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COGNITIVE DEVELOPMENT IN RELATION TO SCIENCE EDUCATION

By

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DECLARATION

This thesis has been composed by myself and has not been used in any previous application for a degree. The results presented here were obtained by myself under the supervision of Dr.G.Raper and Dr.P.Screen and all sources of information have been specifically acknowledged by means of reference.

Lesley A. Dunham

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ABBREVIATIONS

AAM	Association of Assistant Mistresses.
'A'Level.	The General Certificate of Education at Advanced Level.
APSSM	Association of Public School Science Masters
ASE	Association of Science Education
BAAS	British Association for the Advancement of Science
CASE	Cognitive Acceleration through Science Education
CSE	Certificate of Secondary Education
DES	Department of Education & Science
DNA	Deoxyribo Nucleic Acid
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
HMSO	His/Her Majesty's Stationary Office
IPAT	Institute of Personality and Ability Testing
JMB	Joint Matriculation Board
NCC	National Curriculum Council
NEA	Northern Examinations Association
NEAB	Northern Examination and Assessment Board
NUJMB	Northern Universities Joint Matriculation Board
'O'Level	The General Certificate of Education at Ordinary Level
RNA	Ribo Nucleic Acid
SEAC	Schools Examination and Assessment Council
SSR	School Science Review
SPSSX	Statistical Packet for Social Sciences
WPSP	Warwick Process Science Project

SUMMARY

Various skills have been considered quintessential to the scientific method. The need for these skills was highlighted by Armstrong at the beginning of the century and continues to be re-iterated to the present day within the criteria of the National Curriculum. Pupils as scientists are expected to make accurate and meaningful observations; record results from experiments formulated to test hypotheses, controlling all the relevant variables except the one under investigation; identify patterns within the results and recognise anomalies; draw valid conclusions from the data collected and extrapolate from the data to predict further results. These criteria were included in the list of thirty-two teacher assessed skills in domains five and six of the Northern Examination Association, NEA, GCSE Biology Syllabus.

This research project endeavoured to test the acquisition of these skills in a large sample of students drawn from a variety of schools in an effort to establish the relative difficulty of the individual skills. The correlation of performance of the skills with a range of factors, including IQ, the influence of gender, school type, and associated subjects they studied was explored. In particular the effect of an exposure to the Warwick Process Science Scheme was investigated to establish whether a transferable long term enhancement resulted. The main body of the research was undertaken on Year ten (4th Year) pupils, the sample being drawn from ten schools of varying types. The work was extended to include both younger and older age groups, to identify the progress made with age in skill acquisition and to investigate whether success in the skills is of predictive value for the final GCSE grades of future 'A' Level achievement.

The results indicated a wide variability in degrees of difficulty of the individual skills and a wide range of performance by individual candidates. Success in the skills correlated very closely with IQ, so to eliminate this effect samples cross-matched for IQ were investigated to establish the effect of other variables. Only the study of the three separate sciences and tuition within a selective school proved to have a significant effect on the outcome. Only skill 30 devising three separate hypotheses to explain a complex set of results, had predictive value for GCSE and none were of value for predicting capital 'A' Level success.

Dedication

To Cayt, Ian and Andrew,

Who spurred me on by encouragement and example .

CHAPTER ONE

INTRODUCTION

A Parallel Consideration Of The Historical Aspects Of Curriculum Development In Science During The Nineteenth And Twentieth Centuries And The Theories Of Cognitive Development That Evolved Over The Same Period.

Introduction to Chapter One.

Chapter one can be divided into two main areas:-

Part 1.1 deals with the historical aspects of curriculum development in Science and examines the theoretical principles relating to Science Education that found acceptance over the last one hundred and fifty years. It also deals with the influences of politics and philosophy relating to the changes in Science Education and the curriculum developments within the education establishment to accommodate the particular requirements in Science Education deemed necessary at that time.

The fluctuation in popularity of General Science as a means of providing a comprehensive science background is considered, as are the changes in both the method of delivery of the science curriculum and its examination and certification.

Section 1.1.6 discusses the extensive changes in Science teaching that were catalysed by the Nuffield Foundation and the development of other Science teaching projects eg., Process Science.

