free to develop and modify its own curriculum and modes of examination, permits the simplest form of self-regulation. In Germany recent Federal Government legislation on universities permits universities through a so-called "experiment clause" to deviate from existing regulations if it wishes to try out new models ;

f) special arrangements must be made between universities, not least between universities in different countries to pool experiences and to train faculty to take part in inter-disciplinary work. There should also be facilities for preparing and circulating new materials.

Each of these structural pre-conditions is important. If they are not all present there will be a tendency for the university as an institution either to atrophy or to split up into clusters of separated activities. The motive forces behind the movement for change have already been noted, but two of them will be further developed in the last section of this chapter and in the next chapter. The first is care for the needs of the individual student, the second the reform of the curriculum which is almost impossible to achieve within rigid departmental structures.

Section 3. THE INDIVIDUAL IN THE STRUCTURE

Within structures, attention must always be paid to the developing needs of individuals. Educational systems have often been based in the past on the independent functioning of disconnected units intent on autonomy and self-assertion. The sense of the continuity of education has suffered in consequence. No account of structures which does not deal with the individual *before* he enters a university or other institution of higher education and *after* he leaves it will be complete.

School and University

The structures of school education are directly related, therefore, to those of universities, although the ability of universities to determine or influence school structures will vary from country to country. In some countries, like France and Germany, the administration of the different levels of education is unified : in other countries, notably Britain and parts of the United States, the influence of universities is mainly indirect. The basic problem, however, is in all countries the same. There is a sharp break between school and university. And the student entering university is often unprepared for the new choices open to him and the new rhythms of work required.

For this reason alone several countries are experimenting with pre-University colleges designed to establish a sense of contact and continuity rather than of break. There has also been increasing discussion in most countries in recent years about the effects of continuing education of differentiation between different types of schools ; of the conventional "turning points" in schools, when increased specialisation on the part of the individual student begins ; of "general", as distinct from specialist, studies in schools ; and of the balance of the school curriculum, and of the effects on it of examinations of the type of the German *Abitur*, the French *Baccalauréat* and of the English *General Certificate of Education*, examinations which are at the same time leaving certificates for the majority and certificates of entrance to universities for the minority. These examinations have in the past often set limits on the freedom of schools to devise their curricula in an experimental fashion.

"School and University", it has been argued by Professor von Hentig, who is pioneering new higher educational structures in Germany, "must be forced into cooperation with one another by having their interests institutionally interlocked. They must share responsibility between general and specialised education, school instruction and academic disciplines, and the practice and theory of propadeutics : they must jointly present academic knowledge and study in a form which is both usable and learnable'" Professor von Hentig has prepared a detailed plan for a pre-University college which will take in students in their eleventh school year and conclude with a final examination at the end of the fourtheenth. The duration of courses in the college will depend not only on their content and level but on the individual learning ability of the student. The school year system with its strict curricular sequences will give way to a system of a wide range of courses with a common didactic structure, permitting independent and free choice of course combinations on the part of the student. This will involve a modified credit system, which it is hoped will enable the student to review and control his own programme.

Some of these points have relevance in university education itself. It is interesting to note, however, that there are in existence foreign counterparts to the American junior or community colleges, designed to serve as short-cycle higher educational institutions. In Jugoslavia, for example, the *Visa Skola* (two-year post-secondary schools) offer both terminal and transfer courses. In Quebec the *Collèges d'Enseignement Général et Professionnel* have direct relationships with universities, and the first cycle of university studies is provided exclusively in these colleges along with courses of a terminal and vocational nature. In some countries, notably Britain, with its selective university system and its binary organisation of higher education, the *Polytechnics* are engaged in providing academic and vocational courses of all kinds and of all durations, not only in technological subjects. Many of these courses are pluri-disciplinary in character, but there have so far been few moves towards inter-disciplinary work.

In universities themselves, structures will have to be devised which will enable students to follow patterns of study which allow at the outset for informed choices in terms both of individual and social needs and subsequently both for freer movement out and in. The tendency in the past for universtiy courses to be spread out over long periods of time — with very heavy drop-out rates on the way — proved both economically wasteful and academically stultifying. It has been argued, indeed, that in some countries universities have become "parking lots" in society for large numbers of frustrated students. Whereas in Britain the undergraduate course has normally been three years in length (with an increasing number of students spending a fourth year on "research" or further education in their selected disciplines) in France and Germany, where there have been no such limits, students have been spending even up to ten years in university detached from society as a whole. It was not until 1968 that Germany drastically reduced the maximum length of its longest courses to four years. Medicine remained an exception, as it still does in Britain.

THE FIRST CYCLE

Questions of pluri-disciplinarity and inter-disciplinarity are directly related to this context. The main emphasis of reformers has been on the critical importance of the "first cycle", which provides an opportunity, usually not taken in the past, for giving the student a *mise en place du savoir*. This involves both pluri-disciplinary and inter-disciplinary studies. The danger in ill-considered change will be that if for good reasons mono-disciplinary work gives way to a broader span of work, there will be a tendency to encourage a smattering of superficial knowledge about an ever increasing number of unrelated subjects. It is because of this that there must be careful thought both about curriculum and the organisation of the student's timetable.

British structures, more flexible than those in continental Europe are relevant here. One of the first experiments in changing first-year patterns which has undergone many modifications in practice, was the "Foundation Year" of the University of Keele, Britain, the only English university to have a four-year rather than a three-year undergraduate teaching pattern. During this Foundation Year students had to work (with options open to them) in both arts and science subjects. In many other British Universities the first year has for long been devoted to pluri-disciplinary work, the student selecting new subjects to add to the subject which he will ultimately be taking on its own for a single-subject honours degree. Yet inter-disciplinary possibilities have usually been overlooked, and the student has frequently lacked any sense of focus. Departments have not come together sufficiently openly or constructively to relate their courses to those of other university departments in the interest of he particular student. In consequence, the student has felt a only really "at home" when he has embarked on his specialised departmental courses. It is clear that universities as a whole must consider carefully this first crucial stage of university education, distinguishing "basic" subjects from optional ones, common subjects, which should be taken by large numbers and specialised subjects which will be taken by smaller groups. The question of "combinations" is of critical importance.

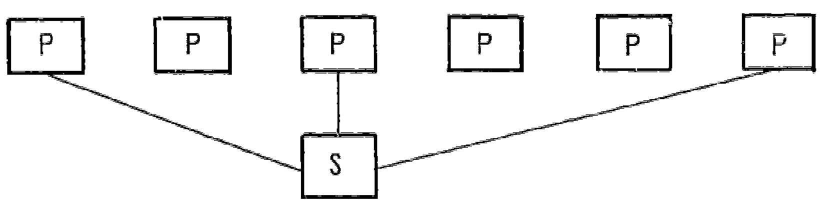
STUDENT PROGRESS

There are alternative ways of planning the subsequent course of student progress at a university, with two diametrically opposed alternatives in theory, either of which is usually followed in a completely single-minded or doctrinaire fashion. The first is a model of "student freedom", a model which is applied, usually with modifications, in a number of American universities. The second is a model of carefully planned group functions, a model which is applied, again with a variety of modifications in many traditional professional schools with set subject context and accepted "standards".

Within the first model the individual student is free to choose whatever courses he wishes *à la carte* from a wide range of courses, some of which may be specially designed for him. There is no set pattern. In such circumstances it is for the student himself to decide to what extent he will move from one single discipline to work in related disciplines or, if the chooses, in distant disciplines. If, for example, he is interested in studying a language he might move

a) to the study of a second language
b) to a study of linguistics or
c) to a study of literature, with follow-ups in each case, for example, from linguistics to experimental psychology or from literature to history.

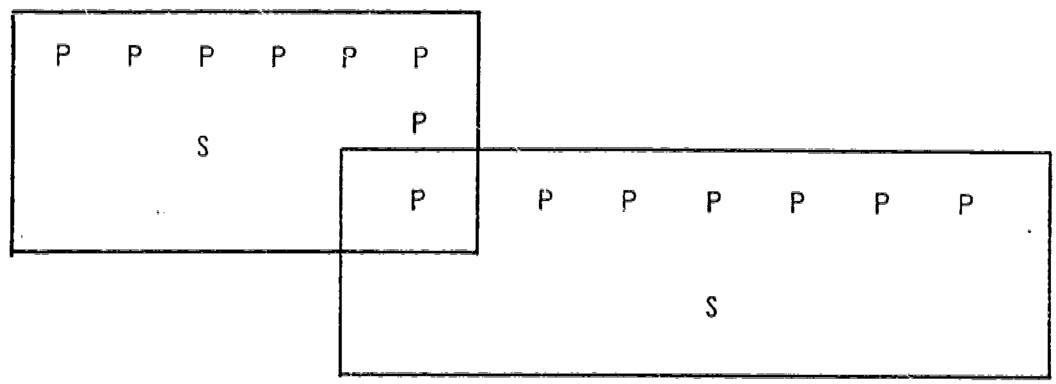
These would be moves which would take him across disciplinary boundaries. But if he chooses he could make leaps across disciplines, studying say a language and physics. In any given year in the life of a university graduates under such a system, which is set out in diagrammatic form below (S for student : P for professor or tutor) would have followed different personalised routes to their degrees.



Such systems are qualified in practice

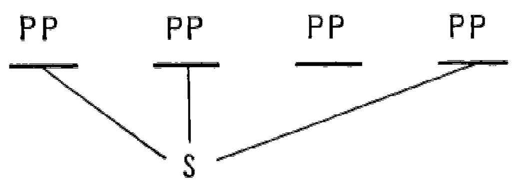
a) by the availability of course teachers
b) by counselling, which may lead students into following particular combinations and
c) by regulations concerning the sequence in which particular courses can be followed.

Within the second model, common in professional schools for engineers or doctors, the student as to follow a prescribed set of courses within a prescribed sequence. The courses may include "basic" courses during the first cycle and options among specialised courses during later cycles. The courses may also include, according to the imagination of their designers, inter-disciplinary courses amongst the building blocks.

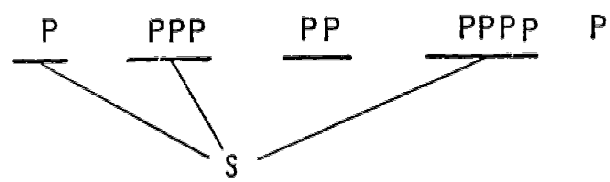


It is often with such definite *schema* in mind that the planners of new universities have designed their initial structures : more frequently, however, the *schema* have been passed on from generation to generation within existing universities with little interest in re-drawing maps of learning. Particular courses are usually associated with particular professors or departments.

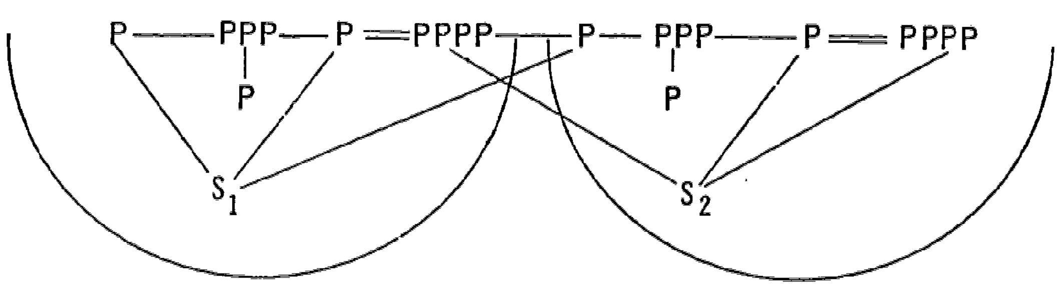
For inter-disciplinarity to be successful professors (or departments) must associate with each other, either coordinating their purposes (with pluri-disciplinarity as an intermediate phase) or from the start looking at the same topics from different angles (with inter-disciplinarity, however primitive, as an immediate result).



Within a university there will be some arrangements of this extended kind and some of a concentrated kind :



or there could be a whole network of interdisciplinary relationships with students turning to professors in different clusters of subjects and working alongside other students studying different combinations of subjects.



Within this "network" model, the "course" is obviously the main constituent part of the system rather than the "subject", and the "school" (in the Briitsh sense of the word) offers a far more efficient unit of organisation than the department. The concept of a system of study units *(Bauka system)* is fundamental, whether or not the units are examined on a "credit" basis either by continuous assessment or through a sequence of examinations or whether or not they are "interchangeable" between different universities, thereby facilitating student mobility.

TOWARDS PERMANENT EDUCATION

It has recently been suggested in Britain that at the end of two years a student might choose to leave university if he wished, and, if his work had been satisfactory, he would obtain a qualification which would enable him to finish his degree by working for a third year in the same or a different university after an interval of time. The idea of intermission between university work and a further spell at a university is merely one variant on a range of possibilities of linking university work more directly with work outside.

Whatever the pattern, it will clearly be important in the future not to regard the acquisition of a university degree or diploma as a terminal qualification. It will have to be followed by refresher and post-experience courses of a wide variety of kinds, some extending specialised knowledge, some inter-disciplinary or trans-disciplinary in character.

As this transformation takes place the university will cease to be associated almost exclusively with one age group, and will inevitably be drawn into far closer relations with agencies outside. This transformation itself will lead over time to further substantial changes in structure.

Chapter 3

CURRICULA

Section 1. MAPS OF LEARNING

PRESSURES FOR CHANGE

The reform of institutional structures does not by itself guarantee a new approach to the arrangement of the university curriculum in terms of content and method. The re-shaping of the curriculum has always been rightly considered, however, to be the most exciting task of university reform. In present circumstances the late nineteenth-century view that the *advancement* of knowledge depends upon a continuing process of specialisation within particular disciplines no longer holds. Instead the advancement of knowledge in such fields as the life sciences or the economics of development depends, as we have seen, on team work and the interplay of different kinds of concepts, methods and insights. When the *transmission* of knowledge is considered, there is mounting impatience both with drawing dividing lines between "subjects" in terms of formal definitions of content and scope and with attempts on the part of teachers, themselves usually educated to understand only one discipline, generally to restrict the first stages of the higher education of others to the pursuit of one single specialisation.

The reform of the medieval curriculum of *trivium* and *quadrivium* — grammar, rhetoric, and logic ; and arithmetic, geometry, music and astronomy — was associated both with a burst of new knowledge outside these confines and with the emergence of new ideas concerning the purpose of university education. It was recognised long before the nineteenth century that in education and perhaps in life, as Daniel Bell has put it, there is "no quota of eternal verities, a set of invariant truths, a single trivium and quadrivium that must be taught to a young man lest he be charged with the failure to be civilized or humane." There is equal dissatisfaction in the twentieth century with the view advanced during the nineteenth century with the emergence of the specialised mono-disciplinary curriculum, when specialisation was considered as the main engine of academic progress within a new academic division of labour parallelling the social division of labour in the world outside. It was A.N. Whitehead who pointed out in his *Science in the Modern World* that there was danger in confining progress to grooves. "The groove," he said, "prevents straying across country, and the abstraction abstracts from something to which no further attention is paid."

During the twentieth century the main intellectual influence which has been brought to bear on the approach to the curriculum has been the "exponential growth" of knowledge, a growth charted and popularised since Derek Price produced his *Sciences Since Babylon* in the 1950s. In 1964 nearly

320,000 book titles were published throughout the world, while in one single field of study, medicine, it has been estimated that some 200,000 journal articles and 10,000 monographs are published annually. The world of knowledge becomes increasingly unmanageable within the frames which were constructed during the nineteenth century.

Processes of Change

In practice the curriculum of a university is in large part inherited : it is seldom thought out as a whole, and there are powerful forces resisting its revision. Much is taken for granted rather than argued out. Changes in knowledge (as reflected, for example, during the last hundred years not only in the "exponential growth" of knowledge as a whole but in the answers given by students to the changing range of questions in examination papers) are expressed within an existing curriculum : they do not modify the whole. It is usually only in new universities that there is any real possibility of a general review of the curriculum. The changes which do take place in universities usually derive from the following processes :

a) the fission of existing disciplines into sub-disciplines, some of which then become disciplines in their own right. Thus, for example, economic history as a sub-branch of history, physical chemistry as a sub-branch of chemistry or aerodynamics as a sub-branch of physics reach a stage where their practitioners acquire an independent or quasi-independent control of their subject in universities. This process can narrow academic communication, when the communication with practioners of other sub-branches of what was initially the same discipline becomes intermittent and limited. Yet the process of fission continues to accelerate. Thus, in the United States the National Register of Scientific and Technical Personnel registers over 900 distinct scientific and technical specialisms (outside the humanities and social sciences) compared with only 54 twenty years ago.

b) some of these sub-disciplines may thrive on relationships other than those associated with their original parent body. Thus, for example, economic history is fed from two disciplines — history and economics — and if the influence of economics, with its strong analytical and theoretical preoccupations, increases in relation to that of history, then the new sub-discipline, nourished by theory, may develop on new lines — into what is now called "Cliometrics", economic history with an econometric bias. There are parallel processes at work in relation to biochemistry. Many of the new sub-disciplines derive their theoretical reinforcement from a discipline other than that with which they were originally associated. The pursuit of inter-disciplinarity interests within this context may be regarded as a transitional stage in the making of new disciplines out of the other sub-disciplines, but such new disciplines will seldom thrive if they become closed in character. The deficiences of economic history narrowly defined, for example, have encouraged the growth of "social history" which has looked not only to economic history with which it was previously often bracketed, but to sociology.

c) new "subjects" emerge when there is a sufficiently large body of practitioners interested in a particular range of limited questions to separate themselves off from practitioners interested in a wider range of question. Thus, for example, the study of demography as an independent discipline has increased in recent years while its close association with sociology (and eugenics) had diminished. Likewise pharmacology has carved out "territories" of its own. At the same time it should be noted that when attempts have been made not to branch out from existing subjects but to combine them (for example, by fusing anthropology and sociology) these attempts have usually failed. The two most interesting recent "combining specialisations" are psycholinguistics and sociolinguistics, the former of which has developed rapidly in some universities in the United States.

d) when a university turns for practical reasons to "problem solving" activities, particularly, but not exclusively, in the technological field, then it may set up departments or institutes devoted to the examination of a particular range of problems which subsequently turn out to have far wider ramifications. Thus, the University of Leeds in Yorkshire, which set up during the 1930s a department to deal with practical problems concerning textile fibres found the department moving from textile fibres to molecular structures and on into both the study of muscle fibre and of materials science.

e) within broad areas, particularly in engineering, there may be rearrangements of subjects and disciplines, previously considered separately in terms of educational provision. Thus the "old" tripartite division into civil, mechanical and electrical engineering has been challenged, even though in many countries the division is reflected in a tripartite professional structure, and new approaches based on the identification of such subjects as control engineering and materials science have been introduced into the curriculum. In medical education the creation of "schools of public health" has led both to an extension of multi-disciplinary work through the extension of the interests of professors into the fields of behavioural, social, ecological, economic and communications sciences, into operational research, population dynamics, engineering and architecture, and to experiments with inter-disciplinary courses. Medical education as a whole, Professor H.G. Pauli has written, "cannot remain product orientated but must become process orientated. In other words, instead of providing the future physician with the factual components of his professional activity we must establish the mechanisms he will need to adapt to future demands". The object is not to broaden the mind, the object set by many of the university reformers anxious to develop "general education" in the past but to introduce essential new elements and linkages into medical education itself.

f) What applies in traditional areas of professional education applies also in new and developing professional areas also. The growing interest, for example, in "the city" has forced a regrouping of the cluster of subjects or sub-subjects concerned with "the city", and a sub-subject, like urban sociology, no longer figures as independently in the map of learning as it once did, while some applied sciences associated with control do and there has been an increasing interest in "eco-systems". As Patrick Geddes, a writer with strong biological interests, put it as long ago as 1921, "neither the most practical of engineers nor the most exquisite of aesthetes, neither the best of physicians nor of pedagogues, neither the most spiritual nor the most matter-of-fact of its governing classes can plan for the city alone." For quite different reasons, sociologists have become uneasy about the dividing line between "urban" and other kinds of sociology, including "rural" sociology, thereby further obliterating distinctions which had for decades tended to be taken for granted.

g) In addition a new group of subjects has come into existence through the development of what has been called the new "intellectual technology": the group includes game theory, decision theory, simulation, linear programming, cybernetics and operations research, many of which are "tooled" by the computer. This emergence of this group of subjects has had and will have important bearings on the "traditional" group of social sciences. The "definitions" of the content of the constituents of the new group and of their relationships with each other remain impressive, but it is clear that there will be need in future for a high degree of mathematical sophistication.

h) Finally there have been changes in "practical" social studies in relation to such fields of action as "social work". As Jean Snelling wrote in her short study *The Boundaries of Case Work in 1959,* "Ten years ago we might have dismissed boundaries in social work. Today the term boundary does not seem right for anything *within* the case work field. A boundary separates off things which are different by nature and centred apart from one another. Where these irreconcilables come most nearly together, there we can draw a boundary line. Now this is not an appropriate concept for us. We can think more readily of case work as a figure of...... interlocking and overlapping circles, each with only a small segment file from its neighbours. I hope that in the next ten years we shall come to feel increasingly certain of the depth and richness and essential rightness of this figure?" After ten years much still remains to be accomplished, but there is a firmer conviction than ever before of the rightness of the figure.

Universities and other Institutions of Higher Education as Agents of Change

The re-arrangement of professional education involves bodies other than universities and often entails a severe (and sometimes abortive) re-assessment both of degrees and of qualifications. Yet there is no doubt that moves towards inter-disciplinarity can be made in some professional schools and institutes more easily than in universities. The practical orientation of the profession may pose such urgent new priorities that if the profession is to remain alive and active curricular change must take place.

Within the university there is need to think in terms of the "map of learning" as a whole. Different universities span different groups of subjects, leave some out and sub-divide others which are united in other places, and even the general debate across universities leaves some universities untouched. Yet it is remarkable how the geographical metaphor of the map of learning, whatever its limitations, recurs in discussion of universities in different periods and places, going back at least to the seventeenth century, when Francis Bacon complained how slow universities were to change their curricula, failing to consider frankly and honestly whether old courses might be "profitably kept up, or whether we should rather abolish them and substitute better".

In the next section some new combinations of courses which can enliven existing curricula or serve as a point of innovation are discussed. For a general change in the map of learning inside a university, however, the following point seem essential :

a) full inter-communication between members of different subject groups.
b) changes in structure and resource allocation of the kind described in Chapter 2 ;
c) a forward orientation in the university with commitment to course planning ;
d) a feedback from research into teaching ;
e) the will on the part of professors and lecturers to spend a great deal of time and effort on undergraduate teaching, and to learn from the experience.

Section 2. REFORM WITHIN THE PATTERN

If it is impossible for a university as a whole to re-draw its map of learning with a view to generalising multi- and interdisciplinary education, it may nonetheless be still possible for useful, even large-scale, changes to be made within particular units—departments, schools and faculties. Some "schools" or faculties may think naturally in terms of the relationship between a cluster of related subjects — in the social sciences, for example — and seek to pass from *multi-disciplinary* combinations (like economics and political science or sociology and psychology) to inter-disciplinary courses (like the comparative history or methodologies of different social sciences or the role of converging social sciences in the study of cities or countrysides or industrial or international relations). In any university there are usually pace-setting departments or schools which not only initiate changes in their own curriculum but consider carefully the relationship between what they are seeking to achieve and what other departments or schools are seeking to achieve.

FOUNDATIONS

Any large-scale changes often start with first-year or cycle courses, where three kinds multi- or inter-disciplinary activity can take place :

a) preliminary cources of a *conspectus* kind designed to provide a shop window for new students. An element in the conspectus may be new disciplines which the student has not had the chance of studying at school. Another element may be comparative—a demonstration of how practitioners of different subjects approach the unravelling of the problems with which they are specifically concerned. Another element may be of "the subjects which meet and overlap at the boundaries with the student's main subject are brought into view ;

b) courses designed to elucidate *"inclusive organising principles"*. The search for a common theory which may influence later courses in the pattern of the curriculum may influence the way in which the preliminary courses themselves will be taught. Less emphasis will be placed on content and there will be no attempt to secure complete coverage. Instead the principles will be picked out and some of their applications studied ;

c) courses designed to introduce students to the *tools* which they will require in studying a whole range of subjects. Thus, for example, many first-year courses for social scientists involve work on statistics and the use of computers, and in some of the courses an attempt is made to take examples from different disciplines or from subjects where disciplines overlap.

In relation to each of these three types of "foundation" course a great deal depends on the quality and imaginative grasp in the teaching. There are often weaknesses in broad survey courses which deal very superficially with complex phenomena, and courses dealing with underlying principles require the most lucid gifts of exposition and a full interchange between professors and students. Courses about the use of intellectual tools can also lose much of their point and interest if they are simply treated as service courses.

Foundations work of all kinds can be continued through the later years of a student's life. Thus, as long ago as 1929 the first of three broad courses at Columbia University in the United States on "Contemporary Civilisation", a course in which members of faculty from different disciplines took part, was extended into a two-year sequence, the first year dealing with intellectual traditions and institutional changes and the second with contemporary socio-economic issues. It proved far more difficult — for staffing and other reasons — to develop at Columbia a parallel course in basic science and in lieu of such a common course students were allowed to fulfill their science requirements by selecting combinations in a number of different fields each of which was studied separately.

In Chicago the way specialist subjects are taught is related from the start to inter-disciplinary considerations. "The basic principle," according to Franklin Patterson in his *The Making of a College* (1966), "is that in each field of specialisation the emphasis would be on the *structure of inquiry* as it becomes manifest through subject matter. The underlying proposition is that by developing experience in the processes of inquiry in a special field, students would understand the principles of description, exposition and argument that are applicable in other subjects as well." Knowledge was so organised that the student would be aware of a comprehensive range of "fields" and would aquire not a sum of factual knowledge in that field but its basic organising principles. One of the most interesting courses tried out was called "Observation, Interpretation and Integration".

In Sweden, where enquiries are being carried out by sub-committees of experts on the extent to which common basic courses and common basic units can be constructed in relation to education in public and business administration and health and welfare, some of the practical difficulties in the way of progress have been identified. Amongst the "drawbacks" of a time-table of foundation courses followed by multi-disciplinary combinations and inter-disciplinary ventures it is pointed out that there are practical problems in devising time-tables. "It may also be difficult to decide how much and what each subject or discipline can contribute to the common course. It could prove more difficult to change the contents of a common course than that of a course within a single subject because one will have to rediscuss the aim of the course with all the parties involved. Further, students with very special and uncommon interests would prefer to start at once with the subjects they want to concentrate on."

Common Work

There is scope in the later stages of university education for common work bringing together students from different disciplines while they are in the actual course of studying particular disciplines. Thus, for example, it may be more profitable to study problems associated with the social sciences as a whole (conceptual frameworks : methods of enquiry ; value judgements in so far as they influence research and decision making ; decision making itself, and so on) or with the environment (land use and the influence of market factors and legislation ; environmental sciences ; practical problems of control and decision-making) after students brought together for common courses from different disciplines have mastered the rudiments of their own specialised discipline. Common seminars may be more valuable in this context than common lecture courses, and lecture courses given by a number of people from different disciplines (and from outside the university faculty may be more valuable altogether) than lecture courses given by one single professor or lecturer. There can be a workshop element involved.

One of the gaps which exists in many universities and which has often been talked about is that between students and faculty in the sciences on the one hand and in the arts and humanities on the other, with social sciences occupying straddling territory. There is a need for common work here, although it usually faces both academic and practical difficulties. Common work might be carried out by students in such fields as science policy making, the sociology of literature, model making in different sciences, the role of the imagination in the arts and sciences and so on.

In the last year of the student's university studies there is a powerful argument for trying to "pull together" aspects of the over-all education of the student, bearing in mind, as was pointed out in the last chapter, that the degree, however examined, can no longer be properly regarded as a once-and-for-all qualification. It is at this point that the student should have become aware through his own studies, if not formally through the curriculum, of the relationships between different disciplines and of the number of problems, including research problems, which cannot be tackled in terms of one discipline alone.

Degrees and Examinations

The nature of the final examinations is of importance in relation to all changes made at the unit level inside a university. In this connection it is useful to note two kinds of question arising in relation to degrees, where the pattern varies in practice from country to country, often from university to university and sometimes from department to department or school to school :

a) The American conception of *major subjects* studied in depth (sometimes when a pluri-disciplinary cluster of subjects is being studied it is called a *concentration*) and of *minor subjects* whether chosen *à la carte* (electives) or prescribed as obligatory because there seem to be academic links between majors and minors. While emphasis is often placed on the need for developing "related courses", these are not always forthcoming, and there are many cases of departments spending little time thinking out or indicating what work a student should carry out in related fields in order to do adequate work in that particular major. When there is inadequate indication students often see no connections, even when connections exist.

b) The British conception of "combined" honours degrees, where two subjects are studied together but not always in parallel. It is not easy to guarantee that such combined degrees (for example in history and geography or physics and chemistry) will involve inter-disciplinary study. Usually it is left to the individual student to discover for himself how the different subjects relate to each other — a virtue has been made of this far from universal process in the well established tripartite Oxford University course in Philosophy, Politics and Economics, "Modern Greats" — and usually the two halves of a combined degree are worked at separately by specialists in two departments. Only occasionally are there joint seminars or courses deliberately designed to relate history to geography or physics to chemistry. In a generally inter-disciplinary curriculum there must be association at every stage in the preparation of the syllabus. In the meantime, graduates who also have studied for combined degrees or have followed up a degree in one subject with a degree in another have useful qualifications for teaching in situations where inter-disciplinary projects are being tried out.

Section 3. EXPLORING AHEAD

Doing without Maps

The image of the map which has been used in this chapter is a useful image as far as it goes, but it loses its point if we forget

a) that maps are always changing and

b) that there is always scope for more kinds of exploration.

In the first connection, it is important to bear in mind that there is little point in members of a university feeling that if they have once changed a map they have changed it for ever. First, there should be scope for regular evaluation of courses, pluri-disciplinary and inter-disciplinary, which have been introduced in recent years—with allowance being made not only for faculty evaluation but for student feedback. It is important that such evaluation should take place before the text-book outlines of new disciplines or of combinations of disciplines have become too set. Second, it should be remembered that those members of the faculty and students who are born explorers, travel without maps. As Michael Polangi once put it well, while the traveller equipped with a detailed map of a region across which he plans his itinerary enjoys a striking practical superiority over an explorer who first enters a new region, nonetheless "the explorer's fumbling progress is a richer achievement than the well-briefed traveller's journey". "Even if we admitted that an exact knowledge of the universe is our supreme mental possession it could still follow that man's most distinguished act of thought consists of producing such knowledge : the human mind is at its greatest when it brings hithero uncharted domains under its control."

PRACTICAL IMPLICATIONS

This analysis has many pedagogial implications :

a) there is scope in undergraduate courses for introducing more project work, particularly in the last cycle, where there is a less sharp division between undergraduate studies and post-graduate research work than has become conventional. Experiments have been both in chemistry and physics teaching, in particular, with undergraduate courses designed to strenthen the research element ;

b) there is a need for educational materials other than text books or standard course notes. New courses entail the use of experimental kits of materials which can be supplemented, replaced or discarded as the student progresses through his work. Some of these must be prepared by inter-disciplinary teams. Progressive discovery of this kind on the part both of students and professors may break the pattern described by Professor Kuhn in his important book *The Structure of Scientific Revolution* whereby change within a subject or across the dividing lines of subjects takes place only when the "paradigmes" of knowledge are disposed of in conflict situations between generations often with revolutionary fervour.

c) the method of teaching, more fully described in a later chapter, must be more open. Some defenders of the existing mono-disciplinary system claim that it is already open within subjects and that in any case the form of the curriculum counts for less than the way it is taught. There is some truth in both these claims, although it is more difficult to teach in an inter-disciplinary context in an authoritarian fashion than it is in relation to set courses within single disciplines. Francis Bacon's complaint about "the manner of the transmission and delivery of knowledge, which is for the most part magistral and per-emptory, and not ingenious and faithful ; in a sort as may be soonest believed, and not easiest examined" has still not lost all its force.

BEYOND THE CURRICULUM

There is a sense finally in which preoccupation with the formal curriculum may obscure other aspects of university education which have been touched on in other chapters. William James once wrote that "the intellectual life of man consists almost wholly in his substitution of a conceptual order for the perceptual order in which his experiences originally come." Through both mono-disciplinary and inter-disciplinary work, this substitution process can become increasingly sophisticated. Yet the American emphasis on the place of the creative arts and of sport in the curriculum or just beyond it deserves to be taken into the reckoning if only for three reasons :

a) the elaboration of the concept of the continuity of education cannot leave out aspects of the formation of the individual or of the group ;

b) given the pressure of organisation on the lives of individuals after they leave university a university education which does not offer the opportunity of enhancing the quality of individual experience will leave chasms in society and culture ;

c) not only is the element of experience frequently emphasised by university students, but the whole conception of "post-experience" education for members of an older age group than the conventional university student population rests on the assumption that experience itself counts in the learning process.

Chapter IV

TEACHING METHODS AND TEACHER TRAINING

How can a reform so thorough and varied in its requirements and forms be accomplished ? It must be realised that little progress will be made so long as new methods of operation as well as new operators have not been selected and set up. In other words, introducing interdisciplinarity into the Universities involves both a profound change in teaching methods and a new type of teacher training, the whole being governed by a change of attitudes and faculty-student relationships.

In this field, the older European Universities certainly have much to learn from the English-speaking countries where, at least up to now, students and teachers were close and trusted one another, and where curiosity and the desire for a two-way exchange were often more in evidence than the mere transmission of knowledge. It may be asked, however, whether this type of relationship may not be challenged here as elsewhere by the development of the University for the masses, and whether by itself it suffices to facilitate acquiring an interdisciplinary spirit. We therefore deem it essential to put the problem in all its dimensions, even if the following observations do not seem to apply equally to all countries or to all levels of education.

It is certain, however, that the problem of the teaching relationship is closely connected to that of interdisciplinarity and also to the new forms of culture. So long as the printed book reigned supreme, and with it the intellectual culture for which it was the vehicule, the teaching relationship was based essentially on the transmission of a type of learning that was usually practised within the framework of a subject or discipline. Hence the kind of relationship between teacher and taught that was seen in hierarchical and usually one-way terms and found its natural extension in the school textbook, in turn depending closely on the strict division into disciplines.

But it is likely that the growing use of audio-visual aids, the importance of mass media in everyday life and the accession to the level of artistic creation of new languages such as the movies, radio and television will rapidly change this state of affairs and transform attitudes as well as the contents and methods of teaching. For not only do these languages give new dimensions to our perception of the world and appeal to new reaches of our personality which now correspond only distantly to the traditional disciplines, but the world perceived in this way seems henceforth to be a multiform and total universe which has to be grasped in its infinite variety.

This has several important consequences. First of all, in view of the many forms of aggression which young people are almost permanently prey to, the teacher's task is less to increase still further the quantity of information that they receive than to help them master it. He must arm them against the dangers of a fragmentary culture with interdisciplinary frameworks of thought which will enable them to locate problems and to grasp the connection between apparently disparate phenomena. In short, the traditional function of passing on information must, at least in the first stage, partly give way to a function of *general education* based on the orderly arrangement of knowledge.

They must be then taught how to master these new languages themselves, which involve exercises of quite a different kind from the traditional essay or any other intellectual composition based on books. Cultivating sensitivity, the art of listening and seeing, and the creative and imaginative faculties should henceforth take a much more important place in teaching. This, as we can see, is quite another thing from the transmission of learning. It is much more a training in know-how which can only be obtained through practical work of a new type closely associating disciplines regarded hitherto as poor relations or an unnecessary luxury, such as the appreciation of music, films and art. Last but not least, corporal and dramatic expression should be added, and ought to become the basis for a real science of movement. Obviously, this type of activity requires that the future teacher be given a really interdisciplinary training which prepares him to serve as a kind of "studio head" who is able to practise what he preaches. To "lend a hand" himself and to be a leader rather than a teacher in the usual sense of the word.

These few preliminary remarks are obviously not sufficient by themselves. If we want to specify what a pluri- and interdisciplinary outlook is likely to involve in the way of change in teaching methods and techniques, we need to examine in succession the different levels or "cycles" of higher education.

Section 1. FIRST LEVEL : GUIDANCE AND DEVELOPMENT OF THE PERSONALITY

We cannot overemphasize the importance of guidance at the beginning of higher education. Many people think that guidance should be given before the end of secondary school, so that time could be saved to the advantage of specialisation. Pre-guidance would certainly be far from unimportant and might avoid much trial and error and much waste of time. However, we believe it would be dangerous and illusory to rely exclusively on the secondary school to carry out this task for several reasons.

The first reason involves maturity. Prior to the end-of-school examination, there are of course several levels for guidance ; but at that level this can only be academic guidance, i.e. a preliminary choice between very broad fields of study. But as we have already pointed out (see above, p. 196), very few pupils have made a career choice before the age of eighteen. Until then, the range of vocations and professions tends to be confused with the range of disciplines, and this gives an increasingly distorted perspective. However, far from all disciplines are represented in secondary schooling and those which are have small kin with the sciences students will discover when they enter the University. There is therefore a second reason for delaying any real guidance until this crucial moment, and this concerns the requirements of science. A third reason, which is probably the most important, is that the very word guidance implies an interdisciplinary approach, for otherwise it is meaningless. Thus, while it is necessary to introduce a certain measure of interdisciplinarity into secondary schooling, it should be admitted that only relatively mature minds can understand how important and interesting it is.

What does guidance consist of, therefore, and through which pedagogical procedures can it really be carried out ? We believe that it has subjective and objective aspects.

The subjective aspect : giving guidance means first detecting the tastes, aptitudes and potentialities of each individual in order to help him take the path which will best bring out his personality. This not only demands much intuition on the part of the teacher and a permanent personal relationship with each student, but a theoretical and practical knowledge of differential psychology and characterology. This knowledge must be properly applied in order to be really effective, i.e. it must be supplemented by a sufficient practice in the various disciplines and in their specific methods for the teacher to know the type of qualities and abilities required for each of them. Here, educational psychology must itself be pluridisciplinary, i.e. it must be extended into differential and comparative pedagogy. The teacher should of course have appropriate tests for this purpose to add to his direct observation of each individual.

The objective aspect : giving guidance also involves knowing the career opportunities available to the student and especially the ability to foresee as far as possible the development of openings in a rapidly changing society. This is vocational guidance in the best sense of the word and for this purpose the teacher needs to have a *guidance table,* prepared by the responsible organisations according to combined forecasting and prospective methods, and which is kept constantly up to date. Such objective guidance implies recourse to a pluridisciplinarity of another kind which is found in the career profiles themselves and brought into play by the problems raised by a society in evolution and by the resulting fields of activity. To take just one example, it is evident that in the present decade, and no doubt also in the next few decades, the problems concerning the environment will expand considerably and open up a great variety of possibilities. But they demand a very broad background including in disciplines such as geography, economics, town-planning, biology and most of the social sciences.

How are these two aspects of guidance to be reconciled as regards teaching methods and techniques ? If we want to avoid the pitfalls of both excessive generalisation and premature specialisation, two types of approaches will probably have to be closely combined during the first term or terms : studying specific cases, problems and situations, together with a general perspective of the drift of present-day society. In short, two teaching methods should be associated within the broad framework of an *introduction to contemporary civilisation* — the workshop, and the classroom with a discussion seminar. The workshops will offer a range of collective studies of practical problems chosen in a wide variety of fields : town-planning, environment, media, mass culture, social issues, international relations, etc. Such studies could very well be based on topical events and on a file of press clippings prepared by a team of students, or on the analysis of books or else on the interpretation and discussion of documents—maps, films, slides, speeches, etc. The main thing is that they use different disciplines and provide the opportunity for contrasting the various approaches. The organising teacher should therefore call on his colleagues for assistance, as well as persons outside who could bring real experience into the discussion. This workshop activity should always lead to a form of written or oral expression whether individual or collective, and should result in preparing simulated models.

Classroom work, which is always to be accompanied by a discussion seminar, should enable students to locate these individual projects in relation to an overview of the problems of our time. It is essential that they be provided first and without delay with the indispensable conceptual instruments for properly approaching the social sciences and that they become used to handling the terms that have become common to these various sciences, such as model, structure, graph, chart, synchronous and diachronous structure, isomorphism, set, class, sign and symbol, and to giving them a precise content. They should then practice taking an overall view of phenomena and grasping the web of relationships uniting the various sectors and levels of reality. Lastly, they should be able to grasp the essential aspects of change in our time through its political, economic and social as well as cultural manifestations. In short, this general training based on a transdisciplinary approach should make students aware of the unity existing nowadays among the various branches of learning and the necessity for an interdisciplinary approach when studying the problems arising in the modern world.

However, relying exclusively on these guidance studies would no doubt be insufficient and perhaps harmful. In this first stage, the latter should be associated with a course introducing a specific scientific discipline, both in order to prevent some students from feeling that they are "losing ground" and to test the preliminary choice. But at this level the specialist must concentrate less on dispensing knowledge than on initiating students in the spirit, basic concepts and methods of his discipline. Thus, with this approach, each student can best check up on his abilities and tastes and if necessary change his path before it is too late.

Section 2. SECOND LEVEL : SPECIALISATION AND VOCATIONAL TRAINING

It is often difficult to distinguish between specialisation and vocational training and still more to dissociate the two. The link between them is obvious in the case of medical studies ; it is apparent for law, economics and business schools, as well as for the training of technicians and engineers. While very definite and exhaustive specialisation is generally required in these different fields, it has to be accompanied increasingly by acquaintance with a number of complementary disciplines. The specialist physician should also be a general practitioner, the engineer should be familiar with human relations and the economist and the businessman with public relations and all forms of communication. In fact, it must be admitted that universities prepare students less and less specifically for a particular profession, due both to the rapid evolution of science and to that of society. Thus, if we do not wish to swell the ranks of the highly educated misfits and unemployed elite, it is essential, at the advanced undergraduate level, to supplement scientific specialisation with both an introduction to neighbouring disciplines and training programmes in the public or private sector to give students a sense of reality and the necessary flexibility of adjustment and to show them that it is useful to be somewhat "well-rounded", even though many employers are not yet aware of such usefulness.

These observations bring us back once again to continuing education. However, we must be agreed on the real meaning of this expression. It is not what often gets called adult education which is generally nothing more than cheap schooling and tardy catch-up training. The full sense of continuing education means that an individual's life is no longer broken up into a stage when he learns and another when he lives off the knowledge acquired ; everyone now has to continue his education throughout his life. What we call "retraining" is itself only a temporary palliative for we must now speak of continuous training. This entails both a change in the pace of study, in curricula and in teaching methods. The cloistered life of the student for several years — which are precisely those when he is most extroverted and most interested in the issue of how man fits into society — must give way to a form of activity which is wide open to the outside world and to effective simultaneous introduction to the world of science and to life. Theoretical and practical training should then be closely associated right from the start of what is called higher education, which must continue well beyond the degree and "graduation" from the University.

In other words, degrees are probably necessary as a form of verification and proof, but they are no longer enough to define a real *qualification,* and the knowledge which they are supposed to guarantee represents only a small fraction of that qualification. In this new perspective, teaching through training attachments becomes extremely important and constitutes an additional but essential task for the University. For although these attachments have to be made within the framework and under the responsibility of private firms or public departments, the University cannot dissociate itself from them ; it must on the contrary co-operate in making them succeed and therefore join in the teacher training of the group leaders. But the methods involved here are no longer didactic in the standard sense of the word. What is called for, above all, is communicating an experience, introducing students to the operation of an organisation and making them understand the place and function of each individual and the interdependence of the different parts of the machine. The trainee must also be made to take part in this experience, he must be induced to perform "tests" and, lastly, he must be given the necessary flexibility in human relations. This is a delicate task which demands special qualities and training of those who have to take it on. The training attachment should ultimately be a training in team work and schooling in efficiency, where sucess is less the reward for knowledge than know-how, a practical mind and will power.

There are thus considerable advantages to such a change in the pace of work and study. Not only will the student be much better motivated for study, but he will know what to expect and what to demand of it. He can in the light of his own experience make a strict "learning economy" and choose wisely what he requires from among the necessary plethora of course offerings. On the basis of requirements he has recognised he will himself be able to combine essential specialisation with the acquisition of methods and basic knowledge in other disciplines whose usefulness he would not otherwise have perceived. What is more, he will feel the need to develop in himself the attitude and aptitude for an interdisciplinary approach which he will then require of his teachers. This will solve or at least reduce the too frequent conflict between scientific specialisation and vocational training by means of selective programming where the students, grown into a true adult through his training attachments, will take his own initiative and responsibility. There will therefore be a fundamental change, at this second level too, in the relationship between teacher and student and in the methods of teaching, whose incentive will come mainly from the latter and for which it would consequently be pointless to fix norms and methods in advance.

Secton 3. THIRD LEVEL : INTRODUCTION TO RESEARCH

It is apparently difficult to speak of teaching methods at the research level. Yet it is in this field that perhaps most has to be done. Moreover, as already mentioned, there is no clear dividing line between teaching and research. After all, any university teaching which aims to be undogmatic is in some way an introduction to scientific research.

There is nonetheless a level, generally situated after the undergraduate degree or its equivalent, where this introduction has to take an established form and needs its own methods.

It is not possible to lay down general principles here : each field and each discipline has its own procedure which depends on the competence of the specialist alone. However, we have a number of suggestions to make that are based on our analysis of the present situation and on specific examples.

In the first place, the student should understand that research is a continuing process in which he must join, rather in the same way as one jumps on to a moving train. The "head researcher" should therefore help him by all manner of means to make the jump, not only by selecting essential information for him but by making the student a partner in his own research. Nothing here can replace the force of example or direct experiment. Probably one learns to teach by teaching ; in any event one becomes a research worker and learns to be a real scientist by engaging in research.

In the second place, the student must understand that all research is an adventure, that it should avoid the beaten track and soft pillow of conformity and that, while the scientist generally knows what he is looking for, he never knows what he will find. He must therefore acquire qualities which may at first sight seem contradictory : imagination and exactitude. How ? As opposed to what is often believed, the scientific imagination, which is the prerequisite for any progress, is the hardest ability to acquire. Teamwork is a powerful adjuvant, especially when it is well run. "Brainstorming" is often effective to start with provided the debate it gives rise to is carefully recorded, since usually only afterwards a chance idea proves fertile. This practice should lead rapidly to forming a "brain trust", i.e. a structured group comprising a distribution of functions and tasks according to the aptitudes and tastes of each of its members.

At the same time, in the present state of scientific development, interdisciplinary work has proved to be the best leavening influence on the imagination. Here, all the forms of interdisciplinarity distinguished earlier (see page 89) should come into play one after another if not all at the same time : "linear" interdisciplinarity, whereby a law, a structure, or a model borrowed from another discipline may be brought into the discipline under study as a hypothesis ; "structural" interdisciplinarity, whereby the convergence of the approaches peculiar to several disciplines will give rise to new problems and sometimes to new solutions ; lastly, "restrictive" interdisciplinarity, in the case of applied research where working models have to be prepared taking all the conditions imposed by a particular situation into account. This therefore involves the presence in the working group of qualified representatives of different disciplines who pitch in to have an open-minded dialogue. The leader of the group, who will be its guiding light, has a key role here. He himself must have an interdisciplinary mind and ability, he must be fully aware of each participant's possibilities, and he must be constantly on the alert to suggest connections, analogies or possibilities of transfer or convergence. In short, he must set the example of a creative imagination.

However, it is obvious in any research that the imagination must be constantly held in check by the spirit of exactitude. But, as we saw in Part II, the latter is increasingly governed today by the practice of mathematical logic. The handling of clearly defined concepts, the elaboration of a common language for several disciplines, comparing and cross-referencing different sets of axioms, and the quest for a common set of axioms are the imperatives of any exacting approach. This is probably the most difficult but also the most urgent task facing a team's boss. The full colloquial meaning of the work is called for here, since he must embody for those around him — although always discreetly — *a pattern,* i.e. a model both of imagination and exactitude. That is the level of transdisciplinarity, which should guide and show the way for any interdisciplinary approach.

We should like to refer here by way of example to a practical experiment that has been going on for over six years at the University of Paris X at Nanterre within the framework of a research seminar on the science of literature which year in year out groups a score of senior professors, lecturers, assistants and advance research workers in several disciplines (French literature and comparative literature, linguistics, psychoanalysis, semeiology, characterology, etc.). The way literary texts are approached has surely been profoundly affected for a number of years now by development in sociology, psychology, aesthetics and, still more, in structural linguistics. The seminar first concentrated on the contribution of these various disciplines in interpretating works : this was "linear" interdisciplinarity, where these disciplines were regarded as sciences auxiliary to the study of literature. Then, in the second stage, the attempt was made to bring about the convergence — in the context of "structural" interdisciplinarity — of a linguistic approach and a literary approach which gradually resulted in the definition of a common terminology and enabled certain texts to be re-read much more critically. The outcome of this experiment so far is interesting in several respects : first, because of its length and continuity, which demonstrates that the various participants reap benefits from it ; next because of its fruitfulness, interdisciplinary teamwork having proved very profitable for current individual research projects ; last, because of its effectiveness for teaching itself, in that the members of the seminar who teach gradually introduced in their own courses the interdisciplinary spirit and methods that they had worked out in common.

Other similar experiments that have taken place in different countries in a wide variety of fields could be mentioned. They would prove in particular that research cannot be separated from teacher training in higher education.

***

TEACHER TRAINING

We always come back to this topic for the key to any change lies in teacher training. Of course, this does not only concern future university staff but all levels of education. The teaching function is a whole and constitutes an overall problem which can only be solved by an overall s lution. We therefore think that the training of teachers for all levels of schooling take place within the University itself, in Institutes where they are all grouped together.

These Institutes will form a horizontal structure, i.e. interdisciplinary by nature. They will include a central section of required courses common to all students in which basic academic and practical instruction will be given in educational psychology, characterology and educational science. But they will also have several levels with possible "outle " leading to teaching functions at the different levels. At the same time, the ction of required courses will be naturally supplemented by individual secti for the various disciplines taught, or rather for groups of disciplines that are homogeneous in object and methods. It is necessary for the future teachers to get the feel and practice of pluridisciplinarity right away. They will gradually get accustomed to interdisciplinarity through teamwork associating representatives of several groups of disciplines, such that the teams thus formed prefigure those which will have to co-ordinate and harmonise teaching both at secondary level and in the University, especially in the beginning undergraduate years.

Generally speaking, teacher training cannot e t without practice teaching. Every University should therefore have its nexed pilot schools or high schools where the new teaching methods and techniques elaborated in such Institutes will be experimented and tested, the results obtained being discussed in common later at the Institute itself. Future university teachers should therefore also take part actively, first as monitors or "tutors", in the experiments carried out in beginning undergraduate education, especially by organising workshops and joining in guidance activities and interdisciplinary work. This practice teaching ought to accompany academic training, the link being established both by specialists in educational science and specialists in the disciplines concerned, who would thus hammer out teaching methods for higher education together.

It was thought for much too long indeed that such methods could be improvised and that university teachers could train themselves. This might perhaps be true in the case of classroom teaching given in the form of lectures to a well-prepared "élite". The University for the masses, the development of continuing education, the new requirements of the scientific mind, progress in psychology and teaching methods and the many needs of society all call imperiously now for concerted thinking and experimentation on communication procedures within the University. Whatever age and whatever mental level a teacher is addressing, he is also an educator. Awakening and helping the personality of the pupil or student to develop fully, discerning his abilities, developing his creative faculties, and imparting the appreciation and practice of dialogue are tasks which the teacher had so far been ill or unprepared for and which should in the future form the basis of his mission. This mission should be a vocation but cannot be taken on effectively without a very broad training of a truly interdisciplinary nature since it requires information concerning the most modern educational techniques, training in leading and organising groups, a resolutely comparative approach wide open to foreign experience and last but not least, from the point of view of continuing education, real contact with the practitioners and techniques of certain cultural activities.