1.1.9 examines the current situation in science in relation to the National Curriculum although the main body of the research work relates to the situation

appertaining to GCSE. The gradual development of Biology as an independent discipline and the education of Girls in the area of the Sciences completes Section 1.1.

Part Two of the introduction, 1.2, relates to Theories of Cognitive Development and their relation to Science Education. The author has attempted to explore the different explanations of learning and intelligence and tests purporting to measure the latter factor, with the objective of selecting a test suitable for this piece of research.

The growth and development of cognitive skills by children is considered in detail with particular reference to Piaget and also drawing on the work of Shayer and Adey 1981 and Rosalind Driver, 1983. The gradual attainment of cognitive skills by individuals and their application to the comprehension of science in the group teaching situation, the norm for the delivery of science education within schools, is discussed. Reference to the Schools Council Science 5-13 Project and its introductory book "With Objectives in Mind" is included, as this scheme endeavoured to organise the topics in science teaching in a sequence that correlated with the individual child's cognitive development.

1.1 The Historical Aspects of Curriculum Developments in Science

1.1.1. Factors influencing Science Education

Over the last 150 years curriculum development in Science has been driven by factors which appear to relate to the current political and economic climates as much as any intrinsic educational or scientific considerations. This is exemplified by an expansion of the scientific education of boys, probably the result of the experience of World War One (Napier Shaw, 1916,) or similarly the development of CSE as a realistic solution to some of the problems exacerbated by the raising of the minimum school leaving age in 1975. Discussion as to who is to be taught what at any one time, has been variously influenced by different pressure groups.

a) Humanists - Council for Humanistic Studies Elected 1916 to protect the interests of the classical, English, Geographical and Modern Language Associations (Jenkins, E.W. 1979, 1);

b) Different religious denominations - The Church of England Moral Welfare Council (Jenkins, E.W. 1979, 2);

c) Universities, - through the public examination boards and University Medical Schools - “- the close association of secondary school biology with medical education”. (Mansell, A.L. 1976,) also. (Jenkins, E.W. 1979, 3);

d) The British Social and Hygiene council 1933 - collaborated with the Local Education Authorities to promote Biological Education;

e) The particular Government of the day - The Conservative Government establishing The National Curriculum. (DES 1991);

f) Other influences including Darwins Origin of Species (Jenkins, E.W., 1979, 4);

g) Direct competition from other disciplines,

(i) the classics - Public School Classics masters were often paid more than their colleagues teaching Science, there were 224 higher certificates in classics awarded by the Oxford and Cambridge Board to pupils from Eton, Winchester, Rugby, Clifton, Cheltenham and Marlborough in 1902 whilst only 29 awards in Science subjects (Nature 1902).

(ii) More recently, humanities has limited the time available for the study of Science. The normal curriculum for secondary school girls omitted Science. This is further addressed on page 42 of this thesis, Scientific Education of Girls.

(iii) The introduction of national curriculum 1988 to 1991. (DES 1991.) resulted in the time allocation for science being reduced in some schools from its former level to allow sufficient time for all the core subjects. However, this will ensure that all pupils will continue to study Science up to the end of the compulsory period of education and will not be able to 'opt out';

h) Other influencing factors:

(i) Historically, the need to produce a fighting force conversant with simple principles of Physics and Chemistry for the Boer War and the First and Second World Wars was the driving influence for the expansion of Physical Science Education (Jenkins, E.W. 1979, 5). The First World War revealed the dependence of the British manufacturing industries on the Scientific and technological expertise of other countries (League for promotion of Science in Education 1916) See also page 16 the development of Science Education.

(ii) The technological expansions of the nineteen twenties in the interwar period and again in the nineteen sixties with the expansion of the space programme increased the demand for a scientific education within the schools.

In 1938 the estimated output of professional scientists and technologists was 5000, by 1960 17,000 (ACSP 1962). This trend highlighted the shortage of an

adequate number of well qualified Science teachers to deliver this Science Education. (Jenkins, E.W. 1979, 6) By 1960 over 60% of 6th Form boys specialised wholly in Science and/or Mathematics. (Edwards, A.D. 1960) as compared to 20.7% of the total of exhibitions and scholarships to the Oxford Colleges between 1906 and 1915. (Jenkins, .E.W. 1979, 7)

(iii) Botanists needed for the systematic classification of new plant species were at a premium during the eras of exploration and also for the initial development of the pharmaceutical industry, the British Pharmaceutical industry underwent a major expansion subsequent to the discovery of the sulpha drugs in 1935 followed by the discovery and isolation of penicillin. (Wilson, D. 1976.). Botany had long been taught as an ancillary to medicine. (Singer, C.A. 1959.)