Make no mistake about it : new men must be trained as quickly as possible with a new spirit and a radically different mental outlook. No effective change is possible in the University if the restraints of habit and prejudice are allowed free rein. Such change no doubt demands new structures and new contents, but it is brought about first through teacher training.

Chapter 5

EXPERIENCES THROUGH EXAMPLES

It is easy to discuss disciplinarity, multi-disciplinarity and interdisciplinarity in general terms, even to prepare blue prints for "ideal" universities which will achieve in one dramatic act a new structure and a new curriculum with all else that will go with them. This chapter turns from the general to the particular, from the projected to the already in existence where there has been significant change and in all of which the change is thought to be more than transitional in character. In other respects the institutions are quite different. The University of Sussex in Britain is a university which, although new, claims continuity with the universities of the past: it encompasses a very wide range of subjects, although it has no medical or law schools. The University of Wisconsin (Green Bay) is part of a large American State University: it is orientated, however, within one particular focus of interest and concern — ecology, the relationship between man and his physical, biological and social environment.

Haceteppe University, Ankara, Turkey, is a specialised university institution, concerned with "health" and seeking to turn out educated health practitioners familiar with basic disciplines and the relationships between them. Each case will be considered briefly: what is said about the three of them together should be directly related to what is said earlier and later in this book.

Section 1. SUSSEX UNIVERSITY

The University of Sussex, located near Brighton in England, was founded in 1961, the first of seven new British Universities, created to cope with the expansion of university members. From the start it was designed to operate with an innovatory curriculum and with a new form of internal organisation.

The unit of university development was to be not the single-subject Department but a multi-subject School, and in each School interdisciplinary courses were envisaged. A range of Schools was planned, of which English and American Studies, European Studies and Social Sciences were the first three. These were followed by African and Asian Studies, Culture and Community Studies (first called Educational Studies), Mathematical and Physical Sciences, Molecular Sciences, Biological Sciences and Applied Sciences. Each School was to provide an undergraduate education which would combine specialisation in one discipline with common work (up to four-fifths) in clusters of disciplines or in related work between or across disciplinary dividing lines. The same major subjects could be studied in more than one school — some in as many as five — but since the contextual or the common and related work would vary according to the School, room was left for options and varieties of work within the major subjects themselves. Thus, for example, History could be studied in different Schools with different orientations (e.g. towards Literature or towards the Social Sciences) and the History syllabus itself showed variations according to the School in which History was being studied.

This plan went further than that of any other university in Britain had ever done before to destroy a false antithesis between "general" and "specialized" education. It also entailed abolishing the Department with a professorial head and replacing it by a School with a Dean, part of whose responsibility would be to encourage multi-disciplinary and interdisciplinary work.

The new courses introduced reveal some of the new departures. In the School of Social Sciences, for example, there were originally 4 common courses, of which one "Concepts, Methods and Values in the Social Sciences" involved interchange, comparison and new work both on the history and methodology of the different social sciences in relation to each other and on value problems lying behind the use of the social sciences in contemporary society. The courses were taught in small seminars with two course leaders each from a different social science. This course proved interesting and successful. Less successful was a second course "World Population and Resources", which was designed to relate demography to technology as well as to geography : it proved difficult to recruit faculty with the ability and the desire to make the most of the potential.

One of the most interesting courses common to the School of European Studies and the School of English and American Studies (both of which Schools went far beyond providing conventional "area" studies in the American or British sense) was on "the Modern European Mind". This course brought together faculty interested in Literature (more than a half fell into this category), History, Psychology, Art, Sociology and Philosophy and was designed

a) to explore the concept of a modern period in European culture ;
b) to compare different kinds of diagnosis of what is "wrong" with "modern society" ;
c) to compare different "expressions", artistic, philosophical, sociological and political of this "condition" ; and
d) to consider what light one discipline may throw on another, e.g. Psychology on History or Literature.

This course, which has been taught with imagination and which has already stimulated postgraduate research, should be considered alongside interdisciplinary courses of a somewhat similar scope in the School of African and Asian Studies, like "Cultures and Society" and "Westernisation and Modernisation".

Other interdisciplinary studies in Arts and Social Sciences have been less comprehensive and have involved more work "in depth". They include special subjects linking History and Literature, History and Philosophy and Literature and Art.

In the Sciences attempts were made to develop a common introductory course on "The Structure and Properties of Matter" to be followed by all Science undergraduates : it offered an introduction to the basic concepts and methods of reasoning associated with different scientific disciplines. Stress was placed throughout on significant inter-relationships. At a later stage in undergraduate work courses were designed linking Biological and Physical Sciences and other scientific disciplines. The School of Applied Sciences abandoned old professional distinctions between Mechanical, Electrical and Civil Engineering and introduced new common courses on subjects like Control Engineering and Materials Science. It also had links with the School of Social Sciences.

Sussex experience is now long enough to permit of a number of generalisations, although it is still too early to offer convincing evaluations. No two years in the short life of the University have been quite like each other.

a) there seems little danger of any retreat into "departmentalism", although some subject groups hove been less interested in "integration" than others ;

b) alongside interdisciplinary work it has been necessary and valuable to retain some "subject" organisation, and each subject group, while unable to determine its own resources or to make final decisions about its own curriculum, has a life of its own ;

c) success in managing and maintaining and developing new courses has always depended in each case on good faculty, and the power of the University from the start to attract good faculty (some already well established, but with genuine interdisciplinary interests) has been of strategic importance ;

d) once the right kind of faculty arrived, several new "unplanned" interdisciplinary activities emerged at "nodal points" of the enterprise. Thus, for example, a Medical Research Group came into existence in a University where there was no Medical School and established close relations with the Hospitals. It included biochemists, engineers, sociologists and educationists ;

e) after nine years several new Schools are being canvassed, among them a School of Science and Society and a School of Cognitive Studies. The latter illustrates the way innovation continues and some of the obstacles to its implementation. The School would focus on the convergence of studies in Artificial Intelligence, Linguistics, Experimental Psychology, Logic and certain non-numerical branches of Mathematics. It is being proposed by a group of faculty in these and other disciplines, would attract undergraduate entrants with either an Arts or a Science background at school, and from the start would be committed both to interdisciplinary courses and interdisciplinary research. According to the sponsors, who argue that it is focussing attention on a problem area of great practical importance as well as of intellectual stimulus, such a School would provide an undergraduate education of a novel and stimulating nature. At least some undergraduates would be exposed to those intellectual developments that are likely to shape thinking in their time. Although all of the individual disciplines could be taught on their own to undergraduates (and indeed each already is taught in some universities in Britain) teaching several of these subjects together should help to broaden the undergraduate's perspective. The combination of subjects chosen fulfils the primary requirement of a multidisciplinary education — they are all directly relevant to one another. Moreover, the subjects are not taught much at school and by combining them in the way envisaged, undergraduates would be able to learn something about the separate subjects before deciding in which to specialise.

In relation to two of the subjects (Experimental Psychology and Philosophy), these are already well established at Sussex and in expanding these subjects within the framework of Cognitive Studies the University would be building on existing strengths.

The arguments for founding such a School spring from inside the University, but "external" factors have not been ignored. It would be hoped that the establishment of such a School would play a small part in arresting the swing in schools from Science into Arts. Although the University would expect to fill half the places with undergraduates who had studied primarily Arts subjects at school, they would be exposed in the course of their university education to scientific ways of thinking. It has been repeatedly found that Arts students can do well at Experimental Psychology, formal Linguistics and Computing Science. Moreover, the demand from government and industry for graduates with some understanding of computing far exceeds the supply. This applies not merely to specialised posts (e.g. systems analysts and programmers) but to less specialised posts in management, and it could be argued that some understanding of the potentiality of computers will become more and more a pre-requisite for managerial success. The demand for university places in Philosophy and Linguistics is at present high relative to the number available. Unfortunately career openings for graduates with first degrees in these subjects are not so numerous. The sponsors of the School believe that by combining an education in Philosophy or Linguistics with an education in the relevant parts of Computing Science or Experimental Psychology, we would be giving an education that was at least as intellectually viable as existing courses in Linguistics and Philosophy and far more interesting.

Whether or not such a School can be started at Sussex in 1972 depends not so much on the willingness of the University to continue to innovate as on resources being made available to the University as part of national policy.

f) The Sussex system has emerged hitherto within the framework of national educational policy, i.e. it has had no privileged position in relation to costing, capital provision or staff/student ratios, all of which are set in national norms ;

g) at the same time, it has involved somewhat longer teaching hours for members of academic faculty and a great deal of additional effort planning new courses for which books and materials do not at present exist. The teaching has made the fullest use of small group work, and lectures have been strictly ancillary. In this connection, however, there has been no significant difference in organising multi-disciplinary or inter-disciplinary teaching as compared with teaching in single disciplines ;

h) the University as a whole has been concerned with and committed to innovation and has brought into existence a Centre of Educational Technology which examines teaching methods and the effect of curricular changes on resources and which has provided the nucleus of an academic "services" group employing television, programmed learning and other devices ;

i) all undergraduate students, irrespective of their School, must carry out an agreed programme of work across the Arts/Science divides. A detailed Arts/Science scheme has been in existence (subject to many modifications) since 1962. Moreover undergraduates in the School of European Studies are required to spend the third year of their four-year degee course (one year longer than the normal English duration of a degree course) studying in Europe. In each student's degree course in any School increasing weight has recently been placed on ' project" work as a part of the commitment : some of this links up directly with postgraduate research work ;

j) although the initial Sussex plan envisaged changes mainly in relation to undergraduate education, Sussex has a higher proportion of postgraduates (over 20 %) than most British universities. Only a minority of them are engaged in interdisciplinary work, but some of the M.A. and M.Sc. work (one year postgraduate work following the award of the first degree) is inter-disciplinary in character and many doctoral theses have begun to reflect the Sussex approach at the undergraduate level. So far very few Sussex graduates have been appointed to the Sussex faculty, but a considerable number of graduates have joined the faculty both of other universities in Britain and overseas and of other institutions of higher education.

k) In addition there are 18 Units, Centres and Institutes at the University, some fully integrated, some attached to Schools, two "free", i.e. with a separate government of their own, although with links with the government of the University. Of these, the biggest is the Institute for Development Studies which is deliberately inter-disciplinary in character (Economics, Politics, Sociology, Anthropology, Psychology, etc.) and which caries out some "trans-disciplinary work. All the Units, Centres and Institutes with a social science base are designed as "problem-solving" organisations with policy preoccupations. One of them, the Science Policy Research Unit, links the social sciences and the natural sciences and brings together historians, geographers, economists, psychologists and sociologists as well as computer specialists, operational researchers and cyberneticians and systems analysts on the one hand, and practicing scientists on the other. Every effort is made to ensure that members of the Units, Centres and Institutes (although not necessarily all of them) do some teaching in the university, in other words that there is a feedback between research and teaching. All the Units, Centres and Institutes are international in character and include staff on short-term secondment, including some from outside universities altogether. Nearly all have some of their staff overseas of any given moment of time , *l*) the University has also built up a continuing education programme, with its own Director, an *animateur* rather than an administrator. He works through faculty inside the University, a few specialised faculty engaged mainly in this work and part-timers, some from outside the University world. Long and short term courses are held, including refresher courses and post-experience courses for particular groups ;

m) the University has a small *planning committee* which coordinates these activities, determines priorities and allots resources. The Committee includes 3 students alongside 15 members of the academic faculty. The Planing Commitee draws up a five-year plan for the University, and each year asks each "unit" in the University ("Subject", "School", "Centre" or "Institute")

  a) to confirm or to amend its basic objectives, which it sets out each five years in terms of :
    i) undergraduate teaching and learning ;
    ii) postgraduate training ;
    iii) research activity.

  b) to state the main problems if any, anticipated in achieving the objectives set out in the programmes referred to in (*a*) above ;

  c) to make any specific proposals for change relating to the unit in respect of the next quinquennium within the framework of the Quinquennial Planning Assumptions. In regard to academic units, proposals are expected to cover :
    i) changes in the existing commitment (e.g. redistribution of student places, faculty posts, other resources already existing within the unit) ;
    ii) new developments (e.g. additional undergraduate and post-graduate student numbers, extensions in the teaching coverage of the unit, new faculty posts, new curricula developments, new research project or programmes). In relation to this latter category, the proposals go on to be costed at the Area level.

    There is an agreed timetable of the main formal committee meetings on annual and quinquennial planning and of the times when decisions have to be reached.

n) On the whole it is general university initiative rather than student initative as such which has made the Sussex pattern what it is, although at least one new course on "Industrial Society" has been initiated in response to student interest and there have been changes in the pattern of some of the schools (e.g. the School of Mathematical and Physical Sciences) as a result of discussion between students and faculty.

All these changes had taken place during a period when the University has grown on its own campus from 50 students to over 4,000. It plans not to be a big university but to grow to 5,300 by 1977 and later to up to 8,000.

Section 2. UNIVERSITY OF WISCONSIN - GREEN BAY

The University of Wisconsin - Green Bay, accepted its first students in 1969 after three years of initial planning. The Chancellor described its mission as that of "nothing less than creating a new kind of educational institution, a university designed specifically to respond to the needs of an era which will have as its dominant concern the preservation and improvement of environmental quality for all men".

"Institutions", he went on, "are essential to the carrying on of our societal business. But institutions, including those devoted to higher education, can lose touch with the times. They tend to continue to respond to the needs for which they were originally created, even after those needs have disapeared or become substantially modified. When institutions get too far out of tune with current needs, they may steadily decline, or they may renew themselves. In either event, a rather violent and painful social process is involved. That is exactly the process into which our institutions of higher education have been plunged in recent years. For the most part it has been the students who forced them into this process, because it was the students who were the first to see that the education they were being offered was only marginally consonant with the great needs of the world in which they were about to become responsible citizens. A consistent theme during these past few years of campus turbulence has been the student demand for relevance — relevance of what is taught in the classroom and laboratory to what is going on in the rest of society".

There is a difference here with Sussex where the drawing up of the University's "new map of learning" preceded the articulation of student demands for relevance and took account also of more varied long-term objectives. At the same time, there is a strong sense of "institutional purpose". The object is not to train narrow specialists, but to extend a broad general education on environmental problems to all students, regardless of their fields of specialisation or their choice of professions. The "sanctity of individual disciplines and professions" is explicitly challenged.

In the first instance, there are four "Colleges" at Wisconsin Green Bay, each grouped within the framework of environmental themes rather than according to traditional "disciplines".

Two Colleges select certain types of environment for attention. The College of Environmental Sciences emphasizes the problems of the natural environment and problems and challenges in environmental control (e.g. man's attempt to change his resources or bio-physical environment). The College of Community Sciences focuses on the social environment. The remaining two Colleges are concerned with the individual within his environments. The College of Human Biology centres its attention on human adaptability — that is, on the impingement of environment on the individual. The College of Creative Communication emphasizes the problem of human identity or the individual's impingement on his environment.

Each College incorporates selected aspects of the liberal Arts disciplines with certain applied or professional emphases. Each theme College has responsibility for a coordinated program of undergraduate and graduate studies, research, and community "outreach programs" related to its special environmental concern. Each College is responsible for developing its own course structure at all levels.

There is also a School of Professional Studies. This School complements the theme Colleges and is not analogous to them. It is reponsible for professional programs that relate to all or nearly all the theme colleges. Undergraduate majors in business and public administration are available through this School. However, even in this instance a theme College must be selected in which special work is undertaken in regard to man's environmental problems.

As far as teaching methods are concerned, the central core of liberal education at Green Bay is a four-year series of Liberal Education Seminars, six credit hours each year, through which every student

a) as a freshman receives an introduction to values, ecology and environment,

b) as a sophomore focuses on a particular set of regional experiences, experiences,

c) as a junior studies previously selected problems in an "other culture" context outside the region, and

d) as a senior integrates what he has learned and experienced with a broad exposure to several academic disciplines and explores problems of values, belief, personal commitment and dedication.

The sophomore year focuses on both the Northern Great Lakes dominant culture and selected sub-cultures such as American Indian, Black, and ethnic-American. The junior year focuses on selected Western and non Western countries, including dominant and sub-cultures.

There are also two all-University requirements. Green Bay requires every student to select 5-6 hours of work in each of four theme Colleges or to demonstrate presence of such breadth by special examination. It also demands study of "tool subjects" such as foreign languages, data processing, mathematics, and studio experiences in the visual or performing arts. A student must satisfy the tool subject requirement on a pass-fail or special examination basis. A student must choose either o foreign language or a studio experience in the Arts and, secondly, either mathematics (calculus) or data processing.

There are in addition three types of choices in regard to majors and minors :

Choice 1. AN ENVIRONMENTAL PROBLEM (The Concentration or Major)

A student must select an environmental problem (or concentration) on which to focus. A *concentration* requires 30 credits at the junior-senior level reflecting an interdisciplinary focus on an environmental problem.

Choice 2. A DISCIPLINE OR FIELD OF KNOWLEDGE (The Option or Co-Major)

A student may, in addition to his concentration, select an option. The terms option refers to a discipline or field of knowledge such as Art, Political Science, Biology, or Chemistry.

Choice 3. PROFESSIONAL APPLICATION

A student may choose to emphasize professional application of his concentration or option. He may do so in one of two ways : a collateral or a pre-professional program.

It should be noted in relation to the so far limited, if exhilarating experience of the University of Wisconsin-Green Bay that *a)* it is only a part of a bigger state University complex. Its degree of "specialisation" in terms of focus, which permits new interdisciplinary activities, is determined in part by the comprehensiveness of the University of Wisconsin when considered as a whole ;

b) there is the closest cooperation between University and the Wisconsin community. "The community joins us on the campus and we of the campus join the rest of the community off the campus in mutual learning experiences". This sense of cooperation has been traditional in Wisconsin, but has had to take new forms of expression in the last few years. The Chancellor of Wisconsin - Green Bay speaks of a "communiversity' ;

c) great emphasis is placed on the changed role of the student and on the needs of the individual student. The 1970/1 catalog begins with "certain assumptions about the contemporary student.

First of all, it states, he is more capable, brighter, possessed of more knowledge, and the product of a better educational system than the students of his parents' day. His advantages do not stop with higher scores on intelligence and achievement tests. He is both more cosmopolitan and more concerned with moral values.

He has been raised in a society of shrinking dimensions, of instantaneous communication, and rapid world-wide travel. The isolationism of his parents' day is anachronistic to him. He has studied about many nationalisms, competing economic and political systems, and religious, racial, and ethnic groups. If nothing else, he has seen it all on television, read about it in newspapers and news magazines.

He has reacted negatively to the kind of education offered on some campuses. He sees faculty members as not interested in and often avoiding the things that he feels are relevant. He wants to participate in the larger community at the same time that he is receiving an education at the university. Frequently his efforts have been greeted with scepticism. Perhaps in part as a result of frustration, he has turned on faculty members and members of the larger community and has charged them with being uninterested in the major problems of the day. On occasion, he has suggested that traditional university and community concerns are outmoded in the new society that needs to be created.

In shaping an academic plan for the new university which first opened its doors as a degree-granting institution in the fall of 1969, the University of Wisconsin-Green Bay faculty and administration took up the challenge of the contemporary student. They began questioning established modes of behavior and traditional approaches to university education. They wished to relate university education to the world of today and tomorrow, without turning their backs to the lessons of the past. They recognized that, if action were not taken soon, society seemed destined for an intensification of intellectual isolationism on the part of the university, a cultural parochialism on the part of the larger community, and an oppressive approach to ideas on the part of both.

d) student work and evaluation is carried out within the American credit system ;

e) inter-disciplinarity (and trans-disciplinarity) are very closely related, therefore, to the student's needs and choices. There are fewer new kinds of prepared inter-disciplinary courses by faculty than at Sussex, although in the College of Environmental Sciences there is a "concentration" on Ecosystems Analysis and in the College of Human Biology on "Human Performance" and "Human Adaptability". "Our effort", the Chancellor writes, "is more in the liberal arts tradition than in the vocational, more in making knowledge more active than in routine application;

f) at the same time, "problem solving" is particularly singled out both as a teaching and as a research objective. "Green Bay believes that man's problems should be observed first-hand and experienced not just studied through books or in the class-room, laboratory or studio". More emphasis is placed on "regional" issues than at Sussex. A focus on ecology demands close collaboration between a university and its region. Green Bay is ideally suited in this regard. Many persons and agencies in Northeastern Wisconsin were involved in planning the institution and are continuing to participate in its development. Among other things, members of the community have helped select many of the ecological problems on which the University is concentrating".

g) given the "specificity" of the academic plan at Green Bay, there are, nonentheless, important problems of priorities. The whole budget could be devoted to one environmental problem and not quite cover it. Careful account is taken of costing and, as at Sussex, it is emphasized that there will be heavier loads on the time of the individual member of the faculty. The whole plan, if it is to succeed, will depend on a level of financial support by the State of Wisconsin equivalent to that of other campuses of the University of Wisconsin system.

Section 3. HACETTEPE UNIVERSITY

The University of Hacettepe, which took in its first medical students in 1963 as a Faculty of Medicine, is now, like the University of Wisconsin-Green Bay, a fully-fledged university institution, organised around a theme — in this case health and health problems. All relevant disciplines are grouped together whatever their origin or their category: they include the natural sciences, the human and social sciences and the medical sciences in the strict sense of the word.

It was in 1964 that a School of Basic Sciences was opened, with basic sciences being regarded as the necessary gateway to the subsequent curriculum, and three years later by Act of Parliament the complex of Hacettepe institutions were constituted a full university. A Charter was granted in the same year. In addition to the School of Basic Sciences, there is a very wide range of faculties, departments and institutes. These include a Faculty of Science and Engineering (with Institutes of Biology, Physics, Statistics, Chemistry, Mathematics and Earth Sciences), a Faculty of Health Sciences (with Schools of Home Economics, Physical Therapy and Rehabilitation and Nursing), a Faculty of Social and Administrative Sciences (with Institutes of Economics and Management, Humanities and Social Sciences a Faculty of Medicine, an Institute of Hospital Administration and University Teaching Hospitals, an Institute of Child Health, a School of Dentistry, a School of Pharmacy and an Institute of Population Studies. There is scope for graduate as well as for undergraduate work.

The basic science curriculum is not conceived of in "service" terms, as in many medical schools, but as an integral part of a linked programme. In all academic activities, indeed, emphasis is placed throughout on the role of the team. In Faculty of Medicine, for instance, students are offered programmes in medicine, dentistry, pharmacy, nursing, physiotherapy and nutrition. Lycée graduates who are admitted to these programmes spend an average of two years in the School of Basic Sciences, after which they receive their instructon from the same departments of Physiology, Anatomy, Biochemistry, Pathology and Clinical Sciences, Although their programmes of instruction differ significantly according to their professional goals, they make use of common practical facilities provided by the Hacettepe University Hospital, and by the Hacettepe University Community Rural Health Centre.

An integrated teaching system of this kind avoids overlapping and repetition : it also guarantees that there will be dialogue between the various medical sciences, so that the student will not learn them in an isolated or segregated fashion. It also encourages communication between the various basic medical sciences, on the one hand, and between the clinical sciences, on the other. According to the Rector, this programme is so devised that progress and development in one science will stimumate progress and development in each of the others. A similar programme is also designed for students of dentistry.

The organisation of the University, like that of Sussex, is as distinctive as the curriculum.

The traditional "chair" system does not exist and instead, the Faculty is composed of four institutes, namely Biological Sciences and Community Medicine, each of which is headed by a Director, who is appointed by the Univeristy Executive Committee for periods of up to four years. Each institute is divided into departments, whose heads are appointed for three-year periods. The institute director or department head is not necessarily the senior member of that unit nor need he be a full professor. It should be observed that this organisational structure does not prevent academic staff of different units from attaining professorial rank, and that there may be more than one full professor in one unit.

The five-year programme of medical education at Hacettepe University Faculty of Medicine is organised into five phases, each of which is designed and directed by a co-ordinating committee of representatives (not heads) of all departments participating in the teaching programme during that year. The five chairmen (phase co-ordinators) of these committees, together with a co-ordinator-in-chief and his assistant, appointed by the Medical Faculty, make up the Committee for Medical Education of the Faculty. The Council of Medical Education is composed, in turn, of the above-mentioned committee, a Chairman of the Council appointed by the University Senate, and the Dean of the Medical Faculty. This Council approves the proposals of the phase co-ordinating committees, after hearing comments from all those concerned.

The teaching programme, which has been so designed as to facilitate integrated learning, enjoys the advantage of having a one hundred percent full-time teaching staff (none being engaged in private practice) who can all be dedicated wholly to the implementation of the integrated system in the medical school. The details of the first-year programme divided up into six blocks of study terms are as follows :

Cell Biology Study Term	Tissue Biology	Cardio-vascular Respiratory	Metabolism	Central Nervous & Endocrine Systems & Reproduction	Mechanisms of Cellular and Tissue Injury
7 weeks	9 weeks	4 weeks	7 weeks	8 weeks	4 weeks
Maternal and Child Health — Community Medicine — Family Clinics					

Each study term is administered by a committee composed of representatives from the different disciplines which are involved that particular study term. Community medicine is an integrated part of the curriculum from the very beginning. During the first year, four hours of theoretical teaching every week are devoted to the introduction to clinical sciences and community medicine. Of these four hours, two are given to lectures and two to discussions in small groups. Topics covered at these sessions include historytaking, observation, the physiology of reproduction and pregnancy, maternal and child care, promotion of health, prevention of illness, and other topics in social medicine as well as elements of physical examination and introduction to diagnostic procedures.

Each first-year medical student is assigned to a family in which there is either a pregnant woman or a baby of less than one year of age. The student is introduced to the family as its "student doctor", and he takes part in the periodical medical checks. Under the supervision of the doctor assigned to the family through the maternal and child health unit of the medical faculty, the student gradually assumes increasing responsibility. In this way, from the inception of his medical education, the student has practical experience and training in observing and recording all pertinent information about the patient.

The second year is also divided into a number of study terms :

Mechanisms of Infection & Infectious Diseases	Cardio-vascular System	Respi-ratory System	Urinary System	Gastro intestinal System	Haema-topoietic System	Musculo skeletal System	Repro-ductive System	Nervous System
8 weeks	4 weeks	2 weeks	3 weeks	3 weeks	4 weeks	3 weeks	6 weeks	5 weeks
Chemical Agents 15 weeks				Clinical Psychiatry 12 weeks			Endocrine System 4½ wks	
Community Medicine — Family Clinics								

During this year, basic medical sciences such as microbiology, pharmacology and pathology are taught, again in an integrated fashion. The student is first provided with an opportunity to observe morphological and physiological changes in mammalian cells and tissue under infective, radiological or metabolic-pathological conditions. This leads logically to a discussion of the principles of re-establishing normal physiological conditions and the basis of drug action. This requires that the student become acquainted with the effects of bacteria on human cells, and the clinical picture and tissue manifestations of infections, as well as with the various immunological disorders. To assist the student in relating information from the variety of medical disciplines, basic pathological changes of the various organ systems are introduced and discussed by instructors form the Departsments of Microbiology, Pathology, Pharmacology, Biochemistry, Physiology and Anatomy, and the clinical departments. Thus, the student is given an overall view of the clinical conditions related to the system under study. During this second year of the programme some 338 hours of the total time for the curriculum are unscheduled, in order to give the student an opportunity either to complete unfinished work or to enjoy recreation.

Beginning in the third year and continuing through the fourth year, students serve as clerks rotating through various clinical departments. During this period, instruction continues in seminars, clinico-pathological conferences, group discussion, case presentations and symposia. The students are also expected to take some responsibility for night duties :

Third Year

Clerkship : Daily 8.0 a.m. tot 5.0 p.m. and night calls			
Medicine	Paediatrics	Surgery	Obstetrics and Gynaecology
2½ months	2½ months	2½ months	2½ months

Clinico-Pathological and Radiological Conferences and Social Medicine Seminars

Fourth Year

Community Medicine & Maternal & Child Health (Rural Internship)	Psychiatry	Neurology	Electives	Rotation in Dermatology, Urology, Ophtalmology, Orthopaedics, Otolarngology and Physical Medicine
2 months	1 month	1 month	2 months	4 months

Clinico-pathological and Radiological Conferences and Social Medicine Seminars

During the fourth year, each student is assigned to live in a village, where he serves as a rural health intern, and makes home calls as part of his responsiblity. For rural internship purposes in Ankara, seven health centres, located in 7 villages with a total population of 50,000 are used. These centres are attached to a 50-bed rural hospital and the entire complex is staffed by members of Hacettepe University Medical Faculty. The instructors in this internship programme live in the villages and serve as rural health officers. This arrangement has been made with the co-operation of the Ministry of Public Health and the respective local authorities. The medical student working with nurses and students of other health science programmes finds an opportunity of practicing team work for benefit of the community.

During the fourth year the student has a two-month elective period when he can choose what he does. Some students work in other hospitals.

The fifth year is the pre-diploma internship period. The student can select one of four alternatives, as shown below. During this year the student lives at the hospital and is on duty every other night. He carries the usual responsibilities of a junior resident or house physician, under the supervision of the senior house staff and the teaching staff.

Fifth Year

I

Internal Medicine	6 months
Paediatrics	4 months
Emergency Service	2 months

II

Paediatrics	6 months
Internal Medicine	4 months
Emergency Service	2 months

III

Internal Medicine	4 months
Paediatrics	4 months
Surgery	2 months
Emergency Service	2 months

IV

Internal Medicine	4 months
Paediatrics	4 months
Obstetrics & Gynaecology	2 months
Emergency Service	2 months

Two general points may be made about the Hacettepe system which has created much international interest (and some imitation):

a) teaching methods are related to the new curriculum. There is a strong reliance on the tutorial system, small group teaching and mixed laboratories. Each student has laboratory facilities of his own. There is little reliance, as at Sussex, either on textbooks or on formal lectures;

b) there are savings in financial and manpower as compared with alternative and more conventional practices, yet while the "system", according to the Rector, is more "economical" in that there is a less wasteful use of funds, there are higher costs because of the care devoted to different individual students with different needs. "The University will also find, as the student becomes a self-directive agent in his own learning, that it has to purchase, not less but more laboratory equipment to meet alle demands of his enquiring mind". Thus, the Rector concludes, "a university which wishes to establish an integrated medical education system should be prepared to allocate a significantly larger proportion of its budget to medicine than it does at present. This it can do, however, with the realisation that it is both reducing the waste of duplication and increasing the value of medical education to the student."

Annex 1

SAMPLE MODEL OF AN INTERDISCIPLINARY UNIVERSITY WITH SPECIAL EMPHASIS ON "INTERNATIONAL RELATIONS"

A. WHAT IS A UNIVERSITY WITH AN AREA OF SPECIAL EMPHASIS ?*

Various models of a university with an area of special emphasis can be dreamed up :

Type 1. The simplest but most inaccurate model is the type defined, for instance, in France by the Orientation Act, which decrees in part: Universities will be pluridisciplinary", but which also includes a clause specifying that some universities may contain an "area of special emphasis". This means that under the label of "pluridisciplinarity", the old-time Schools or "Faculties" are being kept and merely rebaptized as "Universities" for the occasion. This is obviously not what we mean here by "area of special emphasis".

Type 2. One of the first models of a true University with an area of special emphasis seems to us to be the University of Hacettepe, which gathers together a large number of disciplines around the theme of public health and its problems, and brings about a great deal of co-operation among them in this way. Another instance can be found at the University of Wisconsin in Green Bay, which places special emphasis on Environmental Issues.

Type 3. More tightly knit models could be thought up based on the theory of interdisciplinary relations as it is set forth in this volume by Jean Piaget (see pp. 127). This theory uses the mechanisms which are common to several disciplines and the points at which various methodologies overlap. The area of special emphasis, in that case, no longer involves problems, but rather methodology.

> *Example.* A University with special emphasis on "linguistics and semeiology" or on the "language sciences" might be based on communications theory and the growth of semantics and semeiology, and would gather under its roof, first a comparative study of languages and their literary expression, and then other kinds of languages (plastic arts, music, gestures, cinema, and so forth), yielding esthetics, sociology and

* The interested reader should also consult the CERI/HE/CP/22 document which also outlines a theoretical model for an interdisciplinary university with special emphasis on the Environment.

psychology, and finally ending up with a comparative history of civilizations.

B. Outline of a University with Special Emphasis on International Relations

The broad description given here of a sample model of a University "with special emphasis on International Relations" will only deal with the problems and themes involved. Such a model can fit into a much larger model of an International University, and would serve as a kind of nucleus for it. This model is hence variable in size, geography, structure and content.

This model is principally noteworthy in that it is not entirely theoretical. Indeed, it is based on some past and present experiences, such as those at the European Institute for Advanced International Study which is connected to the University of Nice.

Essentially what is involved is combining at least the three standpoints which, as has already been stated, control the conception and creation of any truly new type of University. These are the interdisciplinary standpoint, the international standpoint and the future standpoint. It goes without saying that each of these touches on structures, methods and contents, albeit in varying proportions.

1. *Structures*

1.1. *Recruiting.* As an interdisciplinary, international University, it must act accordingly in its recruiting policies for both faculty and students. International relations are merely a subject to be studied or a game for diplomats and politicians unless they are experienced in common by the younger generations, at the level of group life in university institutions designed for this purpose. The same is true for interdisciplinarity. It is therefore important for this University to gather together (as was done at Nice) professors and students in law, economics, politics, geography, history, sociology, etc., coming from different continents, but recruited and selected on the basis of a single two-pronged criterion: their [illegible] interdisciplinarity and their awareness of the international dimension of what they are studying.

1.2. *Decentralization.* If a University with special emphasis on International Relations has its campus located at some particular place, just like any other university, it cannot be considered truly "International" in the full sense of the word on account of this. So to fulfill its mission, the International University, in our opinion, should be largely decentralized, and should consist of an institutional network stretching beyond national frontiers within which each University could have its own place, with its own "area of special emphasis". The present model hence implies two levels of reference, one local, and the other international and federative. Nevertheless, only the first of these two aspects will be discussed here.

1.3. *Levels of study.* The curriculum should be designed to be as flexible as possible, with attention given to the wide diversity from one country to another in educational systems, and the difference from one individual to another in the ability to acquire an international way of thinking and the knack for interdisciplinary practice. Each student should therefore be allowed to shorten or lengthen the time required for study, in accordance with his personal needs, so that the following statements are to be merely taken as guidelines.

With this word to the wise, four levels can be distinghuished in the curriculum (in some cases these levels may overlap in part) :

a) An introductory level lasting one or two years : broad orientation (identifying talent for interdisciplinarity and the study of international issues) ; introducing the study of world-wide problems in contemporary society and presenting interdisciplinary methods ; acquiring knowledge and basic techniques in one or two neighbouring or complementary disciplines.

b) An undergraduate major level of one or two years : learning one or several of these disciplines more thoroughly, with emphasis on their international aspects ; based on such specialization, preparing the student for international relations ; acquiring the necessary tools.

c) Master's degree level and introduction to research, lasting one or two years : studying the problems and outlook for international relations, treated with an interdisciplinary frame of mind.

d) Research level : preparing a doctorate within the framework of a joint research project in a specialized laboratory.

Level C obviously occupies a pivotal position and is the key to Universities "with special emphasis on International Relations". The other levels can be offered by traditional Universities or by Universities with special emphasis on neighbouring fields. The fact that the international University is decentralized should make it possible for students to move around easily and spread themselves out among the various universities, depending on what they are majoring in and what career choices they have in mind.

In addition to this practical experience in international life that they will be able to have by attending a series of Universities in different countries, the students ought to engage in a number of work-study apprenticeships at various international agencies.

2. *Contents and curricula*

Just as the structures were not frozen into rigid patterns ahead of time, course syllabi should not be set up far in advance. Courses should be worked out each year for each level as a result of prior experience, and the needs of the students as well as the opportunities offered by the faculty should be taken into consideration. An *ad hoc* commission should be responsible for guaranteeing such continual readjustment.

Nevertheless, it is possible for us to suggest some guidelines on this topic.

2.1. *Cultural background.* Right from the first terms of their undergraduate careers, students planning to do international studies need to get an overview of the issues involved, within the framework of the global society coming to pass in the Twentieth Century. For this reason we suggest that an introductory course use the following outline :

a) A comparative study of the leading civilizations in the world today, with attention to their basic characteristics as well as to an historical perspective. This study should be based on a *methodology of civilization.*

b) A world-wide view of the crises and changes in contemporary civilization.

c) Enough psychology and anthropology to allow students to define man's place among these changes.

d) The fundamentals of a methodology for the interdisciplinary approach to problems, based on the present development of the scientific way of thinking and on epistemology. This should mold the student's conceptual tools (concepts of structure, model, homology, function, and so forth.)

2.2. *Technical tools.* Right from the first terms of their undergraduate careers, students must also receive the intellectual and technical tools which are both broad and accurate enough to cover at least the following aspects :

a) introduction to applied mathematics ;

b) techniques for the social sciences (tests, questionnaires, surveys, interviews, content analyses, etc.) ;

c) mastery of the student's native language in both spoken and written form ;

d) adequate practice in two foreign languages.

2.3. At the undergraduate major and master's degree levels, the interdisciplinary and international nature of the courses offered can be guaranteed essentially in two ways :

a) By grouping activities around *major themes and issues* of our times in which international elements play a decisive role :
- — problems of war and peace (polemology) ;
- — problems of development and hunger in the world (economics) ;
- — problems of the environment in the post-industrial, scientific and technical society ;
- — problems of planning on an international scale ;
- — problems of international understanding and harmonizing different cultures (ethno-psychology) ;
- — problems of conflicting ideologies.

b) By grouping the issues according to *geographic areas* and the major axes of international relations :
- — problems of Europe and European integration ;
- — problems of relations between East and West ;
- — problems among the Atlantic nations ;
- — problems involving building up Africa and its relations with Europe and the rest of the world;
- — problems of the Middle East and the Far East ;
- — problems involving relations between highly industrialized nations and the Third World.

Each of the disciplines involved will set up an introductory program, and in some cases this will be followed by a more thorough course whose importance in the student's overall program will be determined on the basis of his particular background and goals. Care, must be taken that each student at least be familiar with the main methods of those disciplines which are necessary to make up a science of international relations, namely, politics, international law, economics, ecology, geography, history, sociology and ethnopsychology.

3. Methods

Course offerings which are both interdisciplinary and international require methods which are especially flexible, capable of being adjusted and altered to fit new circumstances and practical opportunities. This report will merely contain a handful of suggestions, which should be applied in a manner appropriate to the place, level and problem being treated.

3.1. The need to call upon teachers from many different countries and who have international standing must result in arranging their programs that they teach for a relatively short period of time (generally one to six weeks each). Within an overall time-table organisation, an effort must be made:

a) to group together in the same time period and around an issue or carefully chosen theme, professors from different countries and disciplines; they can meet for round-table discussions, personal debates, or panel discussions prepared and led by a team of advanced students;

b) to express these themes and issues in a coherent, progressive course syllabus which will bring out, among other things, the dependence on one another;

c) to prepare for the presence of each professor by familiarizing students in advance with the discipline he represents (or has founded), with his publications and the direction his research takes, and especially by providing students beforehand with a summary of his teaching experience in order to guarantee that his presence will be fully taken advantage of and that he be readily brought to participate in the overall interdisciplinary work.

3.2. International relations is probably the field in which the various aspects of issues and the various sectors of activity are most intimately connected, in that any decision in some sector immediately results in consequences for other sectors which are usually hard to measure. Therefore, the students should be given practice systematically in identifying these relationships and their consequences, by every means possible:

a) analyzing the press, using an interdisciplinary approach;

b) interviewing personalities from the world of politics and diplomacy and members of international organisations;

c) holding round-table discussions to deal explicitly with the type of relationship;

d) having students simulate analogous types of situations and figuring out their possible consequences.

3.3. Last but not least, the field of international relations requires that predicting the future be given a highly important and stimulating role. It is hard to "teach" how to anticipate future trends. Rather it is the outcome of a combination of specific methods to approaching issues, and involves the joint efforts of many imaginations. For this reason, a University "with special emphasis on International Relations" must put a lot of stress on *creativity:* simulating models, having students organise a new style of encounter more conducive to discussing the future, and so on.

Annex 2

A PLAN
FOR A CENTER OF INTERDISCIPLINARY SYNTHESIS

In 1963, a group of faculty members at the University of Ghent felt the need to institutionalize interdisciplinary research and teaching. They hammered out the following plan.

This plan was presented to each of the major divisions of this university. The School of Philosophy and Arts, the Law School and the School of Education voted in favour of it, whereas the School of Exact Sciences, the Medical School and the School of Engineering rejected it.

The humanities faculties believed that it was urgent and necessary to undertake such a reform and hoped that the pure and applied Sciences would cooperate, whereas the Scientists didn't think it was possible to set up such a broad teaching program and rejected working with the Humanities and Social Sciences.

Following these events, the plan was never taken under consideration by the Administrative Council of the University of Ghent, and at the present time it would appear that despite the desires of some supporters, more pressing tasks are now preventing this plan from being reexamined.

We are herein publishing the complete text of this plan. To be sure, the underlying drives which are expressed have been emphasized on numerous occasions in this book, but we have chosen to avoid cutting out part of so well-balanced a project. Furthermore, we wish to present it because *it describes so accurately the contents of course offerings and research work* with regard to the interdisciplinary synthesis of the natural sciences and that of the cultural sciences.

A CENTER FOR INTERDISCIPLINARY SYNTHESIS

Leo Apostel
University of Ghent, Belgium

1. Background

A group of faculty members drawn from all the various divisions of the University of Ghent gathered together in October 163 for the purpose of working out a program in interdisciplinary research, and decided to create a working committee which would frame a proposal in this direction. Since the *timeliness* and the *possibility* of organizing a center for Interdisciplinary Synthesis seemed rather obvious, this committee framed a proposal which it set down in these pages and which it submits to the judgment of its fellow colleagues.

2. Motivation

The following arguments plead in favour of establishing a center for interdisciplinary synthesis :

i) *Scientific grounds :*

a) Nowadays the various specific scientific disciplines, feeling the consequences of out-and-out specialization, are branching out in such a complex pattern that a first-rate scientist needs to come into contact with a whole series of other disciplines.

b) In addition to such divergent trends leading to specialization, various scientific fields feel a very strong need to draw together. Many approaches to unification are beginning to make headway in both the natural and cultural sciences.

ii) *Technico-economic arguments*

Most front-running industries as well as some of the most complicated governmental agencies need men with broad educational backgrounds who have had earnest contact with a wide spectrum of cultural and natural sciences.

iii) *Teaching grounds*

Most teaching programs aspire to achieving a tighter synthetic unity. That is indicated clearly by both the changes suggested for establishing well-rounded programs and the proposals for introducing a more synthetic kind of teaching.

iv) *Socio-cultural arguments*

In our rapidly evolving society, a student expects the university to lead him to some justifiable conclusions, which he definitely needs, on the most vital ethical, political, scientific and religious issues. In order to attain this level of meditation on the meaning and value of life, linked with the latest scientific, technical, social and economic developments, one needs to engage in interdisciplinary study.

These powerful motives seem to have led many universities to attempt to supplement the specialization into branches deeply anchored in the traditional university system, by opening up interdisciplinary courses and research. Therefore, considering the scientific grounds, as well as the technological, economic and scientific arguments which make it necessary to promote interdisciplinary research, and taking into account the fact that newly created universities as well as the older ones have taken and will in the future take steps in this direction, RUG can not afford to lag behind in this field.

3. A CENTER

A. Since the need for interdisciplinary cooperation goes beyond the dividing lines of the university's Schools, interdisciplinary research must not be located within one of the existing Schools or Faculties. An autonomous agency should be formed within the university to meet the needs for synthesis.

B. An interdisciplinary synthesis can be carried out according to two basic formulae : either a general syntheses, or a special synthesis.

The purpose of the general synthesis is to bring together major groups of sciences which have a mutual correlation, while a special synthesis tries to bring together two or three sciences which were already rather closely allied.

The Center for Synthesis should emphasize both general synthesis and special synthesis. Its task nevertheless basically consists of working out and contributing to attempts at central synthesis which cannot fit into any other slot. Besides that, the center should serve to give impetus to promoting forms of synthesis (including forms of special synthesis).

Therefore we suggest :

1. That a center be set up which would start out with three forms of general synthesis, chosen and based on motives which will be explained below.
2. That the Board of Directors of this center look into what other forms of study and research might be of social interest and practical use, and what the scientific future of such a program would be.

The list of the three groups of syntheses to be formed is hence not an exclusive one, but is merely based on the need to face up to the most pressing needs.

C. In order to insure its continuity and stability, the center should acquire an *institutional* character. Unless this occurs, everything will depend on the individuals who are or are not there. To expand spontaneously and freely as a fresh initiative, it must become an entirely *autonomous* institution, and might, just like the various Schools in the University, grant separate degrees and offer a thorough enough course of study (four undergraduate years plus two years of doctoral work were anticipated).

D. This *institutional* character should nevertheless include special qualities.

1. The center must be run jointly by its General Board. The various sections of the center must be run in the same fashion by their various individual managements.
   Furthermore, each course should be run jointly : *Since the basic job being done here is synthesis, one branch cannot be offered without the cooperation of other course instructors and researchers.* Several attempts have heretofore failed because this basic principle was overlooked. *The principle of collective responsibility is merely an expression of the fact that on the one hand we see the necessity for partial syntheses (within the limits of specific branches), but on the other hand we wish to fit these special syntheses into large overarching patterns.*

2. The center should have an *organisation for self-correction,* which is both considered as part of a brand new experiment, and given a constantly changing task, for trends toward unification obviously move along very swiftly. *No final time table* can therefore be set up. Every five or ten years a working committee made up of the members of the Governing Board ought to be called upon to overhaul the syllabus in view of the latest scientific, technical and economic developments and the teaching experience acquired in the meantime.

E. *No isolation*

The center should in various ways maintain major ties with the rest of the University :

a) For some courses in synthesis, groups of qualified experts from other sections of the university will be invited to help the professor running the course by offering their advice and specialized knowledge.

b) A student at the center is required to do laboratory work or take seminars in other Schools. (See below.)

c) A student who has finished his course work in this center should have a chance to undertake more specialized training in some specific fields for which his particularly broad background gives him a special preparation. His professors at the center must reach an agreement on this with their colleagues in those departments involved.

d) A student who has just graduated from some special branch of the university and who has a particular background allowing him to pursue his studies in an area involving synthesis, should be able to have a special program arranged for him in the center.

e) The center must earn a good reputation and gain understanding for its activity and purpose of synthesis, by sponsoring symposia and colloquia, which should be open to students as well as invited guests and colleagues. The center should also plan to sponsor publications.

4. The Three Sections of the Center

A. Although the center obviously intends to train people who are able to see connections between highly disparate scientific fields, and who are as much at home in the liberal arts as in the natural sciences, it nevertheless needs to move towards this overall synthesis step by step. Before we attempt to reach a total synthesis which, on account of the enormous task involved, would seem utopian and which might result in failure if there is inadequate preparation, we must use the traditional distinction between the natural sciences (pure sciences, applied sciences, and medicine) and the cultural sciences (philosophy and the humanities, law and the related schools of social sciences and education) in order to try to reach a synthesis of the natural sciences on one side and the cultural sciences on the other, such that a total synthesis would be led up to in a final, crowning effort during the years of graduate study.

The problem of synthesizing the natural and cultural sciences is one of the hubs and toughest issues of our time. This arduous task can be undertaken only with a great deal of caution, and that after thorough preparation.

Following from this concept, three sections should be set up :

a) natural sciences synthesis ;
b) cultural sciences synthesis ;
c) total synthesis (available only to those students who have done undergraduate work in one of the first two sections).

B. Therefore three sections would be established. They ought, however, to acquire an institutional character, so that they can overlap as much as possible. The following measures should be taken to ensure that :

a) students in one section take basic courses in the other sections (to the extent that this is compatible with the needs of teaching and research) ;
b) it is easy for a student to transfer from one section to another during the course of his career ;
c) extending, strengthening and encouraging total synthesis for the doctorate (in graduate courses) is possible ;
d) a large enough number of representatives of the Board governing each section work in another section.

5. Overall concept of teaching

The working committee makes this suggestion with a eye to the social and cultural role a "Center for Interdisciplinary Synthesis" would play.

1. If the student does not have a thorough, critical acquaintance with the major parts of the field he is synthesizing, he can not engage in interdisciplinary synthesis. Hence, one pitfall to be avoided at all costs is the wordiness of the dilettante, which is based on his having inadequate knowledge.

2. If the student were required to study thoroughly all the courses currently offered at the university which are relevant to the part of the field he is making a synthesis of, he would be asked to reach the superhuman and unobtainable goal of having an encyclopedic background.

3. If the student were supposed to narrow down and limit the part of the

field he ought to make a synthesis of, he would end up with something very much like the educational background which welfare workers used to have — an arbitrary selection of introductory material inadequate for anything in particular, and not leading to any creative work or personal fulfillment.

4. It is thus necessary to avoid verbal and artificial syntheses as well as a program for unobtainable encyclopedic knowledge or for an inadequate background in introductory material.

5. The only way to skirt around this danger and form students having *a thorough-going, broad educational background* is to teach *the standard basic courses using a unifying approach and in this fashion pave the way for the synthesizing approach in thorough, introductory courses.*

6. This unifying approach should be designed to both encourage understanding and promote the creative progress of these sciences in our times.

7. Such a unifying approach exists for both the natural sciences and the cultural sciences. It is an approach which allows us :

a) to reach the most basic and hence the most general aspects of the particular field in question more readily than the classical norms do, and

b) to get into more direct contact with those parts of the field which are developing most dynamically, so that their interdisciplinary aspects can be studied.

8. During the beginning undergraduate years, this unifying approach would be accompanied and preceded by a thorough introduction to both the techniques of mathematics and those of experimentation and observation. This would be true for the cultural sciences as well as for the natural sciences.

9. The methodology and philosophy of the fields to be synthesized would come forth as the crowning effort of this education, at least to the extent that these can be offered and put in close contact with the unified approach. The methodology and philosophy ought as a result to try to come up with the widest possible formal and practical unification of the field.

10. In that a particularly heavy and demanding course of study is involved here, and a student needs time to reach maturity in his subject matter, only a full undergraduate program is conceivable.

The attempts made previously to set up a course of study in synthesis yielded unsatisfactory results for one of the following reasons :

a) the attemps were limited to partial syntheses ;

b) they brought together in a mosaic pattern the subjects to be synthesized without changing them ;

c) they hoped to come up with improvised syntheses in situations where the only chance of succeeding depended on students having a thorough background.

11. During the course of each school year, no more than five or six subjects can be taught. The student certainly should sample a wide variety of basic disciplines, but in so doing, he sh[illegible]d be given a solid and serious

course in each one. By concentrating on the major areas of knowledge, he can avoid having his attention dispersed.

12. The teaching method used should basically be that of active discussions and analysis, right from the beginning of the undergraduate course. Each subject being studied (and as has been indicated, only a few major subjects are expected) should require the student to be familiar with at least two modern textbooks and to read at least two original scientific books, as well as to prepare an individual or group project each year.

6. THE TEACHING BODY

This brand new undertaking will either prove fruitful or will yield absolutely nothing, depending on how the teaching staff is selected.

1. The working committee is starting out with the idea that since this teaching program assumes that professors will have contacts and will engage in continuous discussions with their students, no person will be considered for the post who devotes most of his professional time to activities outside the center (as either a teacher or administrator).

2. The committee is likewise starting out with the idea that such a teaching program can only be accomplished by someone who has proved himself worthwhile in the field of synthesis by publishing an original piece of scientific work.

3. Finally, the committee still upholds the principle that the only way for the center to produce a new mode of operation is to gather men trained differently into a collegial relationship, where the very statutes of the institution expect them to work together.

4. It seems like an overwhelmingly hard job to find men who have this new kind of training, who will devote themselves principally to the activities of the center, and who have also already proved that they are capable of carrying out a project involving creative synthesis. The center ought to already exist elsewhere, but this happens not to be the case. How can this difficulty be solved ?

5. The committee suggests that a group of people be put in charge of each course for a transition period varying between five and ten years.