(iv) The expansion of the study of Biology was linked to Health Education. The low level of health of the general population, the high level of infant mortality (Dyhouse, C. 1880-1920) and the poor physical condition of young men became apparent when conscription for the forces occurred in times of war. When this was followed by the epidemic spread of venereal disease subsequent to the wars, the Government was alerted to the value of Biology as a means of instructing the population in the principles of health and nutrition.

(v) Tropical medicine became an essential discipline as the Empire and the Colonies increased in economic significance necessitating competent biologists. The need to increase food production became apparent during and after the wars which exposed the shortage of competent biologists, as was discussed in correspondence to 'The Times' 1929 (Jenkins, E.W. 1979, 8).

(vi) During the nineteen seventies and eighties developments in pharmacology increased the demand for microbiologists and geneticists whilst

consideration of national and international environmental problems highlighted the need for Ecologists.

(vii) The Science Masters Association (SMA), formally predominantly Public School Masters (APSSM - Association of Public School Science Masters), have throughout the period exerted considerable influence on the content and method of delivery of the Science syllabuses. The first issue of the School Science Review 1919 published information relevant to Science Education and is continuing to do so to the present day.

(viii) An industrial fund for the Advancement of Scientific Education in Schools was established to further the cause of Science education and the Association for Science Education, ASE, evolved from the SMA, and the Association of Women Science Teachers.

From the evidence cited above, and that in future sections, it appears to the author that political events such as war, the raising of the school leaving age, the development of Comprehensive Education and latterly the implementation of the National Curriculum, have been significant contributory factors influencing and directing the evolution of Science Education throughout the School System.

1.1.2 The Development of Science Education from the 1850's to the 1990's

Scientific education during the nineteen thirties to sixties appears to have been delivered principally by didactic methods. Accepted 'Scientific Facts' were presented by the teacher and memorised by the pupils to be regurgitated appropriately for the purpose of examination.

Ramsay's investigation in 1950 (Ramsay, M.P. 1950) concluded that over 40% of teachers required definitions and principles to be precisely worded and learnt by heart, a good deal of time was devoted to dictated notes or copying from the blackboard, this was established from the examination of students note books. The use of practical work was employed to learn content rather than inculcate a Scientific attitude to problems and accounts of experiments were presented in a standard format. In the extreme, prescribed experiments were performed with predetermined correct results. A conclusion was frequently dictated to the whole class as the only acceptable outcome to the experiment. The author's limited experience both as a pupil during the 1950's and teacher interacting with a considerable range of colleagues over a 30 year period, leads her to conclude that this method continues to be used to a greater or lesser extent up to and including the present time, 1992. The current use of the Overhead Projector, reduces copying from the board and provision of duplicated notes reduces the quantity of dictation but still limits the opportunities for open ended learning by the individual. The blame for this situation is frequently attributed to the restricting influence of the Examination Boards (Jenkins, E.W. 1979, 9).

Many bodies committed to curriculum development in Science have sought to tip the balance of the delivery of Science education away from the content lead approach:-

For Example

- i) The Nuffield Foundation Science Teaching Project 1956 funded by money from the Nuffield Foundation bequeathed by Lord Nuffield. (Revised Nuffield Biology 1974)

- ii) The Development of The Warwick University Process Science Project. Project Director, Dr.Peter Screen. Funded by Rank-Xerox. (Introduction to Warwick Process Science 1984)
- iii) The development of GCSE syllabi incorporating a range of skills and processes, throughout the 1980's to 90's. (Northern Examining Association 1991 Syllabus B).
- iv) Presently, the development of the National Curriculum (NCC 1989). Particularly Science Attainment Target One which relates entirely to skills and processes and not content.

All these enterprises endeavoured to promote Scientific techniques, open ended investigation and independent reasoning by pupils as an integral part of Science Education. Many of the objectives of these last four bodies were anteceded almost a century earlier by H.E.Armstrong in his promotion of the Heuristic Method of Science Education. (Jenkins, E.W. 1979, 10).