6. As a result, this group will include promotors. One expert with an international reputation will be accepted on the commission, which should make a final decision on the functions of each course, where he will give his opinion and will have a preferential vote on account of his professional and synthesizing expertise.

7. The Governing Board of the center sends students of great promise who wish to continue their studies in the direction of synthesis, to enroll in schools abroad where they will be able to get professional and synthetic training in order to be ready to return and take on responsibilities in running the center.

8. The center tries to attract visiting professors specializing in synthesis and who enjoy unimpeachable scientific reputations. They spread their way of thinking in the university and take back with them to their home country,

on a temporary basis, top-flight students who have received travel scholarships. Such students are hired by the center once they complete their education abroad.

9. Overall operation of the center is handled by a limited active group drawn from among the promotors, and the members involved hold office for ten years' time, for the purpose of expanding the center in accordance with the aforementioned conditions.

10. The committee wishes to emphasize the principles which should govern the university which sets up this fresh endeavour. First of all, from the outset they should be both stability and continuity (to lead it to its full expansion in at the most ten years' time). Secondly, its future must be taken care of, in that the center must not suffer in the hands of people who have not already shown by competent actions and in their publications that they represent the ideal of interdisciplinary synthesis.

7. The Student Body

1. Any student who has received a diploma from a recognized secondary school will be accepted by the center. The committee holds the conviction that the very nature of the work done will be a means of selection better than any method of recruiting which could be set up for admissions.

2. The Governing Board, on the advice of the center's board, may exempt people who hold undergraduate degrees from another section of the university from certain examinations.

3. The committee thinks that for the purpose of this new experiment in teaching, a procedure for evaluating a student's progress must be set up which, after examining the student, would enable us, at the end of one, two or three years, to keep tabs on his mental development and intellectual reaction to the education he has received. This may provide a basis for revamping curricula.

4. The examinations may be staggered and given whenever the Board of the center allows.

8. Degrees

1. The center grants the grade of bachelor and master in interdisciplinary synthesis (in the natural sciences section or the cultural sciences section).

2. The center grants the grade of doctor in interdisciplinary synthesis (after completion of doctoral exams, which will be explained below, and after submission of an original thesis).

3. As a dissertation for the master's degree, a student should submit a study comparing specific or general points of either the structures of more than one scientific field in the subjects being synthesized, or the history or the method of more than one such field. In this fashion, the interdisciplinary character of the center will also be reflected in the nature of the work required.

9. CURRICULA

In the following pages, we give a glimpse of a series of courses which can all be given by one or several persons, and for which the schedule is concretely drawn up by the board of the center. This curriculum is then submitted for approval to the University's Governing Board.

The figures 1, 2, 3 and 4 merely show the length of the course, on a sliding scale from a brief to a longer period of time.

We append a short note for some courses, to explain their main features.

The curriculum of each division is followed by a brief description of its overall structure and the reasons for drawing up the course in that particular fashion.

I. INTERDISCIPLINARY SYNTHESIS IN THE NATURAL SCIENCES

FIRST YEAR

1. *Set theory :* intuitive introduction (1).
2. *Logic* (2).
3. *Survey of algebraic and geometric patterns* (2).
4. a) *Integral and differential calculus* (3.)
   b) *Probability calculus* (3).
5. *Techniques of observation and experimentation* (4).

In this clear, practical course organised to give a balanced survey (which is offered by various instructors on the basis of a mutual agreement), the techniques of observation and experimentation are presented, with particular reference to various branches of physics, chemistry, biology and geology.

The general theory of observation and experimentation is not taught, and only the barest minimum specific theory required by each branch will be taught, for the purpose of leading students to understand what observation and experimentation are, and how to compare their relative difficulties and specific methods.

Our intention is to present a sample and uniform description of various techniques of observation and experimentation, by virtue of the cooperation among various instructors from different areas.

SECOND YEAR

1. *Theoretical physics, using a unifying approach*

Based on the mathematical theory taught in first year programs, this course will elaborate on theoretical physics in its most modern forms in quantum theory and relativity, as specific examples of known algebraic and geometrical patterns. (At the present time, group theory and vectorial space theory will play a special role.) Classical mechanics appears as a special extreme case.

2. *Theoretical chemistry, using a unifying approach*

Chemistry will be derived from quantum mechanics as a special case. The theory of organic compounds will be related to compound topology (3)

3. *Analysis*

Bases an applications (as preparation for the unit theories of the fourth year, non-classical geometries will be presented, and integral and differential calculus will be related to the fundamentals of analysis) (3).

4. *Organisation levels for live matter*
   1. Viruses.
   2. Micro-organisms.
   3. Cells (morphological, biochemical and physiological studies).
   4. Pluricellular forms of organisation.
   5. Bio-ecology. (2)

5. *The functions of life for conservation and progress*
   1. phylogenesis (birth of life and systematic phylogenetics)
   2. embryogenesis (with emphasis on causal embryology)
   3. heredity and environment (2).

THIRD YEAR

1. *General Technology*
   a) Physical technology: general machine theory from a unifying standpoint (cybernetics of Zwicky).
   b) Biotechnology:
      — General theory of illness: diagnosis and therapy from a unifying standpoint (Seley's approach, for instance)
      — general theory of agriculture and animal husbandry, from a unifying standpoint (3)

2. *History of the natural sciences*

The development of the physical, chemical and biological sciences, as well as technology and medicine, outlined in a comparative study with references to both sources and trends and structural laws (3 - 4)

3. *Examination of the fundamentals of mathematics and axiom systems*

(Mathematical, as well as empirical and applied sciences), with the elements of the theory of automatisms. (3)

4. *Universal algebra*

(with morphisms, categories and topological groups — emphasizing both an overall philosophical basis and the theory of magnetic fields) (3)

5. *Theoretical biology.* Theory for mathematical models for living things.

FOURTH YEAR

1. *Unit theories for a magnetic theory, astrophysics and cosmogony* (4)

2. *Preliminary sciences*

a) Morphological sciences : introduction to the macrostructures of anorganic matter — cristals, minerals, landscape.
b) General cybernetics with information theory
c) Colloquia and panel discussions will be organised in cooperation with those sections of the university which are outside the center, for the purpose of investigating what partial interdisciplinary attempts are already being made and which ones can yet be accomplished.

3. *Methodology of the natural sciences*

This course will contain an organised study of the methods used by creative science, an introduction to heuristics or the theory of research in varius fields, an analysis of possible analogous or digital simulation of the attitude of the science (all with a comparative and genetics approach), and in addition, a study of the development of theory, induction, experimentation, measurements, etc. (3)

4. *The philosophy of the natural sciences*

This course will present a general systems theory for various branches of the field to be synthetised, while trying to define the features of the overall form of the system.

5. Theoretical psychology or theoretical sociology (choice offered between them) : a course in the section on synthesis in the cultural sciences.

In addition :

During his undergraduate years, the student is required to choose a laboratory where he will undertake one practical piece of research in one of the natural sciences (minimum of one year in duration). A list of such laboratories will be drawn up.

NOTE

The nature of these four years is rather clear :

In the first, introductory year, basic mathematical techniques will be taught along with basic techniques for observation and experimentation.

In the second year, students will come into direct contact with very advanced theories in physics stemming from mathematical structures : the theory of relativity and quantum theory, and based on these theories, chemistry can be presented in turn. Furthermore, the grounding in mathematics is carried on some more, and the student encounters the broad structures and functions of live matter (in accordance with a conception which is both structural and genetic, and which is based on the theory of self-reproducing molecules).

In the third year, our action on live and dead matter is studied in general theology. A comparative approach is used to look over the major lines of this evolution. The bases are studied more closely, the axiomatic method is emphasized with particular attention to its overall character and applications, and the mathematical method is applied to the study of life as well.

In the fourth year, a study will be made of attempts to unify disciplines, even in physics, bringing together the different fragments on the basis of the theory of relativity and quantum theory. Those efforts at unification based on studying the analogies of form or content show up in the course of philosophy and methodology. Within the framework of the preliminary sciences, the topics discussed will include typical transition disciplines between the natural and cultural sciences, and among the various natural sciences (physics, chemistry, biology).

In this context, it is important to emphasize how the ties between the center and the other sectors of the university are strengthened by the fact that, in the colloquia, the various partial interdisciplinary research projects will be given attention, and in addition, those new interdisciplinary endeavours which may have a chance of succeeding will be examined.

II. INTERDISCIPLINARY SYNTHESIS IN THE CULTURAL SCIENCES

First Year

1. *Set theory and logic* (3).

2. *Algebraic and geometric patterns* (3).

3. *Integral and differential calculus* (3).

4. *Techniques of observation and experimentation* on man :
   a) Observing the individual : clinical methods, and techniques of observation in psychology.
   b) Observing the product of culture : the techniques of interpreting texts stylistically and semantically, along with general methods in philology and historical criticism, each seen in a theoretical context.
   c) Observing groups : sociometrics, observing masses, techniques for conducting statistical surveys.

5. *Social checks and balances :*

How law, politics, morality, and education make it possible to have social equilibrium in various societies and cultures. The general study of comparative law, the study of the institutions for education and morality will be on a descriptive basis, for the purpose of obtaining a series of general rules defining the notion of social checks and balances.

Second Year

1. *Probability theory*

Based on the theory of measurement, probability theory and especially the theory behind statistical testing, sampling and confirming hypotheses will be presented here, using the factorial hypothesis. (3)

2. *Human biology*

This course will present endrocrinology and neurology, the systematic place of man in the chain of living things, embryogenesis and philogenesis for man, all on a descriptive basis. The purpose will be to achieve an overall structural view. (3).

3. *Theoretical psychology*

(Based on a general theory of behaviour, theoretical psychology presents the origins of behaviour in the theories of learning and genetic psychology, This same course will also examine the patterns and typology involved in this behaviour, establishing relationships between observation, thought, memory and affect. (3)

4. *Theoretical sociology*

Using mathematical techniques made applicable by the natural of group relations, this course will present the properties and laws which govern social groups. (3)

5. *General hermeneutics*

Analysis of the techniques used to understand reasonable behaviour and reasonable books in order to understand the symbolism of mankind. (3)

THIRD YEAR

1. *Major aspects of culture*

   a) *General linguistics :* Using diachronic and synchronic, structural and statistical, syntaxic. phonetic and semantic approaches, an overall study wil be made of the basic laws of the phenomenon of language (with stress placed on the study of a prototype language).
   b) *Structural economics :* Using the mathematical structure of economic development, different facts and economic theories will be looked at.
   c) *The structural science of art :* Comparative theory of art seen as forms. (We take these three aspects because the formal standpoint is best developed here, and in this way, we can take in structure (language), function (economics) and the product (art)). (4)

2. *Theoretical history :*

(Based on a synthetic study of all aspects of a given period, this science compares the forms of development of different methods, and is thus a half-way house between the traditional specialty of history and the traditional philosophy of history.) (3)

3. *General theory of action on man*

(Psychoanalysis, pedagogy, propaganda techniques, psychotherapy, social action, welfare economics, and so forth. (3)

4. *Theoretical physics*

A basic course in the synthesis section of the natural sciences.

5. *History of the cultural sciences*

Using a comparative approach, this course will compare the history of philology, law, the historical sciences, economics, psychology, sociology, and neuro-endocrinology, and structural patterns will be sought). (3 - 4)

Fourth Year

1. *Chance and determinist models of human conduct*

— game theory, communication theory, chance models of learning processes, and econometric models are developed in this course.

— in the forward-looking portion of this course, a systematic study of interdisciplinary endeavours in the social sciences (in colloquia) will be undertaken, with concern for the possibility of increasing such attempts. (3)

Trial efforts such as sociological economics, psycholinguistics, psychosomatic medecine and economic psychology should be given their place here.

2. *Theoretical anthropology and ethnology*

Following the example of structural synthesis given by Lévi-Strauss, all aspects of a society are connected, and the subject is approached with configurational ethnology, using the method of Benedict and Mead, and made more accurate by means of relational mathematics. (3)

3. *Existential anthropology and psychoanalysis*

Instead of trying to understand man through structure, one can also try to understand him in his various forms, according to the existential situation he experiences. (2)

4. *Methodology for the sciences of man*

As in the preceding section, the heuristics and theory of scientific construction are examined comparatively, structuraly and genetically, for the various branches of the field to be synthetized.

5. *Philosophy of the sciences of man*

The various systems involved in behaviour and the human body, in human groups and their products are compared from the standpoint of systems theory.

NOTE

The overall nature of this curriculum is very clear. During the first year, basic formal courses are taught. and the student learns to be familiar with the techniques of observation and experimentation. During the second year, the basic sciences of the field in question (sociology, psychology, biology) are offered, hopefully using a unified approach. During the third year, very general, partial aspects of man are treated, and during the final year, total syntheses are worked out. Besides this brief classification, there are courses still more methodological, such as those in statistics and hermeneutics (which counterbalance one another just as theoretical anthropology counterbalances existential anthropology), and courses for general background, such as that in the history of the cultural sciences.

Since the situation in the cultural sciences is less clear than elsewhere, we are appending a longer explanatory note here to plead in favor of various features inserted in this curriculum, even though they are organised in a different way.

The following principles should be applied when drawing up the curriculum:

1. The student should be put in touch with the most important methods of studying mankind. (He should especially come into contact with widely divergent methods.)

2. The student should study those social sciences which are developing most swiftly and which are being transformed most dynamically.
3. The student should come into contact with those courses which are interdisciplinary in character and which tie together various aspects of human beings.
4. The student should be familiarized with the most important attempts to unify disciplines in our time.
5. These first four goals should be sought after at the following levels: the student should be put in touch with both the individual and with human groups, and he should be put in contact with man (the individual) as well as with human products. That means that the core of the subject matter should be taught, whether in the teaching area or in the socio-economic area. That also means that the core of the matter must be emphasized, whether the syllabus is planned for the Law School or for the Liberal Arts School. Nevertheless, it is impossible to offer this subject in small scattered doses. Therefore, it should be stressed here, the success or failure of this plan depends above all on the chance of offering a new way to treat the subject matter.

As far as the method is concerned

Those social sciences which are developing most rapidly basically use mathematics (structural linguistics, economics, sociology). Furthermore, any contact between the studies made on mankind and those done on nature are rendered impossible due to a lack of thorough use of mathematics. Finally only the accuracy of mathematical thinking can save someone who is trained in synthesis from producing literary verbiage. For this reason it is absolutely necessary for students to be given a background in mathematics which includes the following items:

a) naive and logical set theory (as a basis),
b) algebraic patterns (mathematical applications in the social sciences — Leontief matrices, sociometrics, family structures, for instance, fit in here).
c) analysis based on measurement theory (it is impossible for someone to understand domestic statistics or to follow the variational principles of classical economics or to understand the theory of cybernetic stability without taking this course).

The basis of measurement theory shows the relationship to the fundamentals.

In addition to contact with mathematical techniques, a student must come into contact with the particular nature of mankind in three ways. How should he study what is typically human in individual contacts? How can he manage that with a group? How should he study the products of human culture?

In a large basic course, it is important for the techniques of observation and experimentation to be applied to man. This course would be made up of the three following parts:

a) Clinical observation of man as an individual: techniques for observing people, interviewing techniques, total personality description and the manipulation of concrete interaction are encountered, and psychotherapy, psychoanalysis and psychiatry should be put to use in this course.
b) Introduction to hermeneutics: understanding texts, art works, archeological traces, each in its proper context.
c) Mass observation of man in croups: this is done both qualitatively and quantitatively. The qualitative method appears in sociological techniques, while the quantitative method involves the psychology of testing, demography and observational econometrics. Inductive training must be offered alongside of deductive training, and no one aspect of deductive thinking will be given priority.

That is the makeup of the first basic year.

Such courses obviously would not take on a theoretical appearance, but rather would be both thorough and practical, and the theory behind these methods will be studied later on.

During the following two years, the basic social sciences, the preliminary sciences and the most exciting courses would be studied. Care should be taken to design a harmonious program which brings together the structural, genetic, and comparative approaches.

For the structural approach (the study of systems which are achieved in man), the following courses must be included :

a) Structure of the human body : neurology and endocrinology, based on a structural standpoint (which in this case would use cybernetics).

b) Structure of human groups : structural sociology (In order for the student to manage the huge amount of factual material and yet end up with a genuine total overview, this kind of sociology, which is likewise sociography, should use mathematics to classify relationships between people and characterize them on the basic of group dynamics).

c) Structure of the products of human culture . this course would set out by studying the best known product of human culture, namely, language, and use structural linguistics to make a study of the sructure of language art works, and in this way, investigate the structure of art works generally. Cultural linguistics and general structural hermeneutics (esthetics, archeology, and so forth) should fit in here.

d) Finally, a course in theoretical psychology ought to include the study of human behaviour, given independently of the courses in neurology and sociology. This course would use the special approach of viewing man as a behavioural system and would offer a study of various details (perception, memory, learning processes, effect) on the basis of a mathematically oriented theory of human action.

Balancing out this structural approach (which is already by itself comparative), an historo-genetic approach must now be set up. This genetic approach, moreover, is connected to the functionalist approach. For this reason, the following courses must be offered to countervail the foregoing approaches :

a) Sociogenesis by theoretical history : this theoretical history would be based on a limited form of synthesis, the multi-faceted, systematic description of a period, to be compared to as accurate as possible a total view of the collective history of culture, in which the historical method — for method — and the general trends of development — for content — would be included.

b) Psychogenesis by dynamic psychology, strengthened by the psychoanalytic approach and also touching on existential psychoanalysis. In addition to such psychogenesis of the total personality, this approach may include the psychogenesis of partial mechanisms, for which the psychogenesis of thinking would play a large role.

c) As far as the products of culture are concerned, a course could include, along with a purely dynamic treatment of general history, a functional treatment of the theory of social checks and balance (in which control systems such as law, politics, government, and morality are included on the basis of the way they function).

This course is offered in the first year, as the most intuitive introduction possible.

As a result of the preceding courses, the student has come into contact with the fundamental aspects of human beings, and has seen them from both a genetic and a structural point of view.

At that moment, it is important for him to take a close look at the attempts at synthesis and at the existing preliminary sciences.

a) To get beyond the psychosomatic field, a course is needed in which a relationship is established between the somatic and the psychic. A course in neuropsychology or psychosomatic medicine might be considered. (Ideally, of course, normal as well as pathological aspects would be taken up.)

b) To get beyond the dividing line between the social and psychological fields, a course such as social psychology is needed.

c) To get beyond the dividing line between studying the individual and studying human products, a course is needed which establishes a relationship between psychic patterns and cultural patterns (psycholinguistics, psycho-esthetics, psycho-economics), and another course is needed which connects cultural patterns with social patterns.

Once the student has had the basic courses and the courses which go beyond the traditional dividing lines, a synthesis is required. Synthesis is taught in the following practical form :

a) Ethnology or general structural anthropology should bring out relationships among all aspects of human beings in a general, comparative theory of culture.

b) Game theory, operations research, communication theory (and economics as an application of game theory) provide the other form of synthesis in a survey course entitled "Man as a self-regulating system". In addition to this form of synthesis based on studying man as an object, there should also be a synthesis based on man's own subjective experience. For this reason, there should be a combined course on "existential psychoanalysis and anthropology".

This educational program would nevertheless fail to achieve its purpose unless the synthetic training were crowned by thinking about the methods used and the various stabs at unification that were attempted. For this reason the following three courses crown this structure:

a) history of the cultural sciences,
b) philosophy of the cultural sciences,
c) methodology of the cultural sciences.

III. TOTAL SYNTHESIS

The committee shares the opinion that a post-graduate section should be planned for the interdisciplinary center. This section ought to be made up of a number of *special master's degree ("licence") programs,* which would call for specialization in one direction or another once the student has made either the cultural sciences or the natural sciences synthesis. But in addition to these special programs, the center should also offer a doctorate, which would only be available to a student who aimed at an overall synthesis by connecting his training in one section with a background in another section, and who would write an original dissertation in an all-inclusive manner.

After having laid down these principles, the committee is of the opinion that the task of setting up the requirements of the doctoral program should be handed over to the Board of the inter-school center.

Nevertheless, the following guidelines should be observed:

1. The doctoral examinations are required to include courses in methodology and philosophy in sections in which the student has not taken courses.
2. The doctoral examination must be planned so as to include a branch on "The major philosophical systems" and a course on "General systems theory".
3. Preparation of the doctorate should require at least two years.
4. The doctoral dissertation is required to connect two sections. For the special master's degree programs, as broad a range of choices as possible should be sought and planned. In view of the economic interests of these two majors, the committee has already planned two special master's degree programs which could be elected by students who had either done their previous work in the natural sciences section or had graduated from the School of cultural sciences.

   These sections are:

   a) *The scientific organisation of scientific research,* and
   b) *Operations research.*

In addition to these two possibilities, the committee urgently recommends specializations such as *electronics, mathematical statistics, business administration* (to the extent that agreement can be reached among professors in these sections for the purpose of obtaining special waivers for graduates of the "Center for Interdisciplinary Synthesis", and *moral science and philosophy.*

On the issue of those special master's degree programs which do not yet exist, the committee only wishes to take a theoretical stand. It is hoping to gather additional information, and should like to hand decision-making powers on this issue over to the Board of the center. The committee should like to suggest, however, that starting right now, planning the two master's degree programs (a) and (b) mentioned above should by principle be considered the *sine qua non* for the social usefulness of the center.

GENERAL CONCLUSIONS

GENERAL CONCLUSIONS

Guy MICHAUD
University of Paris X, France

I have to admit that when the directors of CERI honoured me in November 1969 by asking me to help prepare an international colloquium on interdisciplinarity — and although I was convinced of the importance of interdisciplinarity since I myself had practised it for over 30 years — I wasn't very sure I knew exactly what it meant. After 10 months of working together, we nevertheless had the sense that we had made a lot of progress, but the colloquium itself and the often lively discussions which occurred there rekindled my old doubts. Hadn't we been pursuing a will-o'-the-wisp, riding a fashion to death, exaggerating the importance of our topic out of all proportion ?

I have just re-read in their entirety the various contributions to the present volume and I am now persuaded that our premises were correct and the method we adopted pertinent, and while the results may not always be convincing the problem has at least been put in all its dimensions so that today we already know a little more about interdisciplinarity. The work done since the Nice seminar by the team of editors has helped us to get the proper perspective, to see more clearly what the prospects are, to learn the ins and outs, to cut the topic down to size, and to emphasize parts or even rearrange a subject which is often compact and incoherent, at least in appearance. In short, this team has done its best to orchestrate the many and sometimes discordant voices which had made themselves heard. I hope you will allow me to add a coda to the work which you have just read.

This is not a conclusion. At the very most, it is a preliminary balance sheet, since the present volume can only serve as the starting point for new thought and new action and, we hope, as a working tool for some readers. The following lines have been written in the hope of facilitating this work by reviewing some of the ideas and some of the principal findings.

*
* *

To begin with, I feel that beneath the apparent diversity of the book's various parts and chapters one can discern a real unity of views in the actual spirit with which it is imbued. There are two reasons for this. First, it has been the constant aim of the editors to elucidate the concept of interdisciplinarity from both the theoretical and practical viewpoints, but always in the light of real situations or on the basis of actual experience. Second, they have been constantly guided by their concern to be objective and critically minded. They have always kept half-way house between immoderate enthusiasm and constant scepticism, in their desire to keep a cool head and to examine the problems and appreciate the ideas and experiments according to exclusively scientific criteria. This has also enabled them to express themselves with complete freedom. Encouraged by a number of replies to the questionnaire, confirmed in this attitude by their own discussions, they have endeavoured to make a clean sweep of prejudice and habit, and to call in question and come up with new concepts and structures as well as actual practices. This bias may perhaps have sometimes disconcerted the reader but it does at least guarantee him straightforward, uncompromising thought.

That was necessary. Often enough we have heard blame or fear regarding interdisciplinarity which may have seemed justified. "Is it really genuine ? You can't know everything... we must beware of encyclopaedic knowledge ! You are encouraging dillettantism, superficial knowledge, self-sufficiency and the illusion of learning..." Although the answers to the survey come mainly from people who have been convinced, they should themselves have sufficed to remind us that the very notion of interdisciplinarity to start with raises certain major problems. We could not brush them aside with a wave or the stroke of a pen. We first had to put the *problems* of interdisciplinarity and in doing so no doubt to start all over again with criticism of a certain view of learning and teaching.

That in any event is apparently what impels the most fervent supporters and justifies their conviction in their own eyes. *What's the use of interdisciplinarity ?* Many people regard it as an answer to a three-pronged protest : against "fragmentary learning" crushed between a multitude of specialities in which each person shuts himself up as though he were running away from true knowledge (wouldn't that be rather the illusion of learning ?) ; against the growing rift between an increasingly compartmentalised University and society, which is "real life" regarded as a complex and indivisible whole, but at the same time against that society itself insofar as it confines the individual to a narrow repetitive function and alienates him by preventing him from fully exploiting his potential abilities and aspirations ; lastly, against conformity and "accepted ideas". The result is that many people think interdisciplinarity is, in Guy Berger's felicitous phrase, a "polemic practice", which shows up readily, as the table on page 56 demonstrates, as rather strong alternative pairs of expressions. Hence the basic query about learning and also about man and society. When all is said and done, this would appear to be the Promethean ambition of interdisciplinarity laid bare.

Such an ambition may raise a smile. It is therefore necessary to state at once what interdisciplinarity *is not* and what it neither desires nor claims to be. It is neither a fashion nor a panacea.

Interdisciplinarity is not a fashion, or at least it is better and much more than a fashion. It is a new stage in the development of scientific knowledge. Nor is it a panacea, for there can be no doubt that science also proceeds along other paths, that it includes approaches which are not always interdisciplinary and that the new University must have many other dimensions, if only the international dimension. Interdisciplinarity must not therefore be expected to provide more than it can give.

Nor is it a simple question of curriculum, and even if it must necessarily be reflected in new curricula, it is something more. Last but not least, it must not be confused with pluridisciplinarity. Agreement seems to have been reached these last few months on nomenclature. Pluridisciplinarity is the juxtaposition of two or more disciplines which are not interrelated ; at best, it is the meeting point of some of them, which may as appropriate permit mutual borrowing. Interdisciplinarity is something quite different.

***

WHAT THEN IS INTERDISCIPLINARITY ?

Whereas pluridisciplinarity is more of an educational practice, interdisciplinarity is first and foremost a scientific category, related mainly to research[1]. In this respect, it corresponds both to a certain theoretical level of formation of science and to a particularly important moment — a turning-point no doubt — in the history of science. I refer the reader to the significant essay in which Jean Piaget shows how after an initial phase during which knowledge tended to fragment into increasingly specialised disciplines and subdisciplines — a process, moreover, which is still continuing before our very eyes and will probably continue for some time to come — we are now witnessing something like a complete reversal of the scientific approach. The historian Fustel de Coulanges wrote nearly one hundred years ago : "A whole century of analysis is required for one day of synthesis". That day would now appear to be imminent and the interest shown in interdisciplinarity is an obvious sign of this.

Let me make myself clear : no true synthesis is yet involved in interdisciplinarity but at least there is significant move towards it. After Piaget, Léo Apostel has indicated the main reason for this. The exponential curve of the growth of scientific research is now imperiously demanding internal organisation for such research, both for the sake of economy and efficiency and for operational purposes — on an international scale, it could be said. In view of the ever higher costs involved, it is no longer possible nor acceptable for each discipline to develop independently of the others and to go its own way. There is another reason which has been emphasized several times in this book, namely, that the ever more complex problems raised by a rapidly changing society require interdisciplinary consultation. Whether it concerns town-planning, the environment, culture for the masses, the organisation of international and inter-racial relations, mass communications media or even quite simply what André Lichnerowicz very rightly dubbed "the economics of learning", any research, to be successful, must break out of the framework of disciplines and define an n-dimensional strategy.

These two reasons throw significant light on the distinction suggested by Marcel Boisot between two types of interdisciplinarity — what he calls "linear interdisciplinarity" or Erich Jantsch calls "cross-disciplinarity" being as yet only an elaborate form of pluridisciplinarity in which contributions are made by one discipline to another but without any real reciprocity and above all without any methodological co-operation. This heading can include one discipline's resorting to other disciplines, which are then called "auxiliary", thus demonstrating their dependence on the former. "Structural interdisciplinarity",

1. See in this connection the excellent remarks by J.R. Ladmiral. "Le Discours scientifique" in *Revue de Psychologie des Peuples*. Sept. 71.

on the contrary, involves, as Roger Bastide pointed out[1], at least a dialogue on an equal footing between two or more disciplines. But it normally demands more : the pooling of a number of axioms, concepts or methods and mutual fertilization which will often give rise, moreover, to a new discipline whose own purpose will be defined by the association itself. We have seen many examples in the present work : bio-chemistry, geo-politics, psycho-sociology, ethno-psychology, etc. Thus, structural interdisciplinarity is neither an addition nor a mixture but a combination.

"Restrictive interdisciplinarity", finally, corresponds very precisely to the study of new problem fields where several disciplines converge and each defines the constraints and limits required for effective action.

Different approaches are therefore needed according to whether one is in the field of theory or application. What is required here is a typology of interdisciplinarity based on procedures, techniques employed and aims pursued. We are also likely to have to deal with separate approaches and perhaps typologies depending on whether they concern the exact sciences or the social sciences. Léo Apostel has outlined this pattern. He has also demonstrated that a rational study of interdisciplinarity occurs at a certain formal level and that it must call on logic and mathematics.

It is thus quite clear that mathematics — or mathematic as André Lichnerowicz prefers to put it — is the special tool of interdisciplinarity, and it is probably no accident that mathematical logic, with its apparatus for organising concepts and structures, appeared at a time when the representatives of the various disciplines felt the need for encounters and better mutual understanding and that at the same time linguistics and subsequently semeiology provided the first example of a formalised social science. For the first condition of interdisciplinarity is the possibility of comparing and harmonizing vocabularies and languages, thus necessitating the preparation of an inter-language between disciplines, and it is to this task that the "Movement for the unity of science" has dedicated itself. Nonetheless, the extreme complexity of this task requires that computers be used, even if, as Léo Apostel thinks, they are not really in a position to integrate the different languages.

This seems to indicate that interdisciplinarity will inevitably surpass itself. Since the movement of convergence taking place before our eyes has begun and since we have recognised the problems raised by preparing a common language and comparing, or even interlocking the methods, concepts, structures and axioms on which the different disciplines are based, we can no longer be halted on the road to unity. Such unity is, of course, dubious and probably asymptotic, but it is none the less the end result and ideal goal of any interdisciplinary approach and looms today on the horizon of scientific thought. In this respect, general systems theory and research on hermeneutics and, at operations level, on praxeology are all working in the same direction — even though their approach and immediate targets are very different. In the course of our work there emerged a kind of general consensus for designating this move beyond the interdisciplinary stage by the name of *transdisciplinarity*.

1. Roger Bastide, "Psycohlogie et ethnologie", in *Ethnologie générale*, Encyclopédie de la Pléiade, pp. 1650 ff.

So far as interdisciplinarity as such goes, clearly its theory has yet to be formulated. To do so, we will have to compare the various experiences acquired and to instigate further experimentation in order to see under exactly what circumstances discoveries and progress occur in the various branches of science. And we shall probably have to admit that they often arise from a more or less accidental meeting between experts in several different disciplines, but that they are still more often the fruit of a creative imagination capab... of handling different concepts and meth... and juggling them to produce unexpected combinations.

In short, interdisciplinarity is not only a theoretical concept ; it is also — and perhaps first and foremost, — *a practice*, and we have a right to wonder what this practice actually consists of. In other words, by all means, let's have interdisciplinarity. But *how* and *at what price* ?

*
**

To begin with, it is practised by individuals. I hope that the reader of this book understands that interdisciplinarity cannot be learnt or taught, for it is a way of life. It is basically a mental outlook which combines curiosity with openmindedness and a spirit of adventure and discovery ; and it also includes the intuition that relationships exist between all things which escape current observation and that there are analogies of behaviour or structure which are perhaps, as the mathematician would say, isomorphic. It is the desire for selfenrichment through new approaches, like the pleasure an architect has, in combining perspectives and handling forms. Last but not least, it is the conviction that discovery by definition, means going off the beaten track.

Interdisciplinarity is not learnt, it is practised. It is the fruit of continual training and systematically working towards more flexible mental patterns. In this sense, it may increasingly appear today as the *sine qua non* of true scientific research.

While interdisciplinarity is practised by individuals, it is also, and perhaps especially, practised collectively. It is obvious that at the research level, there can be no effective encounter between disciplines unless highly qualified representatives of each of them give their full co-operation. Moreover, they must be open to dialogue and capable of recognising what they lack and what they can get from others. This openmindedness can only be acquired after a long while and from interdisciplinary teamwork, which ought to become the rule at the introductory research level and should also be set up in teaching.

Interdisciplinarity also teaches us that there can be no discontinuity between education and research. By constantly questioning the knowledge acquired and the methods practised, it transforms the University, as Guy Berger puts it, "from a place where pre-prepared learning is transmitted into a place where new learning is produced collectively" and that occurs at all levels and stages.

Interdisciplinarity therefore brings about a new student-teacher relationship. Of course, the two are not to be confused, and many teachers have altered their attitudes and methods without necessarily practising interdisciplinarity. But this is inconceivable without a profound change in their habits of teaching. For this reason, we regard teacher training as the keystone of the new edifice which has to be built, or at least rebuilt and fit out for use.

Such training ought to closely associate theory with practice. It should comprise constant training in interdisciplinary work both at the research level and at the various teaching levels, where the future teacher will take part as a "trainee", familiarising himself in this way with staffing techniques and helping to create new structures, new contents and new methods.

It would be a mere pipedream to suppose that some law or series of administrative measures taken at the national level — even if they were due to some farreaching protest movement as was the case for the French Orientation Act of 1968 — would suffice to conquer established habits, routines and structures. Interdisciplinarity does, of course, require flexible structures and, as we have seen, it nearly remained a dead letter when the vertical discipline structure were not at least juxtaposed with various types of horizontal structure. It also demands new contents which are no longer limited to juxtaposing disciplines, and it makes them relevant of the real problems and the needs of society. Lastly, it postulates methods that are based less on doling out knowledge than on training people in certain skills and on developing psychological faculties other than memory and pure discursive reasoning.

But even assuming that general measures are decreed in this direction, they can at best only be incentives. Nothing durable will be achieved, it must be emphasized, unless it is based on the solid support of a few and on a pattern of practical and initially limited experience which serves as a catalyst and nucleus for innovation in our Universities. In this respect, interdisciplinarity may be regarded as an instigator of change, the only one which is apparently able to breathe new life into an institution where rigor mortis has all too frequently set in. Moreover, it must be sufficiently dynamic to quickly overcome the resistance and obstacles which will not fail to beset its path.

It would be dangerous to underestimate them. First of all, there are the established positions — all kinds of cushy spots in the hierarchy — whether in research, teaching or administration. Then there is the weight of routine, the inflexibility of mental sets and the inevitable jealousy which any conformist feels towards an attractive innovation and which he is quick to reprove as "demagogic".

And above all there is the question of cost. We cannot hide from the fact that introducing true interdisciplinarity represents a very heavy investment, both because of the number of teachers and the amount of training required and because of the technical equipment needed if basic knowledge which must be acquired somehow, is to be learned through programmed teaching. Fruthermore, introducing interdisciplinary structures and content demands exhaustive preliminary research, i.e. prefinancing, if we want to avoid the risk of failure which might throw discredit on this type of experiment.

However, such increase in certain costs should be largely balanced out by having a more profitable institution. It is clear that for many well-known reasons, the Universities' present rate of profitability is low (merely compare the flow of students entering and leaving). The current failure of our university institutions to adjust to progress in science and changes in society is a downright waste of both financial and human resources. In this respect, introducing interdisciplinarity ought to bring with it a number of advantages that are relatively easy to evaluate, if not to measure exactly: improved student drive, better guidance and consequently a lower attrition rate, streamlined curricula and lastly, on a social level, better adjustment to socio-occupational life as each individual is more able to be retrained to cope with change.

However, one final problem arises here concerning the relations between the University and society, and more especially the University and society, and more especially the outlets offered by the latter to young people upon graduation. The society of tomorrow will very likely have a grater need for relatively "well-rounded" individuals, and the expansion of interdisciplinary studies is better preparation for this well-rounded quality. Nevertheless, presentday society — whether we are speaking of employers, administrators and political men or families — is clearly still largely unaware of this change. So faith in the fetish of diplomas and well-trodden paths persists, and there is the temptation, quite understandable for a technocratic society based essentially on the profit motive, to bring pressure to bear on the institution to "produce" individuals trained to fit in easily. So very often, students feel "alienated" and wish to challenge both society as a whole and the institution which caters to its needs. This is a political problem which cannot be brushed over lightly. Scientific objectivity must not be confused with any kind of vague neutrality which eludes the real issues, and it is no cause for surprise that many faculty members are troubled by this sub-ordination of the university as an institution, both at the teaching and research levels, to a certain type of society which they do not regard as conducive to the free development of learning and fulfilment of personality. It is understandable that such professors view interdisciplinarity as a weapon and, as Guy Berger says, the implement for a "blithe liberation".

* * *

We are very aware of the shortcomings of the present book. It should have been possible for us to suggest models of an interdisciplinary University, but that seemed premature at our present stage of thinking and corresponding experience. At least we have presented in the form of annexes, with all the necessary reservations, an outline for a "university with a major vocation" as well as the project for a "university centre for synthesis", both of which appear suitable ways to give concrete form to some of the ideas expressed here.

Above all, students should have been given a say. The operating conditions of this project did not allow for this. But obviously this work of thought and experiment cannot continue without a dialogue and consultation between all the groups making up the University and especially the principal persons concerned.

Such a dialogue should give true meaning to a *strategy* of interdisciplinarity which we hope will carry on this first joint effort. Further broader and more systematic surveys should first be made, followed by a greater number of pilot experiments which differ from one country or one field of problems to another, and information exchanges between them should be made easier. It is also essential that specialised centres should at the same time be examining the theory of interdisciplinarity, together with the concepts it introduces and the approach it involves. Ultimately an international team of leaders could be formed to promote and organise these various experiments, report regularly on their progress, and help train new staff who in turn will organise new experiments and ensure the continuity of this undertaking once it is in full swing.

In conclusion, let us make an appeal for all the goodwill we can get. If this book has been able to convince some readers that an interdisciplinary approach is justified and that it can play a part in transforming an institution which in the future ought not be the servant but the conscience, the analytical mind and the driving force in society, the effort we have already made will not have been in vain. The stakes involved in sustaining this effort are such that every individual must make a personal commitment to carry on.

APPENDICES

Appendix 1

SOME BIBLIOGRAPHICAL REFERENCES

We thought the reader would perhaps like to refer to some basic books on interdisciplinary teaching and research, and we therefore present here a select bibliography. We would like very much to express our thanks to those who have provided us with the following information.

GERMANY

These references were given to us by
H. von HENTIG *(University of Bielefeld)*

Bundesassistentenkonferenz (Hrgb.). Beiträge zur Studienreform, Materialien der BAK Bd. 6, Bonn 1970.

Dempf, Alois. Die Einheit der Wissenschaft, Stuttgart 1955 (Kohlhammer), Urban Bücher Bd. 18.

Deutscher Bildungsrat, Empfehlungen der Bildungskommission. Strukturplan für das Bildungswesen, Bonn 1970 (Bundesdruckerei).

Die Idee der deuschen Universität, die 5 Grundschriften aus der Zeit ihrer Neugründung (Schelling/Fichte/Schleiermacher/Steffens/Humboldt), Darmstadt 1959 (Wissenschaftl. Buchgesellschaft).

v. Hentig, Hartmut. Universität und Höhere Schule, Bielefeld 1969 (Bertelsmann Universitätsverlag Reinhard Mohn).

v. Hentig, Hartmut. Das Bielefelder Oberstufen-Kolleg, Begründung/Merkmale/Allgemeiner Funktionsplan/Flächenprogramm, Publikationen der Schulprojekte der Universität Bielefeld, Heft 1, Stuttgart 1971 (Ernst Klett).

v. Hentig, Hartmut. Die Einheit der Wissenschaft — dargestellt als Problem einer allgemeinen Wissenschaftspropädeutik und Wissenschaftsdidaktik in: Merkur (September/Oktober) 1971.

Herz, O./L. Huber/M. Walter (Hrgb.). Blickpunkt Hochschuldidaktik Br. 9: Organisationsmodelle der Hochschuldidaktik, Hamburg 1970.

Jaspers, Karl/Kurt Rossmann. Die Idee der Universität, Berlin/Göttingen/Heidelberg 1961 (Springer).

Klages, Helmut. Rationalität und Spontanität, Gütersloh 1967 (C. Bertelsmann).

Mikat, Paul/Helmut Schelsky. Grundzüge einer neuen Universität, Gütersloh 1966 (C. Bertelsmann).

Neue Sammlung, fünftes Sonderheft. Wissenschaftsdidaktik, hg. H.v. Hentig, L. Huber u. P. Müller, Göttingen (Vandenhoeck und Ruprecht).

Radnitzky, Gerhard. Der Praxisbezug der Forschung, Vorstudien zur theoretischen Grundlegung der Wissenschaftspolitik, in: Studium Generale 23 (1970), 817-855.

Rüegg, W. Humanismus, Studium Generale und Studia Humanitatis in Deutschland, Genf 1954.

Schwan, Alexander/Kurt Sontheimer. Reform als Alternative, Hochschulleher antworten auf die Herausforderung der Studenten, Köln 1969 (Westdeutscher Verlag).

Seiffert, Helmut. Information über die Information, München 1968 (C.H. Beck).

Seiffert, Helmut. Einführung in die Wissenschaftstheorie Bd. 1, München 1969 (C.H. Beck).

Seiffert, Helmut. Einführung in die Wissenschaftstheorie Bd. 2, München 1970 (C.H. Beck).

Weizsäcker/Dohmen/Jüchter. Baukasten gegen Systemzwänge, Der Weizsäcker-Hochschulplan, Müncen 1970 (Piper).

UNITED KINGDOM

These references were given to us by
A. BRIGGS *(University of Sussex)*

R. Beard, F. Healey and P. Holloway (eds.). *Objectives in Higher Education* (9168).

D. Daiches (ed). *The Idea of a New University* (1964).

A. H. Halsey, J. Floud and C.A. Arnold (eds.). *Education, Economy and Society* (1960).

A. H. Iliffe. *The Foundation Year in the University of Keele* (1966).

P. Marris. *The Experience of Higher Education* (1964).

R. S. Morison (ed.). *The Contemporary University* (1966).

R. S. Peters (ed.). *The Concept of Education.*

A. Sloman. *A University in the Making* (1964).

M. Trow. "The Idea of a New Unversity" in *Universities Quarterly,* Vol. 19 No. 2 (1965).

Universities Quarterly. Vol. 19, No. 2 (1965). Report of Discussion on "Changing Patterns of Study".

UNITED STATES

One part of these references was given to us by E.W. WEIDNER *(University of Wisconsin - Green Bay) and the remainder by* J.L. BECKHAM *(Center for research and development in Higher education, University of California, Berkeley).*

Alpert, Daniel. "The Role and Structure of Interdisciplinary and Mulitdisciplinary Research Centers". Address to the Ninth Annual Meeting of the Council of Graduate Schools in the United States. Washington, D.C.: December 4-6, 1969. Outlines problems of present approaches to interdisciplinary research.

Ansbro, J. J. "Experiment in Interdisciplinary Liberal Education," *Liberal Education*, Vol. 54, December 1968.

Aronoff, S. "Interdisciplinary Scholarship." Address to the Ninth Annual Meeting of the Council of Graduate Schools in the United States. Washington, D.C.: December 4-6, 1969. A call for reorganization in the structure and methodology of the university in order to relate academic offerings to social needs.

Axelrod, Joseph. "An Experimental College Model," in *Educational Record*, Fall, 1967, pp. 327-337.

Axelrod, Joseph. *Model Building in Undergraduate Colleges: A Theoretical Framework for Studying and Reforming the Curricular Instructional Subsystem in American Colleges* (Berkeley: Center for Research and Development in Higher Education, 1969).

Axelrod, Joseph. "NDEA Foreign Language Institute Programs: The Development of a New Education Model," in *Publications of the Modern Language Association of America*, Volume LXXXII, Number 4 (September, 1967), pp. 13-18.

Axelrod, Joseph; Freedman, Mervin B.; Hatch, Winslow R.; Katz, Joseph; Sanford, Nevitt. *Search for Relevance* (San Francisco: Jossey-Bass, 1969).

Bell, Daniel. *The Reforming of General Education* (New York: Columbia University Press, 1966). Second edition-Garden City, New York: Doubleday and Company, Inc., 1968.

Brick, Michael, and McGrath, Earl J. *Innovation in Liberal Arts Colleges* (New York: Teachers' College Press, 1969).

Crawford, Bryce. "The Support of Interdisciplinary and Transdisciplinary Programs." Address to the Ninth Annual Meeting of the Council of Graduate Schools in the United States. Washington, D.C.: December 4-6, 1969. Examines problems and alternatives of funding interdisciplinary graduate programs through disciplinary departmental structures.

Gaff, Jerry G., *et al. The Cluster College* (San Francisco: Jossey-Bass, 1970).

Grenander, M.E. "Mark Hopkins' Log: Teaching and the Analysis of Ideas," *English Record*, Vol. 20, No. 1, October 1969. The author advocates use of a four-stage sequential approach to interdisciplinary study: acquisition and evaluation of facts: creative discovery; presentation of ideas; and systematization of knowledge.

Henderson, Algo D. *The Innovative Spirit* (San Francisco: Jossey-Bass, 1970).

Hodgkinson, Harold L. "Walden U." in *Soundings*, Summer, 1969, pp. 172-185. Reprinted in part in Hodgkinson, Harold L. and Bloy, Myron (eds.) *The Identity Crisis in Higher Education* (San Francisco: Jossey-Bass. 1971).

McEvoy, James and Miller, Abraham. *Black Power and Student Rebellion* (Belmont, California: Wadsworth, 1969).

Mayhew, Lewis B. *Higher Education in the Revolutionary Decades* (Berkeley: McCutchan, 1967).

Newman, Frank: Cannon, William; Cavell, Stanley; Cohen, Audrey; Edgerton, Russell; Gibbons, James; Kramer, Martin; Rhodes, Joseph; Singleton, Robert. *Report on Higher Education* (Washington, D.C.: U.S. Government Printing Office, 1971).

Patterson, Franklin, and Longsworth, Charles R. *The Making of a College* (Cambridge, Massachusetts : M.I.T. Press, 1966).

Overholt, T.W. and Schenk, A.P. "Violence and Human Values : The Implications of an Interdisciplinary Seminar for Curriculum Revision," *Journal of General Education*, Vol. 21 No. 2, July 1969. The authors describe their experience in a particular seminar and draw general conclusions in reference to interdisciplinary curriculum revision.

Riesman, David ; Gusfield, Joseph ; and Gamson, Zelda. *Academic Values and Mass Education* (New York : Doubleday, 1970).

Scully, Malcolm G. "A National 'Open University' Is on its Way, Educators Told," in *The Chronicle of Higher Education*, Volume V, Number 24, March 22, 1971, pp. 1, 5.

Secrest, Leig. "The Rationale for Polydisciplinary Programs." Address to the Ninth Annual Meeting of the Council of Graduate Schools in the United States. Washington, D.C.: December 4-6, 1969. "Since academic disciplines are strengthened by interaction with each other... polydisciplinary efforts should be accepted as a viable means of intellectual progress."

Sherif, Muzafer, and Sherif, Carolyn W., eds. *Interdisciplinary Relationships in the Social Sciences.* Chicago, Illinois : Aldine, 1969.

Silent Committee on Education, Academic Senate, University of California, Berkeley. *Education at Berkeley* (Berkeley: University of California Press, 1968). (Commonly known as the "Muscatine Report".)

Simas, Philip W. "A New Supra Discipline, Policy Sciences, Aims to 'Integrate Intelligence and Action,'" in *The Chronicle of Higher Education*, Volume V, Number 16, January 25, 1971, pp. 1, 5.

Stickler, W. Hugh (ed.). *Experimental Colleges* (Tallahassee, Florida : Florida State University, 1964).

Taylor, Harold. *How to Change Colleges* (New York : Holt, Rinehart and Winston, 1971).

Tussman, Joseph. *Experiment at Berkeley* (New York : Oxford University Press, 1969).

Vallance, Theodore R. *Structural Innovations in Higher Education to Meet Social Needs.* Washington, D.C. : ERIC Clearinghouse on Higher Education, December 1970. A focus on nine institutions of higher education which were designed specifically to respond to social problems. Conclusions relate to interdepartmental institutes or centers.

Wilson, Logan (ed.). *Emerging Patterns in Higher Education* (Washington, D.C. : American Council on Education, 1968).

Wolfe, Alan. "The Experimental College-Noble Contradiction," in *Change*, March-April, 1970, pp. 26-32.

N.B. Most of these books contain very exhaustive bibliographies. They mention all of the interdisciplinary programmes currently in operation. To obtain specific detailed information concerning any interdisciplinary programme in the United States, you may request a copy of the catalogue of the college in question by writing to the Director of Admissions (The usual charge for such catalogue is one dollar).

L. APOSTEL *(University of Ghent, Belgium) provided us with the following:*

I. We mention for the interested reader a short series of books, introducing the various "interlanguages".

- *Input Integration:* "Encyclopedia of Unified Science, (2 vols) - University of Chicago Press" (edited by *R. Carnap* and *C.W. Morris*).
- *System Integration:* "Yearbook of the Society for General System Research" (eds. *L. von Bertalanffy, A. Rapoport, K. Boulding,* Vols I - XVIII).
- *Action Integration: T. Kotarbinski:* "Praxeology" (Pergamon Press).
- *Hermeneutics:* "Philosophy of Symbolic Forms" (3 volumes - from the German original: "Philosophie der Symbolischen Formen") by *E. Cassirer.*
- *Genetic Integration:* 1) "Introduction à l'Epistémologie Génétique" by *J. Piaget* (3 volumes); 2) For a modern introduction to recent dialectic materialism, influenced by general systems theory, see "Dialektik der Entwicklung objektiver System" (by *G. Pawelzig,* Berlin, 1971).

II. The paper "Conceptual tools for interdisciplinary: an operational approach" is to be considered as an attempt to develop *Bernal's* "Science of Science", to point out its relations to operation research, and to relate it to the problem of interdisciplinary research.

Three basic works are:

1. *J.D. Bernal:* "The Social Function of Science", London, 1939,
2. *G.M. Dobrow:* "Die Wissenschaft von der Wissenschaft. Eine Einführung in die allgemeine Wissenschaftslehre". Kiew 1966, translated Berlin 1969, and
3. *G.M. Dobrow:* "Aktuelle Probleme der Wissenschaftswissenschaft". Dietz, Berlin 1970.

A recent collection of papers called "The Science of Science" (edited by M. Smith and A. Mackay, London, 1964) recalls Bernal's achievements.

III. A large bibliography on the problems of Interdisciplinary Research is to be found in:

M. Barron Luszks: "Interdisciplinary Team Research, Methods and Problems, N° 3 "Research Training Laboratories", 1958, New York University Press.

IV. The journal: *"Studium Generale",* (Heidelberg, Germany) offers since many years important interdisciplinary material.