H.E.Armstrong was a Fellow of the Royal Society and President of the Chemical Section of the British Association. He propounded to the International Conference on Education 1884 (E.W. Jenkins, 1979, 11) the Heuristic Method which aimed to train students in the Scientific Method such that they themselves performed experiments, recorded results and built up a systematic body of knowledge related to their own experience. The pupils were to be put in the position of the original scientist and make their own discoveries. Armstrong insisted that all Scientific education should rest on exact observation and measurement.

At best the Heuristic Method is the art of enabling children to discover for themselves.

A syllabus was prepared based on the Heuristic Method, largely by Armstrong, and produced by the Incorporated Association of Headmasters (Brock, W.H. 1973.) and approved by the Oxford and Cambridge Board. A small nucleus of teachers was trained in the Heuristic Method, by Armstrong at the Central Institution in London. In particular Heller who was a peripatetic Science teacher between 1894 and 1897, became the Senior Organiser and Inspector for Science for the Irish Board of National Education in 1900. Heller's influence was particularly helpful in the dissemination of Armstrong's heuristic method. Several Public Schools eg., St.Dunstans College, Harrow and to a limited extent, Clifton college and later Gresham's, commonly used Heuristic Methods, they were widely used particularly when teaching chemistry to younger pupils. (Jenkins, E.W. 1979, 11)

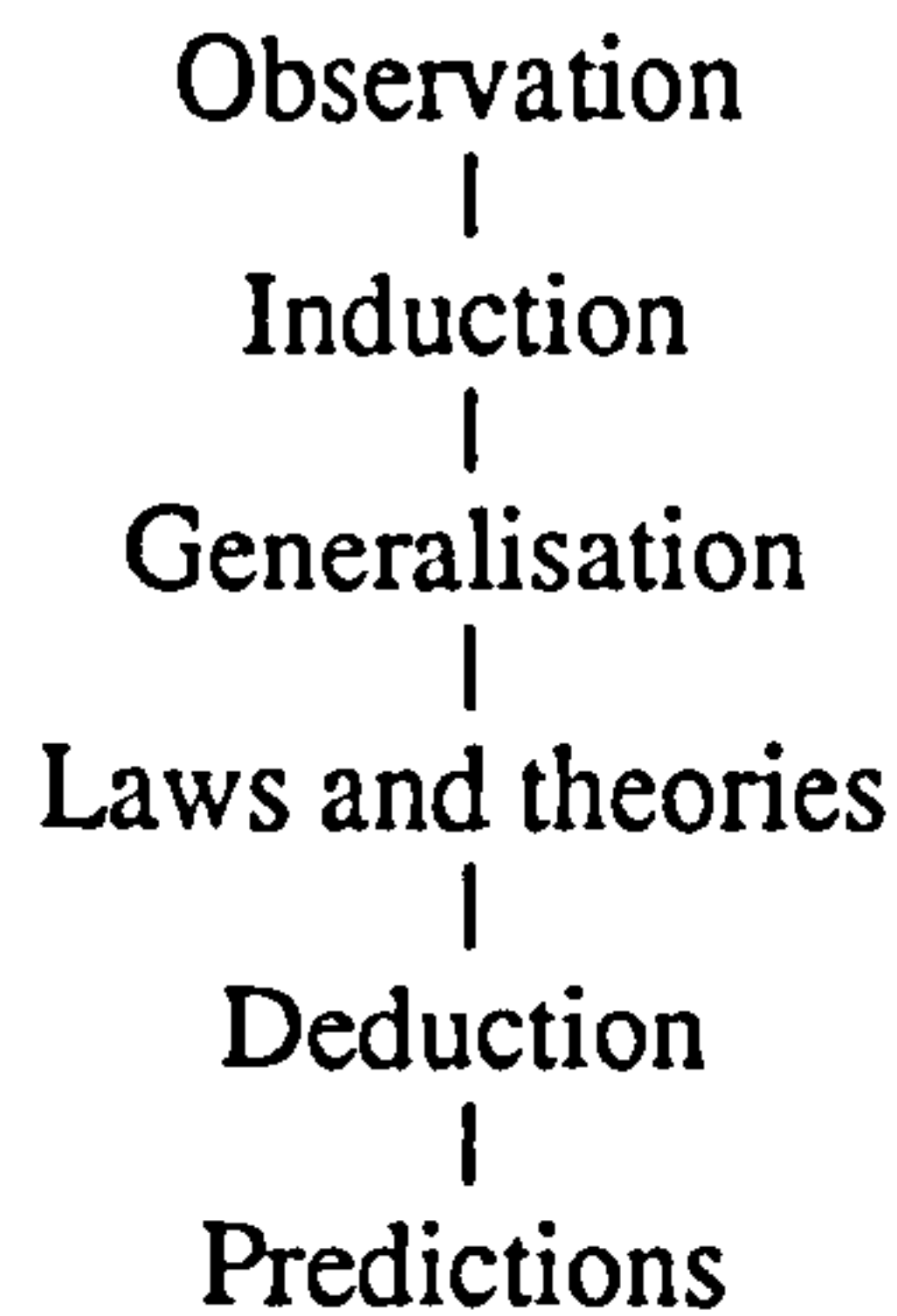
The Heuristic method was subject to criticism as early as 1900, and by 1909 the Board of Education warned against slavish adherence to Heurism stating that the Heuristic method was often misapplied in the hands of inadequate or inexperienced teachers and pupils often could not apply the knowledge and experience acquired in one experiment to other similar situations. (British Association for the Advancement of Science report (BAAS 1908).