D. Rivet *(Centre de Psycologie économique, Paris) has provided us with the following references within the frame of concrete applications of interdisciplinarity : problems posed by the relationships between economic and social sciences.*

1. P. Albou. Problèmes actuels de la psycho-sociologie économique. in Palmade : l'économique et les sciences humaines. T. II — Dunod 67.
2. J. Binet. Psychologie économique africaine — éléments d'une recherche interdisciplinaire. Payot 1970.
3. C. Brisset. Economie et psychanalyse. in Palmade : l'économique et les sciences humaines. T. I — Dunod 67.
4. P. Claval. Les économistes, les géographes et la région. Revue économique et Juridique du Sud-Ouest. N° 3.69. éd Bière.
5. Colloque. La Psychologie économique et les disciplines voisines. Dalloz 67.
6. Congrès des économistes de langue française. Revue d'économie politique. 3.68. Domaines et méthodes des sciences économiques (économie politique, sociologie, psychologie, mathématiques, économétrie).
7. J. Cuisenier. Economie et Sociométrie. in Palmade : l'économique et les sciences humaines. T. I — Dunod 67.
8. R. Duchac. Sociologie et Psychologie. P.U.F. 1963.
9. R. Guiheneuf. Situation de l'économique et des sciences humaines dans la pensée économique contemporaine. in Palmada :l 'économique et les sciences humaines. T. I — Dunod 67.
10. L. Lajugie. L'expérience des recherches interdisciplinaires de l'Institut d'économie régionale du Sud-Ouest. Revue juridique et économique. N° 3. 1969. éd. Bière.
11. Logique et Connaissance scientifiques. Sous la Direction de J. Piaget. Encyclopédie de la Pleiade. Hachette 67.
12. J. Piaget. La Psychologie ; Les Relations interdisciplinaires et le Système des sciences. XVIII° congrès international de psychologie. Moscou. Bulletin de psychologie de Paris. Déc. 66.
13. P. L. Reynaud. Remarques sur les relations de la sociologie économique et de la psychologie économique. Cahiers de sociologie économique. Nov. 66.
14. P. L. Reynaud. Comment l'économie politique moderne doit-elle coordonner les apports des mathématiques et de la psychologie économique revue des sciences économiques. Sept. 67. Liège. Belgique.
15. Revue internationale des sciences sociales. N° 2. 1970 — vers une politique de la recherche sociale. N° 4. 170 — maîtriser l'environnement de l'homme (apport de l'économie, la sociologie, l'écologie, l'architecture...).
16. B. Saporta. Comportement d'achat et comportements collectifs — contribution d'une approche interdisciplinaire à l'étude des problèmes de consommation collective. Revue juridique et économique du Sud-ouest. N° 4. 1969 — éd. Bière.
17. Unesco. Compte-rendu du Colloque international : Science et Synthèse, éd. Gallimard. 1967.
18. Unesco. The social sciences ; problems and orientation, selected studies. Mouton : Unesco 1970.
19. UNESCO : Main trends of research in the social and human sciences. Part I : Social sciences. Mouton/Unesco 1970.
20. J. Valarche. L'Expérience interdisciplinaire d'économie régionale à l'université de Fribourg (Suisse). Revue juridique et économique du S. Ouest. N° 3. 1969. éd. Bière.
21. B. Winiarski. Recherche interdisciplinaire pour la planification du développement régional : les expériences polonaises. Revue juridique et économique du Sud-Ouest. N° 3. 1969. éd. Bière.

Appendix 2

PEOPLE REPLYING TO THE QUESTIONNAIRE ON INTERDISCIPLINARY ACTIVITIES OF TEACHING AND RESEARCH IN UNIVERSITIES

The name, title, university or institute of each person are listed herein together with the activity described in the questionnaire and the disciplines involved. The code letters appearing in the questionnaire have moreover been used to identify the activity, i.e.

A. general education ;
B. professional education ;
C. training of researchers ;
D. basic research ;
E. applied research ;

NOTE. In addition to the completed questionnaires letters were received which are impossible to list owing to their vast number. Many of them are of considerable interest and contain a wealth of information.

AUSTRIA

VIENNA :

P. BERNER, Director, Psychiatrisch-neurologische Universitätsklinik, Spitalgasse 23, 1090 Wien IX. "Social psychiatry", "psychopharmacology", "Music-therapy", "Experimental psychopathology".

B. D. E.

BELGIUM

A. DOUCY, Directeur, Institut de Sociologie, Université Libre de Bruxelles, 44 avenue Jeanne, B. 1050, Bruxelles. Various interdisciplinary activities at research level, e.g. research jointly applicable to sociologists and jurists.

D. E.

J.E. DUMONT, Directeur, Centre de Médecine Nucléaire, Université de Bruxelles, 115 Bd. de Waterloo, B. 1000, Bruxelles, Institute for interdisciplinary research (nuclear medicine, biochemistry, biomathematics, etc...).

C. D.

L. de RYCK-TASMOWSKI, F. VANDAMME, M. de MEY, Assistants, Rijksuniversiteit Sint Pietersnieuwstraat 25, 9000 Gent. "Study of communication and cognition processes" (philosophy of science, linguistics, psychology, logic, history of sciences, sociology, general economics).

D. E.

CANADA

E.W. BANISTER, Chairman, Kinesiology, physical development, Simon Fraser University, Burnaby 2, British Columbia. "Kinesiology", (chemistry, physics, mathematics, biology, psychology, sociology, anatomy of histology, arthropometry, motor learning, applied human physiology, biomechanics).

A. C. E.

University of New Brunswick, Fredericton, New Brunswick

W. RADFORTH, Professor, Director, Muskeg research Institute, "Muskeg Studies" (engineering, design and general, biology, mathematics, computer and systems analysis, survey engineering, geology, forestry, chemistry, physics).

B. C. D. E.

R.N. SCOTT, Professor, Executive Director, Bio-Engineering Institute, "Bio-Engineering Studies" (engineering electricity and sometimes mechanics, physiology, medicine).

C. D. E.

Dalhousie University, Halifax, Nova Scotia

F. HAYES, Killiam Research, Professor, Environmental Studies, "the Social and Political Basis of Science Policy in Canada" (political science, biology, economics, physics, chemistry).

C.

R. RAVINDRA, Associate Professor of Physics, and Philosophy, "Philosophy and history of Science" (philosophy, history, natural sciences, particularly physics). A. D.

G.A. RILEY, Director, Institute of Oceanography. "Oceanography" (mathematics, physics, chemistry, geology, biology). B. C. D. E.

J.A. MORRISON, Director, Institute for Materials Research, Mac Master University, Hamilton, "Materials Research" (physics, metallurgy, chemistry, electrical engineering, engineering physics, chemical engineering, geology, civil engineering). C. D. E.

C. GREFFARD, Co-ordinator. Center for areas studies, department of geography, Faculty of Arts, University of Ottawa, Ottawa 2. "Regional Planning" (planning, computer sciences, economics, geograpy, sociology, management). B. E.

R.A. ROSS, Dean of Science, Lakehead University, Thunder bay, "Materials and Molecular Science" (chemistry, physics, engineering). C. E.

University of Toronto, Toronto, Ontario.

G. PAYSANT, Chairman, Committee on Interdisciplinary Studies, Faculty of Arts and Science. He was instrumental in providing replies from the following:

D.H. PIMLOTT, Professor "Environmental Studies" (biology, geography, forestry, law, sociology, political science). A.

B. BRAINERD, Professor of Mathematics, Centre for Linguistic Studies. "Communications" (anthropology, linguistics, psychology, biology, mathematics). A.

D.B. KING, Academic Co-ordinator and Registrar, Innis College, "Canadian Culture and Society" (history, English, geography, political science, architecture, anthropology). A.

W.R.C. HARVEY, Junior Professor. "Theory, Method, and Practics" (philosophy, physics, political economy). A.

J. LEMON, Associate Professor. "Modernization and Community" (geography, history, political economy, sociology, architecture, planning, philosophy, etc...). A.

L.H. RUSSWURM, Deputy Chairman, Department of Geography, Undergraduate Officer, Division of Environmental Studies, University of Waterloo, Waterloo, "Man-Environment Studies" (resource economics, social work, psychology, geography, animal ecology, engineering). A. C. E.

M.A. CORDT, Assistant Professor of English and Co-ordinator of Colloquium Study, University of Lethbridge, Lethbridge, Alberta. "Colloquium Study" (art, English, psychology, sociology, anthropology, philosophy, music, mathematics, chemistry, biology). A.

I. ROSS, Associate Professor of English, Co-ordinator, Arts One, University of British Columbia, Vancouver 168. "Interdisciplinary Programme for First University Year" (arts). A.

I. HAMELIN, Director, Center for Nordic Studies, University of Laval, Laval, Quebec. 10°. Example of interdisciplinary research programme: "the western shores of the Hudson Sea" (earth, biological and human sciences).

C. D

H.S. GILMOUR, Associate Professor of biology, Course Co-ordinator, University of Saskatchewan, Saskatoon, Saskatchewan "Man and the biosphere" (biology, sociology, economics, animal science, plant ecology, geography, philosophy, theology, anthropology, social and preventive medicine).

A.

FINLAND

University of Oulu, Pakkahuomenkatu 12 B. Oulu.

A. KALLIO, Professor. "Quantum mechanics" (theoretical physics, physics, engineering).

A. B. C.

J. OKSMAN, Head of Department of Electrical Engineering, "Ionosphere Research by Means of Satellites" (physics, engineering).

C. D.

FRANCE

B. BROUSSET, Président de la Section philosophie et Sciences Humaines, Faculté des Lettres, Université d'Amiens, 3 place Devarlly, 80, Amiens. "Interdisciplinary research project on the problems and status of human development in Picardy" (psychology, educational psychology, sociology, geography, medicine, law and economics).

D. E.

J. LAFON, Maître de conférence associé d'audiophonologie, Université de Besançon, Faculté de médecine et de pharmacie, 4 place Saint-Jacques 25, Besançon. "Audiophonology" (medicine, educational psychology, phonetics, linguistics, acoustics, psychophysiology, computer sciences).

D. E.

M. GILLET, Chargé d'enseignement en Histoire Contemporaine, Université de Lille III (Sciences humaines, arts et lettres), 9 rue A. Angellier, 58, Lille, "Methods of economic and financial history" (history, economics, sociology).

C.

B. JEU, Chargé d'enseignement de philosophie, Université de Lille III, 9 rue A. Angellier, 59, Lille. "Russian and Soviet philosophy" (philosophy, Russian language, Soviet civilization).

A. B. C. D. E.

University of Paris VIII (Vincennes), route de la Tournelle (12°).

G. BERGER, Maître assistant, Département des Sciences de l'Education. "Evaluation methods applied to education" (pedagogics, psychology, economics, sociology).

A. C.

D. CHARLES, Responsable du Département musique. Examples of activities: "Music and the computer sciences", "Pop Music Ideology", "Music and civilisation" (music, sociology, economics, politics, history, aesthetics, computer sciences, etc.).

A. B. C. D. E.

H. LABORIT, Professeur, "Biology and town-planning" (biology, psychology, sociology, general and human ecology, urban planning).

A. B. C. D. E.

L. LEBOUTET, Professeur, "statistics as applied to the human sciences" (statistics, mathematics, psychology).

A. C.

R. MARCUS, Coordinator of "Study and Research Group for Latin-America" (Spanish, Portuguese, geography, history, educational science, arts).

A. B. C. D. E.

M. REBERIOUX, Professeur, histoire contemporaine d'orientation culturelle : "Culture of militant industrial workers since the Paris Commune" (history, literature, sociology). "The cultural and political avant-garde, 1890-1914" (history, literature, arts).

A. C.

J.F. RICHARD. Laboratoire de psychologie. "Programmed education" (psychology, mathematics).

A.

A. VEINSTEIN, Responsable du département théâtre. "Interdisciplinary centre of techniques for disseminating culture" (plastic arts, music, cinema, urban planning, architecture, literature, museum science, documentation science, psychology, sociology, educational science).

A. B. C. D. E.

M. VEYRENC, Professeur de Russe. "Slavic studies" (linguistic theory, applied linguistics, general literature, history).

A. B. C. D.

University of Paris IX (Dauphine), place de Lattre de Tassigny, 16e.

GALAIS, Assistant, "Economic anthropology" (economics, sociology, ethnology).

D.

J.L. RIGAL, professeur. "Educational and research unit on computerised management" (mathematics, statistics, operational research, economics, management automation, computerised accounting, language arts, modern languages).

A. C. D. E.

F. SAINT-PIERRE, assistant "Analysis of economic and social factors" (economic, sociology, history, etc.).

A.

P. URI, assistant, "Analysis of economic and social factors" (economics sociology).

A. B. D.

In addition 5 anonymous questionnaires were received from Univerity of Paris IX.

G. BONNEVILLE, professeur, Faculté des Lettres et Sciences Humaines de Nanterre, Université de Paris X, 92, Nanterre. "European problems" (general literature, history, philosophy, economics).

A.

G. RICHARD, professeur, Université de Rennes, 1 rue d'Antrain, Rennes. "Behavioural and environmental sciences" (mathematics, biology, physiology, agronomics, animal husbandry, town-planning, human sciences, etc.).

A. B. C. D. E.

R. BENOIT, professeur, Centre d'Etudes Supérieures de l'Aménagement du Territoire, Université de Tours. Various activities (ecology, geology and physical geography, sociology, economics and law, computer sciences, English, civil and rural engineering, etc.).

A. B.

GERMANY

H.J. ZIMMERMANN, Direktor, Technische Universität, 51 Aachen, Templergraben 55. "Economic engineering and operation research" (national economy, business administration, operation research, industrial engineering, law).
E.

University of Bochum.

J. ZIERIS, Wissenschaftlicher Assistent, Institut für Arbeitssoziologie und Arbeitspolitik. "Sociology of work, work policy" (sociology, social psychology, labor laws, pedagogy in practice).
E.

WERTENBRUCH, Geschäftsführender Direktor, Institut für Sozialrecht. "social law" (social law, social medicine, social politics, social psychology, social pedagogy, labor law).
B. C. D. E.

University of Hamburg 13, Edmund-Siemers Allee 1.

FELDMANN, Abteilungsvorsteher. "Computer sciences" (mathematics, physics).
B. C. D. E.

E. SANDNER, Direktor, Wirtschaftsgeographische Abteilung des Instituts für Geographie und Wirtschaftsgeographie. "Special research area — Iberoamerican Studies" (economics, linguistics, sociology, law, geography, economics, pedagogy, archeology, history).
D. E.

R. SCHULMEISTER, Senatsbeauftragter. "Interdisciplinary centre for university didactics". (sociology, philosophy, pedagogy, linguistics).
B. C. D. E.

E.W. FUSS, Direktor des Europa-Instituts der Universität Mannheim, 8 — Mannheim. "Research on European Problems" (law, economics, history, roman languages, sociology, political science).
E.

R. KOTTJE, Prorektor, Universität Regensburg, 8400 Regensburg, Universitätsstraze 31, "Decret of the Bischop Burchard von Worms" (medieval history, history of Canon law, church history).
D.

W. KROEBER-RIEL, Professor, Universität des Saarlandes, Saarbrücken. "Behavioral approach of marketing, philosophy of social science" (economics, behavioral sciences, especially social psychology, philosophy of science).
B. E.

H. FLECKENSTEIN, Professor, Universität Würzburg, D-87 Würzburg, Sanderring 2. "Seminar on medical ethics and medical law" (Neurosurgery, psychiatry, neurology, forensic medicine law).
E.

JAPAN

C. ISCHIMURA, Director, Professor of Economics, Center for Southeast Asian Studies, Kyoto University, Kyoto. "Southeast Asian Studies" (economy, history, sociology, anthropology, social sciences, geology).
D. E.

University of Tokyo, Hongo, Bunkyo-Ku, Tokyo 113.

T. HAGA, Associate Professor, College of General Education, Several interdisciplinary courses such as : "Modernization of Japan in the perspective of the World History", "concepts of Nature in Contemporary Science".
A.

T. INOUYE, Professor, Department of Urban Engineering, Faculty of Engineering. "Urban Engineering".
B. C. E.

H. KIHARA, Dean of the Faculty of Engineering. "Nuclear Science and Engineering" (engineering, science, medicine, agriculture).
B. C.

K. MIYASAWA, Professor. "Liaison Committee for Statistics" (mathematical statistics, economic statistics, business economics, design of experiment, computer theory, etc...).
A. B. C. D. E.

M. OSHIMA, Professor, Institute of Medical Electronics. Faculty of Medicine. "Bio-medical engineering, Human factors" (medicine, engineering).
B. D. E.

S. OMORI, Chairman, Department of Liberal Arts, "American Area Studies", "English Area Studies", "International Relations", etc.
A.

"Department of Pure and Applied Sciences" : (applied mathematics, solid state physics, theoretical physics, physical chemistry, molecular biology).

NETHERLANDS

J.H. KRITETEMEYER, Professor of Naval Architecture, University of Technology, Julianalaan 134, Delft. "Port of Scheveningen and traffic to Great Yarmouth" (naval architecture, civil engineering, mechanical engineering, economics of transport).
C.

Catholic University of Nijmegen, Heyendael, Nijmegen.

J. AARTS, Director of the Center for Research on Higher Education. "Integrated curriculum in the social sciences", "curriculum change in medicine".

A. MERTENS, Professor of Social Medicine. "Social medicine" (medicine sociology, psychology, law).
B. D. E.

J.A.M. GEUSAU, Professor and Director of the J.F. Kennedy Institute University of Tilburg, Hogeschoollaan 225, Tilburg. International studies : several seminars such as "'science, technology and public policy", "international organisations" (economics, law, sociology, engineering).
B. E.

J. LYKLEMA, Professor of Physical and Colloid Chemistry Agricultural University, Salverdaplein 10, Wageningen. "Molecular sciences" (chemistry, physics, biology, agricultural science).
B. C. D.

SWEDEN

R. KÜLLER, Assistant Researcher, Lund Institute of Technology. Fach 725 220 07. Lund 7. "Perception of Human environment" (architecture, interior design, Landscape design, psychology). D. E.

TURKEY

Hacettepe University, Ankara.

I. DOGRAMACI, Professor, President of the University, Faculty of Medicine, "Medical education" (basic medical sciences, clinical medical sciences). B. C. D. E.

S. ERTURK, associate professor of Education "'Thinking unit" (psychology, sociology, economy, social work, data processing, education). E.

B. GÜVENC, Director of the Institute of Social sciences "Seminar on changes in the contemporary Turkish culture" (social anthropology, sociology, economy, education, psychology, demography, ethnography, social work, philosophy). B. C.

Egee University. Bornova. Izmir.

T. BIRSEL, Professeur de droit à la faculté des Sciences économiques et commerciales, "pluridisciplinary teaching of economics and business science". B. E.

K. KARHAN, Doyen de la Faculté Polytechnique. "Training of mechanical engineers" (statics, dynamics, elasticity, resistance, fluid mechanics, mathematics). Projected : "training of industrial engineers". B. C. D. E.

H. OLALI, Professeur, faculté des Sciences Economiques et commerciales, "Tourism and business economics" (business economics, political economy and applied economics, statistics and mathematics, public relations, accounting, public finance, business law, tourism). B. E.

UNITED KINGDOM

J. COVENEY, Professor, Head of Modern Languages School, University of Bath, Claverton Down, Bath, Somerset, "B.Sc. in engineering with French" (engineering, French). A. B.

J. VAN REST, Senior Research Fellow, University of Aston in Birmingham, Birmingham 4. "Interdisciplinary Higher Degrees Scheme" — Diverse activities (operational research — technology and sciences inlcuding social science — communication theory and practice). B.

M. GANE, Director, Project Planning Centre, Bradford University, Bradford 7, York. "Project planning" (economics, operational research, management, engineering, agriculture, forestry, etc...). B. D. E.

University of Cambridge, Cambridge.

J.A. BARNES, Professor of Scociology, "Social and political sciences" (sociology, social anthropology, social psychology, political science).

B.

J.W.L. BEAMENT, Professor of Applied Biology and Chairman of Faculty "Biology of Cells" "Biology of Organisms" "Biology of Environment" (botany, zoology, genetics, biochemistry, ecology, soil sciences).

B.

University of Exeter, Devon.

McGLASHEN, Professor, Chairman of the Board of Studies for Interfaculty degrees, "inter-faculty degree in science and social studies" (*physics* with economics or economic history or sociology or politics ; *chemistry* with economics or economic history or sociology or politics).

B.

M.D.D. NEWITT, lecturer in History, "inter-faculty degrees in European Studies" (English, French or German, History, Philosophy of Science, Biology or geology, law, music, theology).

A.

University of Lancaster, Bailrigg, Lancaster.

G. GREGORY, Director of Studies in Business Analysis, "M.A. course in business Analysis" (mathematics, economics, computer studies, operational research, financial control, systems engineering, marketing, behaviour in organisations).

B.

H.J. PERKIN, Professor of Social History. "First year course" (three cognate subjects from complete range — pluridisciplinary). "Second and third year course" (three cognate subjects from complete range).

A. B.

J. BURNETT, Reader, Brunel University, Kingtson Lane, Uxbridge, Middlesex, "Combined honours degree in social sciences" (economics, history, law, psychology, sociology, statistics, methodology).

A. B.

LONDON

J.C. ANDERSON, professor of Electrical Materials, Imperial college university of London S.W.7. "Science of materials" (physics, chemistry, metallurgy, electrical engineering, chemical engineering).

A. B. C.

A. ATMORE, Secretary, university of London Centre of International and Area Studies, London W.C.1. "M.A. in Area Studies" (Africa, Middle Eeast, South Asia, South East Asia, Far East, Latin America, United States, Commonwealth, East European) (anthropology, archeology, art and archeology, economic history, economic, education, geography, history, international relations, language and literature, law, music, politics, religious studies, sociology).

A. C.

W.A. HOLMES-WALKER, Professor, Head of School of materials science and Technology, Brunel, Acton, London W.3. "Materials Science and Technology" (materials science, polyester science and technology, metallurgy).

B. C. D. E.

H.H. ROSENBROCK, Professor, University of Manchester, Institute of Science and Technology, Sachville Street, Manchester. Control system centre. « control engineering » (electrical, mechanical and chemical engineering, maths, control).

B. C. E.

University of Salford, Peel Park, Salford M5 4WT.

L. DAVIES, Course Senior Tutor, « Honours Degree in applied chemistry » (chemistry, physics, maths, statistics, computing, English, chemical engineering, instrumental techniques, social psychology, industrial management, administration and economics, Russian).
B.

M.B. GLEAVE, lecturer in geography. M. SC. in Urban Studies » (geography, sociology, economics, politics, civil engineering, statistics).
B. C.

J. HALLING, Professor, « Tribology » (mathematics, physics, chemistry, material Science, Engineering).
B. C. D. E.

A.W. SOMERVILLE, course Tutor, « Joint Honours Course » (two or three subjects taken from a list, including chemistry, physics, mathematics, economics, physiology, etc...).
B.

University of Sussex, Falmer, Brighton, Sussex.

M.R. ERAUT, course Director, « Diploma in Educational Technology » (curriculum theory, psychology, philosophy, sociology, communication theory, system analysis, information).
B.

R. PRYCE, Director, Centre for Contemporary European Studies. « Contemporary European Studies » (economics, politics, international relations, sociology, history).
A. C. D.

K. SMITH, professor, chairman of the Organising Committee, « structure and properties of Matter » (physics, chemistry, materials science, biology).
A.

A.K. THOLNBY, professor of Comparative literature, « the Modern Européan Mind » (literature, philosophy, intellectual history, political thought, sociology, creative arts, religious studies).
A.

D. WINCH, dean of Social Studies, « concepts, methods, values in the social sciences » (history, philosophy, economics, sociology, social psychology, political science, geography, social anthropology, international relations, mathematics).
A.

J.M. PARGETER, Secretary to the Subject-Object Seminar group, University of Sheffield, Wester, Bank, Sheffield 5102 TN. « Subject-Object Seminar Group » (sociology, economics, physics, statistics, pure mathematics, philosophy, modern languages, psychology).
A. D.

University of Edinburgh, Old College, South Bridge, Edinburgh.

J.T. COPPOLIC, Convener, Centre of African Studies, « African studies » (history, geography, social anthropology, politics, islamic studies, economics, social medicine).
A. C.

D. EDGE, Director, Science Studies Unit, « Social aspects of science and technology » (sociology, philosophy, social history, psychology, theology, political theory).
A. B. C. D. E.

J. MacQUEEN, professor and director, « School of Scottish Studies », (literature, folk-tale, folk-song and ballad, ethno-musicology, material culture, social organisation, custom and belief, onomastics).

A. C. D.

University of Stirling, Stirling.

R. BRADBURY, professor, chairman of the Board of Studies for technological economics, « technological Economics » (management economics, science : chemistry, biology, physics or integrated science mathematics ; industrial science, including management science, operational research and systems engineering).

B. E.

A.C. CHITNIS, Lecturer in History, « Early Victorian Society and literature » (history, English).

A.

University College of Wales, Aberystwyth, Wales.

B.M. JONES, Head of Department of Zoology, « Biological sciences » (botany, biochemistry, genetics, chemistry, zoology, philosophy, geography, geology).

A. B. C. D. E.

J.A. TAYLOR, Senior lecturer in geography, « joint degree schemes » (geography-geology ; economic and social studies)
« ecology discussion group » (biology, geography, geology, agriculture), « Area studies » « Welsh Soil Discussion Group », etc.

G.S. KILPATRICK. Dean of clinical studies, Welsh National School of Medicine, 34, Newport Road, Cardiff, Wales. « Medicine and Dentistry » (medical dentistry).

B. C. E.

University of Wales, Institute of Science and Technology, Catways Park, Cardiff CK1 3 AE.

A.D. COUPER, professor, « Maritime studies » (navigation, mathematics, oceanography, economics, law, management, liberal studies, etc...)

B.

H. JONES, senior lecturer, « industrial economics » (economics, accounting and costing statistics, operation research, mathematics, engineering, ergonomics).

A.

K.A. MARKHAM, lecturer, "Occupational Psychology" (physiology, experimental design and statistics, logic, psychology, ergonomics, personnel selection and vocational guidance studies, electronics, law, economics).

USA

State of California.

D.J. PIVAR, associate professor of History, California State College, 800 North State College, Blvd. Fullerton, California 92631 "American Studies Program" (humanities and Social Sciences).

A.

B.C. KLUSS, Director of Special Programs, California State College 6101 East Seventh Street, Long Beach. Many interdisciplinary programs such as "Asian studies", (history, comparative literature, political science, art, anthropology, geography, sanskrit-pali, hindi, philosophy, economics) "General Honours Program" (16 disciplines : photography, history, micro-biology, comparative literature).