In 1918 the Thomson Committee severely criticised the Heuristic Method stating it resulted in narrowness in the Science Curriculum, with schemes of work leading to repetition and teaching grossly insulting to the ages and ability of the students being taught. The Committee concluded that the experimental method of teaching Science had been a failure. (Board of Education Report, 1918, 3)

Armstrong vigorously defended his method, citing inadequate teachers as the method's weakest point, and laying the blame at the door of "Anti heuristic" instruction provided by Teacher Training Colleges favouring the methods of Froebel and Pestalozzi (Armstrong, H.E. 1925,). Froebel, in his 'Education of Man', 1825, stressed the aim of "educating children through their own spontaneous activity". His ideas and those of Pestalozzi place the emphasis on freedom rather than method for a child's optimum cognitive development. The disciples of these two naturalists shared the belief that the prime aim of education was to develop the latent powers of each pupil. Whereas heurism "trained the faculties of thoughtfulness and power of seeing, accuracy of thought of word and of deed" (Armstrong, H.E. 1925, ii) these two Educational theories are scarcely compatible.

Additionally, supporters of the Herbartian scheme (J.F. Herbart, 1776-1841,) favoured the idea that pupils minds should be "fed with a rich repast of historical and biographical ideas" (Hayward, F.H. 1904,) rather than exercised with Scientific method. Further to this, Hayward stated in "Day and Evening School", 1910, that the observations of experimental psychologists indicated - "that accuracy, neatness and observation do not transfer between tasks and neither does 'Scientific Method'." At the Conference of Public School Masters, 1912, more perceptive members of the conference realised that the minutia of the order of teaching topics was less important than the matching of the subject matter and its order of presentation to the maturing intelligence and developing interests of the pupils.

The following sequence denotes processes and their order involved in Scientific reasoning as envisaged by Armstrong:



However, the sequence involved in Scientific Reasoning is called into question in a modern parallel by D.Hodson in the School Science Review, (Hodson, D. 1986). Noting that “Observation is dependent on prior knowledge, knowing what to observe, how to observe it, observing it and describing the observation and in addition accepting or rejecting observations.” Therefore “Observations can be said to be theory dependent” so may be fallible and/or biased. What a Science student observes depends on his prior exposure to theories and his state of ‘readiness’ for the observation. The author finds this concept particularly applicable to observations involving the use of a microscope, when knowing what to look for is the vital prerequisite of a satisfactory outcome. This point of view will be discussed further in the section relating to psychological aspects of learning. (Page 100)

T.H.Huxley quoted in Science and Education’, 1905, had expounded in his statement of 1854 that “Science is nothing but trained and organised common sense”.