A. B. C. D. E.

M. RAZA, Director of the international Affairs Center, Sacramento State College, 6000 Jay Street, Sacramento. California 95819. "International affairs" (history, economics, political science, psychology, sociology and business administration).

U. WHITAKER, Dean of Undergraduate Studies, San Francisco State College, 1600 Holloway, San Francisco, California 94132. "General education". Forty units, all disciplines. For example "ecology course".

A.

C.J. DIRKSEN, Dean, graduate School of Business, University of Santa Clara, Santa Clara, California 95053. "Interdisciplinary courses on the decision making process" (sociology, psychology, quantitative and business).

B. C.

C.J. HAND, Associate Dean, College of the Pacific, University of the Pacific, Stockton, California 95204. "Information and imagination: a programm of disciplines synthesis" (courses joined by a common concern, for example, environmental use given by an biologist, an historian, an economist).

A.

J.S. BATHLE, chairman, division of Social science Stanislaus State College, 800 Monte Vista, Dr Turlock, California. "Interdisciplinary seminar ; social sciences" (sociology, geography, economics, history, psychology, anthropology, political science(.

A. B.

A.C. HURST, director, Ethnic Studies, Stanislaus State College, 800 Monte Vista dr. Turlock, California, "ethnic studies : some interdisciplinary courses, such as "afro-american studies" (history, sociology, political science, English, education, music).

A.

State of New York.

W. LOWEN, Dean, School of Advanced Technology, State University of New York, Binghamton, New York 13901. Many interdisciplinary programs such as "computer systems program" "center for integrative studies" "modeling in social systems" "man and technology" (mathematics, engineering, physics, geology, geography, philosophy, sociology, anthropology, political science, management science, music).

A. B.

A.J. BRONSTEIN, professor, department of Speech, Herbert H. Lehman College of the City University of New York, Bedford Park Blvd. W. Bronx, New York 10468. "Interdepartmental program in Linguistics" (speech, English, anthropology, mathematics, philosophy).

A.

M. STUART, professor of Classical and Oriental Languages, Herbert H. Lehman College of the City University of New York, Belford Park Blvd. W. Bronx, New York 10468". "Interdepartmental world classics" (Hebrew, Greek, Latin, Italian in translation).

A.

H. WASSER, Professor of English and Dean of Faculties, Richmond College of City University of New York, 130 Stuyvesant Place, New York N.Y. 10301. "Integrated studies program : courses on Arts (sociology, psychology, anthropology, economics, political science, humanities, philosophy).

A.

and

"American studies" (history, literature, philosophy, music, atr, political sciences, economics and sociology).

A.

State of Pennsylvania.

G. BECK, Director Center for international studies, University of Pittsburgh, Pittsburgh, Pennsylvania 15213. (all social sciences, education, engineering, all professional schools).

A. B. C. D.

R.C. BRICTSON, Director of Research Programs, Program development and Public Affairs, University of Pittsburg, Pittsburg, Pennsylvania 15213, "university, urban interface program" (sociology, social work, education ; political science, public administration, planning).

E.

H.E. HOEKSCHER, Director, Space Research Co-ordination Center, University of Pittsburg, Pittsburg, PA 15213. "Space research" (sciences, engineering).

E.

State of Texas.

T.W. NUCKOLS, acting director of Basic Studies, Austin College, Sherman, Texas - 75090. "Basic Studies Development of Western Civilization" and "Contemporary Social problems" (arts, social sciences, natural sciences).

A.

A set of interviews in depth not really constituting replies to the questionnaire were obtained from Harvard University, M.I.T. and Antioch College. The following persons were interviewed :

Antioch College :

Dr. James DIXON - President.
Dr. William PARENTE - Dean, Administration.
Professor Howard SWANN - Physical Science.
Professor Jadine SURRETTE - Instructional Systems.
Professor Martin EVENS - Extramural.
Professor Mary FERGUSON - International Education.
Professor James JORDAN - Humanities.
Professor Frank WONG - Humanities.
Professor William JOHN - Social Science.

Harvard University :

Professor James BAUGHMAN - Harvard Business School.
Dr. Jerome BRUNER - Professor, Psychology.
Dr. Lawrence FOURAKER - Dean, Harvard Business School.
Dr. Maurice KILBRIDGE - Dean, Design School.
Dr. George LOMBARD - Assoc. Dean, Harvard Business School.
Professor Howard RAIFFA - Decision Theory.
Dr. Richard ROWE - Assoc. Dean, Clinical Psychology and Public Practice.
Dr. Theodore SIZER - Dean, School of Education.
Dr. Krister STENDAHL - Dean, Divinity School.
Dr. Harrison WHITE - Chairman, Social Relations Department.
Professor Adam YARMOLINSKY - Law School.

MIT :

Professor Robert FANO - Project MAC.
Dr. Peter GIL - Dean, Sloan School of Management.
Dr. John D.C. LITTLE - Director, OR Center.
Dr. Charles MILLER - Director, Urbans Systems Laboratory.

Appendix 3

LIST OF PARTICIPANTS

NATIONAL DELEGATES

AUSTRIA

Dr. W. CLEMENT*
Professor of Economics
University of Innsbruck, Innrain 52, Innsbruck

BELGIUM

Pr. Dr. L. APOSTEL*
Chaire de Logique et Théorie de la Connaissance
Faculté des Lettres, Université de Gand
Blandijnberg 2, Ghent

Pr. J. DEVOOGHT*
Université Libre de Bruxelles
5 Avenue Franklin Roosevelt, Bruxelles

CANADA

Dr. M. L'ABBE
Vice-Recteur
Université de Montréal, Montréal

Dr. M. CHAGNON
Vice-Recteur
Université d'Ottawa, Ottawa

DENMARK

Pr. T.A. BAK
Faculty of Mathematics and Natural Science
University of Copenhagen, Frue Plads, Copenhagen K

Pr. I. BALSLEV
University of Odense
Hjallesevej 230, 5000 Odense

N.B.:
* Those persons whose names are followed by an asterisk contributed to the preparation of the Seminar by writing papers on the problem of interdisciplinarity in one of the following fields: general education, professional education, research, relationships between teaching and research.

** Those persons whose names are followed by two asterisks were members of the Steering Group for the preparation of this Seminar.

FINLAND

Pr. H.G. GYLLENBERG*
Professor in Microbiology - Department of Microbiology
University of Helsinki, Helsinki 71

Pr. S. PIHA*
Professor of Biochemistry
Vice-Rector of the University of Oulu, Oulu

FRANCE

Pr. A. ARAGNOL
Doyen du Centre Universitaire de Marseille-Luminy
70 Route Léon Lachamp (9e), 13 - Marseille

Pr. R. BENOIT*
Maître de Conférences, Directeur du Centre d'Etudes
Supérieures de l'Aménagement
Parc Grand'Mont, 37 - Tours

Pr. J. CABOT*
Président de l'Université de Paris-Vincennes (Paris VIII)
Paris 12e

Pr. D. CHEVROLET*
Sciences du Comportement et de l'Environnement
Université de Rennes, Rennes

Pr. A. COTTA
Directeur du 3ème Cycle
Université de Paris-Dauphine (Paris IX)
3 Square de Pologne, Paris 16ème

Dr. J. COURSAGET
Doyen du Centre Universitaire de Paris-Montrouge
1 rue Maurice Arnoux, 92 - Montrouge

Pr. DISCHAMPS
Doyen de la Faculté de Droit
Université de Nice, 06 - Nice

Pr. A. LICHNEROWICZ**
Professeur au Collège de France
(Chaire de Physique-Mathématiques)
11, Place Marcelin-Berthelot, Paris 5e

GERMANY

Regierungsrat Dr. M. ERHARDT*
Ministry for Education and Science, Bonn

Pr. Dr. H. VON HENTIG**
Centre for pedagogical Research
University of Bielefeld, Bielefeld

Dipl. Hdl. W. KLEIN
Assistent, Language Laboratory
University of Mannheim, Mannheim

Pr. Dr. E.J. MESTMÄCKER

Professor of Law, Centre for Interdisciplinary Research
University of Bielefeld, Bielefeld

Pr. Dr. E. PESTEL

Rector of the Technical University of Hannover
Welfengarten 1, 3 Hannover

Pr. Dr. H. WEINRICH

Professor of Linguistics
University of Bielefeld, Bielefeld

GREECE

Pr. E. BALOPOULOS

Professor of Economics, General Director
Centre of Planning and Economic Research
22 Hippokratous Street, Athens 144

Pr. C. MITRAKOS

University of Athens, Kouponia, Athens 621

IRELAND

Pr. J.N.R. GRAINGER *

Head of the Department of Zoology
University of Dublin, Trinity College, Dublin 2

Pr. P. LYNCH *

Associate Professor of Economics
University College, Dublin

ITALY

Pr. E. BECCHI

Chair of Pedagogy, Faculty of Letters and Philosophy
University of Milan, Milan

JAPAN

Pr. T. MUKAIBO*

Professor of Chemistry, Faculty of Engineering
Special Assistant to the President
University of Tokyo, Tokyo

NORWAY

Mr. K. GISVOLL

Director, University of Trondheim
Utbyggingssekretariatet
P.O. Box 2823, 7001 Trondheim

NETHERLANDS

Pr. Dr. E. VELEMA

Pedagogical Institute, Catholic University of Nijmegen
St. Annastraat 174, Nijmegen

Pr. Dr. P.J. THUNG*

Professor in the Medical Faculty, Dean of Studies,
Medical Faculty, Bureau Medische Faculteit
Wassenaarseweg 62, Leiden

PORTUGAL

Pr. A.J. CORREIA RALHA

Ministry of Education
Praça Pasteur 10-6° Esq°, Lisbon 1

SPAIN

Mr. L. SUAREZ FERNANDEZ
Recteur de l'Université de Valladolid
Valladolid

SWEDEN

Mrs. U. AHGREN-LANGE*
Head of Department
Office of the Chancellor of the Swedish Universities
Universitetskanslersämbetet, Box 16334, 103 26 Stockholm 16

SWITZERLAND

Pr. H.G. PAULI*
Unit of Research in Medical Education, Faculty of Medicine
University of Berne, Berne

TURKEY

Pr. I. DOGRAMACI**
President, University of Hacettepe
Hacettepe, Ankara

Pr. N. TERZIOGLU
Rector, University of Istanbul
Istanbul

UNITED KINGDOM

Pr. A. BRIGGS**
Vice-Chancellor, University of Sussex
Essex House, Falmer, Brighton BN1 9QQ

UNITED STATES

Dr. L. BAGGERLY
Acting Programme Director, College Science Curriculum
Improvement Programme, National Science Foundation
1800 "H" Street, Washington

Dr. L. MEDSKER*
Director, Centre for Research and Development in Higher Education
University of California, Berkeley, California

Pr. E.W. WEIDNER
Chancellor, University of Wisconsin-Green Bay
2309 Bay Settlement Road, Green Bay, Wisconsin 54301

YUGOSLAVIA

Pr. Dr. D. DIMKOVIC*
Rector
University of Novi-Sad, Novi-Sad

EXPERTS

Dr. C.C. ABT**
President, Abt Associates Inc.
5" Wheeler Street, Cambridge, Massachusetts, United States

Pr. B. BARRY
Professor of Government, Department of Government
Unsiversity of Essex, Wivenhoe Park, Colchester, Essex, United Kingdom

G. BERGER
Maître Assistant, Département des Sciences de l'Education
Université de Paris-Vincennes (Paris VIII), France

M.H. BOISOT
Maître de Conférence, Ecole Nationale des Ponts et Chaussées
Professeur au C.U.C.E.S. (Nancy), M.B. - Consult
10 rue de Marignan, Paris 8ᵉ, France

B. GIROD DE L'AIN
Maître de Conférence Associé
Université de Paris-Dauphine (Paris IX)
3, Square de Pologne, Paris 16ᵉ, France

J.G. GODIN
7, rue du Pot de Fer, Paris 5ème, France

Pr. Dr. H. HECKHAUSEN
Psychologisches Institut, Ruhr-Universität Bochum
463 Bochum, Germany

Dr. E. JANTSCH**
Gentzgasse 11, A-1180 Vienna, Austria

C. JEANTET
Assistant de Biologie Moléculaire
Centre Universitaire Marseille-Luminy, France

Pr. G. MICHAUD**
Professeur à l'Université de Paris-Nanterre (Paris X), France
Directeur du Centre d'Etudes et de Civilisation

Mme M. OPPENHEIMER
Comité de Direction de la "Revue de l'Enseignement Supérieur"
173, Boulevard St. Germain, Paris 6ᵉ, France

Pr. J. PIAGET
Faculté des Sciences, Directeur du Centre International d'Epistémologie Génétique, Palais Wilson, Genève, Suisse

Dr. L.H. RUSSWURM
Associate Professor, Deputy Chairman, Department of Geography
University of Waterloo, Waterloo, Ontario, Canada

Dr. B. THWAITES*
Principal of Westfield College, University of London
Hampstead, London N.W.3, United Kingdom

SECRETARIAT
Centre for Educational Research and Innovation, 2, rue André Pascal, Paris 16ᵉ

J.R. GASS**
Director of CERI

P. DUGUET**
CERI

H. NATHAN
CERI

L. CERYCH
D.A.S. (Directorate for Scientific Affairs)

Appendix 4

I

LIST OF BACKGROUND PAPERS

(available at request from OECD-CERI, 2 rue André Pascal, Paris 16°, France)

CERI/HE/CP/69.01	The Interdisciplinary Approach to Higher Education — Main Problems.
CERI/HE/CP/69.04	Note on the Interdisciplinary Concept — Ad hoc Meeting of Experts — Guy MICHAUD (France).
CERI/HE/CP/70.01	First ad hoc meeting of experts held on 8th December, 1969 — Summary of discussion and conclusions.
CERI/HE/CP/70.02	Note on the Interdisciplinary Concept — John WILSON (United Kingdom).
CERI/HE/CP/70.03	Preparation of the Seminar on Interdisciplinary Teaching in Higher Education — Guy MICHAUD (France).
CERI/HE/CP/70.05	Note on Disciplinarity and Interdisciplinarity — Heinz HECKHAUSEN (Germany).
CERI/HE/CP/70.08	Integrative planning for the "Joint Systems" of Society and Technologie — The emerging role of the University — Erich JANTSCH (Austria).
CERI/HE/CP/70.09	Questionnaire — Survey on Interdisciplinary Teaching and Research in Universities.
CERI/HE/CP/70.10	Major themes for consideration at Seminar on Pluri-Interdisciplinarity in Universities.
CERI/HE/CP/70.11	Model for a Pre-University College (17-21) with compulsory Integrated Interdisciplinary courses.
CERI/HE/CP/70.12	
CERI/HE/CP/70.13	The Epistemologiy of Interdisciplinary Relationships — Jean PIAGET (Suisse).
CERI/HE/CP/70.16	Towards Inter-Transdisciplinarity in Education and Innovation — Erich JANTSCH (Austria).
CERI/HE/CP/70.18	University oriented towards integration in medical and health science programmes — Ihsan DOGRAMACI (Turkey).
CERI/HE/CP/70.19	One descriptive and one ideal model and implications for university organization for general, professional and lifelong education and researck — Clarck C. ABT (United States).
CERI/HE/CP/70.20	Interdisciplinarity at the Centre Universitaire Paris-Dauphine — Hervé HAMON (France).
CERI/HE/CP/70.21	Analyses of the Survey of Interdisciplinary activities of teaching and research in American Universities — Clark C. ABT (United States).

CERI/HE/CP/70.22	Example of a theoretical model of an interdisciplinary university oriented towards environmental problems — Jean-Luc MICHAUD and Michel PAOLETTI (France).
CERI/HE/CP/70.23	Mathematic and Transdisciplinarity — André LICHNEROWICS (France).
CERI/HE/CP/70.26	The University of Wisconsin — Green Bay (USA): an example of a university oriented towards environmental problems — Edward W. WEIDNER (United States).
CERI/HE/CP/70.27	The Problem of Pluridisciplinarity — Leo APOSTEL (Belgium).
CERI/HE/CP/70.28	Report on the working groups (Nice Seminar).
CERI/HE/CP/70.29	Discipline, Interdisciplinarity and Interdisciplinary Programme — Marcel BOISOT (France).
CERI/HE/CP/70.30	Survey of interdisciplinary activities of teaching and research in universities (first analysis of the questionnaire) — J. Guy GODIN (France).
CERI/378.1	Proposals of the recommandations (Nice Seminar).

II

LIST OF NOTES PROVIDED BY SOME PARTICIPANTS AT THE NICE SEMINAR

FROM THE CATALOGUE

Books published by the Centre for Educational Research and Innovation (CERI) :

EDUCATIONAL TECHNOLOGY
The Design and Implementation of Learning Systems
(July 1971)
88 pages £ 0.92 $ 2.75 F 12,00 Sw. fr. 10,50 DM 8.40

COMPUTER SCIENCES IN SECONDARY EDUCATION
(July 1971)
242 pages £ 1.90 $ 5.50 F 25,00 Sw. fr. 21,50 DM 17.00

EQUAL EDUCATIONAL OPPORTUNITY
1. A Statement of the problem with special reference to recurrent education
(February 1971)
48 pages £ 0.47 $ 1.50 F 6,00 Sw. fr. 5,50 DM 4.20

THE MANAGEMENT OF INNOVATION IN EDUCATION
Report on a workshop held at St. John's College, Cambridge, UK
(February 1971)
68 pages £ 0.62 $ 1.75 F 8,00 Sw. fr. 7,00 DM 5.60

⁂

EDUCATIONAL POLICIES FOR THE 1970'S
General Report. Conference on Policies for Educational Growth,
Paris 3rd-5th June 1970 (August 1971)
158 pages £ 1.45 $ 4.25 F 19,00 Sw. fr. 16,50 DM 13.00

DEVELOPMENT OF HIGHER EDUCATION, 1950-1967
Analytical Report
(January 1972)
272 pages £ 1.75 $ 5.00 F 23,00 Sw. fr. 20,00 DM 15.60

DEVEOPMENT OF HIGHER EDUCATION, 1950-1967. Statististical Survey
DEVELOPPEMENT DE L'ENSEIGNEMENT SUPERIEUR, 1950-1967. Statistiques par pays
(November 1970)
860 pages bilingual £ 6.30 $ 18.00 F 84,00 Sw. fr. 67,00 DM 56.00

OCCUPATIONAL AND EDUCATIONAL STRUCTURES OF THE LABOUR FORCE AND LEVELS OF ECONOMIC DEVELOPMENT
Possibilities and limitations of an international comparison approach
(November 1970)
322 pages £ 2.15 $ 6.25 F 28,00 Sw. fr. 24,00 DM 18.80

OCCUPATIONAL AND EDUCATIONAL STRUCTURES OF THE LABOUR FORCE AND LEVELS OF ECONOMIC DEVELOPMENT
Further analyses and statistical data
(March 1971)
128 pages £ 1.05 $ 3.00 F 14,00 Sw. fr. 12,50 DM 9.80

« Technical Reports » :
DEMOGRAPHIC ACCOUNTING AND MODEL-BUILDING
by Richard Stone
(March 1971)
128 pages £ 1.30 $ 3.75 F 17,00 Sw. fr. 15,00 DM 11.70

OECD CATALOGUE OF PUBLICATIONS AND SUPPLEMENTS : free on request.

OECD SALES AGENTS
DÉPOSITAIRES DES PUBLICATIONS DE L'OCDE

ARGENTINE
Libreria de las Naciones
Alsina 500, BUENOS AIRES.
AUSTRALIA - AUSTRALIE
B.C.N. Agencies Pty, Ltd.,
178, Collins Street, MELBOURNE 3000.
AUSTRIA - AUTRICHE
Gerold and Co., Graben 31, WIEN 1.
Sub-Agent: GRAZ: Buchhandlung Jos. A. Kienreich, reich, Sackstrasse 6.
BELGIUM - BELGIQUE
Librairie des Sciences
Coudenberg 76-78, B 1000 BRUXELLES 1.
BRAZIL - BRÉSIL
Mestre Jou S.A., Rua Guaipa 518,
Caixa Postal 24090, 05000 SAO PAULO 10.
Rua Senador Dantas 19 s/205-6, RIO DE JANEIRO GB.
CANADA
Information Canada
OTTAWA.
DENMARK - DANEMARK
Munksgaard Boghandel, Ltd., Nörregade 6
KOBENHAVN K.
FINLAND - FINLANDE
Akateeminen Kirjakauppa, Keskuskatu 2,
HELSINKI.
FORMOSA - FORMOSE
Books and Scientific Supplies. Services,, Ltd.
P.O.B. 83, TAIPEI,
TAIWAN.
FRANCE
Bureau des Publications de l'OCDE
2 rue André-Pascal, F 75 PARIS 16e
Principaux sous-dépositaires :
75 PARIS : Presses Universitaires de France,
49 bd Saint-Michel, 5e
Sciences Politiques (Lib.). 30 rue Saint-Guillaume, 7e
13 AIX-EN-PROVENCE : Librairie de l'Université.
38 GRENOBLE : Arthaud.
67 STRASBOURG : Berger-Levrault.
31 TOULOUSE : Privat.
GERMANY - ALLEMAGNE
Deutscher Bundes-Verlag G.m.b.H.
Postfach 9380, 53 BONN.
Sub-Agents : BERLIN 62 : Elwert & Meurer.
HAMBURG : Reuter-Klöckner; und in den massgebenden Buchhandlungen Deutschlands.
GREECE - GRÈCE
Librairie Kauffmann, 28 rue du Stade,
ATHÈNES 132.
Librairie Internationale Jean Mihalopoulos et Fils
75 rue Hermou, B.P. 73, THESSALONIKI.
ICELAND - ISLANDE
Snæbjörn Jónsson and Co., h.f., Hafnarstræti 9,
P.O.B. 1131, REYKJAVIK.
INDIA - INDE
Oxford Book and Stationery Co. :
NEW DELHI, Scindia House.
CALCUTTA, 17 Park Street.
IRELAND - IRLANDE
Eason and Son, 40 Lower O'Connell Street,
P.O.B. 42, DUBLIN 1.
ISRAEL
Emanuel Brown :
9, Shlomzion Hamalka Street, JERUSALEM.
35 Allenby Road, and 48 Nahlath Benjamin St.,
TEL-AVIV.
ITALY - ITALIE
Libreria Commissionaria Sansoni :
Via Lamarmora 45, 50 121 FIRENZE.
Sous-dépositaires :
Editrice e Libreria Herder,
Piazza Montecitorio 121, 00 186 ROMA.
Libreria Rizzoli, Largo Chigi 15, 00 187 ROMA.
Libreria Hoepli, Via Hoepli 5, 20 121 MILANO.
Libreria Lattes, Via Garibaldi 3, 10 122 TORINO
La diffusione delle edizioni OCDE è inoltre assicurata dalle migliori librerie nelle città più importanti.
JAPAN - JAPON
Maruzen Company Ltd.,
6 Tori-Nichome Nihonbashi, TOKYO 103,
P.O.B. 5050, Tokyo International 100-31.
LEBANON - LIBAN
Redico
Immeuble Edison, Rue Bliss, B.P. 5641
BEYROUTH.
MALTA - MALTE
Labour Book Shop, Workers' Memorial Building,
Old Bakery Street, VALETTA.
THE NETHERLANDS - PAYS-BAS
W.P. Van Stockum
Buitenhof 36, DEN HAAG.
Sub-Agents : AMSTERDAM C : Scheltema and Holkema, N.V., Rokin 74-76. ROTTERDAM : De Wester Boekhandel, Nieuwe Binnenweg 331.
NEW ZEALAND - NOUVELLE-ZÉLANDE
Government Printing Office,
Mulgrave Street (Private Bag), WELLINGTON
and Government Bookshops at
AUCKLAND (P.O.B. 5344)
CHRISTCHURCH (P.O.B. 1721)
HAMILTON (P.O.B. 857)
DUNEDIN (P.O.B. 1104).
NORWAY - NORVÈGE
Johan Grundt Tanums Bokhandel,
Karl Johansgate 41/43, OSLO 1.
PAKISTAN
Mirza Book Agency, 65 Shahrah Quaid-E-Azam,
LAHORE 3.
PORTUGAL
Livraria Portugal, Rua do Carmo 70, LISBOA.
SPAIN - ESPAGNE
Mundi Prensa, Castelló 37, MADRID 1.
Libreria Bastinos de José Bosch, Pelayo 52,
BARCELONA 1.
SWEDEN - SUÈDE
Fritzes, Kungl. Hovbokhandel,
Fredsgatan 2, STOCKHOLM 16.
SWITZERLAND - SUISSE
Librairie Payot, 6 rue Grenus, 1211 GENEVE 11
et à LAUSANNE, NEUCHATEL, VEVEY, MONTREUX, BERNE, BALE, ZURICH.
TURKEY-TURQUIE
Librairie Hachette, 469 Istiklal Caddesi, Beyoglu,
ISTANBUL et 12 Ziya Gókalp Caddesi, ANKARA.
UNITED KINGDOM - ROYAUME-UNI
H.M. Stationery Office, P.O.B. 569, LONDON S.E.1.
Branches at : EDINBURGH, BIRMINGHAM, BRISTOL, MANCHESTER, CARDIFF, BELFAST.
UNITED STATES OF AMERICA
OECD Publications Center, Suite 1207,
1750 Pennsylvania Ave, N.W.
WASHINGTON, D.C. 20006. Tel. : (202)298-8755.
VENEZUELA
Libreria del Este, Avda. F. Miranda 52,
Edificio Galipan, CARACAS.
YUGOSLAVIA - YOUGOSLAVIE
Jugoslovenska Knjiga, Terazije 27, P.O.B. 36,
BEOGRAD.

Les commandes provenant de pays où l'OCDE n'a pas encore désigné de dépositaire peuvent être adressées à :
OCDE, Bureau des Publications, 2 rue André-Pascal 75 Paris 16e
Orders and inquiries from contries where sales agents have not yet been appointed may be sent to
OECD, Publications Office, 2 rue André-Pascal, 75 Paris 16e

OECD PUBLICATIONS
2, rue André-Pascal, Paris XVI^{e}
No. 29,569. 1972.

PRINTED IN BELGIUM