Developments at the turn of the century in both Science and philosophy made it impossible to sustain Huxley’s view. (Jenkins, E.W. 1979, 13). The appreciation of complex Scientific Theories eg., Newtonian Mechanics and Einstein’s theory of relativity are simply not explicable in heuristic terms. It is impossible for all

but the most advanced students to comprehend the relevant theories let alone derive them from their own experimental observations. It is extremely difficult to practically demonstrate Newton's assertion:- that a body remains at rest because of the forces acting upon it, the student would observe 'a non-observation', no movement. The Laws of Thermodynamics and the Quantum Theory pose similar difficulties, understanding could not arise from experimental experience.

The developments in Science moved further and further from common sense, as expounded by Huxley 1854, (Jenkins, 1979, 14) into the realms of abstract reasoning, thus eliminating the pupil from the role of discoverer, the objective of Armstrong's Heuristic method.

This Scientific Method, expounded by Armstrong, involving:- Observation, testing hypotheses, thinking logically, verifying provisional ideas and the attitudes of curiosity, willingness to suspend judgement and intellectual honesty, fell into disrepute. The report of the committee appointed by the British Association for the advancement of Science (BAAS, 1917, 2) concluded it was possible to use the Scientific Method only when dealing with Scientific matters contrary to Pearson's opinion, 1892 (Jenkins 1979 14). Armstrong, (1925) continued to vigorously defend his method considering it to be "much more widely applicable than was generally supposed, no subject was mastered until it was reduced to scientific terms. Armstrong considered the method applicable to all other areas of the curriculum and to society in general and the field of politics. Armstrong, a classical organic chemist by training, held a fundamental aversion to the use of theoretical mathematical models to guide and provoke experimental studies, a point of view incompatible with the developing fields of physics ie., quantum theory and thermodynamics.

1.1.3 The Historical Evaluation of Science within the Curriculum

Science as an intellectual activity was long undervalued as compared to Classics. The Thompson committee Report (Board of Education, Thompson Report, 1918.) concluded that “in the public schools, as a whole there had been no general recognition that Science should form an essential part of education”. This attitude unfortunately was transferred to many Grammar Schools who sought to emulate the more socially prestigious Public Schools and remained a cause for criticism during the first two decades of the 20th Century. The view expressed by Huxley in 1854 (Jenkins, E.W. 1979, 15) that Science was organised common sense caused problems for its acceptance as an intellectual activity; the additional outcome of this attitude was that adequate funding was not forthcoming.

Public Schools encouraged the teaching of Classics in preference to Science, actually paying higher salaries to Classics teachers and providing better career prospects 1906-1915. In addition there were more scholarships available at Oxford Colleges for the study of classics, 1008, as compared to 174 in Science.

Figure 1.0

	Scholarships	Exhibitions	Total
Science	115	59	174
Classics	650	358	1008

(Adapted from Jenkins E.W. 1979)

In state schools at the beginning of the twentieth century, the formal education of most pupils was confined to elementary Schools, where the pupils were educated to the statutory school leaving age of thirteen years. The provision of Science was confined to ‘observation’ and nature study lessons, probably the result of the shortage of teachers with a sound knowledge of physical sciences. Payment of fees was normally required in the Secondary Schools where pupils remained after the statutory leaving age, up to and beyond the age of sixteen. By 1907,

Secondary Schools had the requirement to provide 25% of their places free to pupils from State Elementary Schools in order to qualify for State grant aid. Some Secondary Schools, preferred to forego grant aid whilst others saw it as a means of deliverance from financial difficulties. In 1899, the Privy Council on Education decreed that Science should be taught in all elementary schools and grants were paid specific to the subject and the number of pupils involved. This edict resulted in a tenfold increase in the number of departments where elementary Science was taught (Jenkins, E.W. 1979, 16).

Figure 1.1

	1898	1899
Number of departments in elementary schools teaching Science	2,143	21,301

(adapted from E.W.Jenkins , 1979)

The Privy Council specified that Science should be taught by experiment and illustration, rather than description and definition and examined to assess the ideas the pupils had formed from what they had seen. This pronouncement was largely as the result of H.E.Armstrong's influence associated with his activities to promote heurism in Science curriculum development. The 1902 Education Act attempted to divide Secondary schools into two groups, Division A Schools provided a 'thorough Science course' not less than 13 hours per week of Physics, Mathematics, Chemistry, drawing and practical geometry. These schools, 214 in total, obtained special parliamentary funds to establish their Science courses and received further grants dependent on the results of their students, following advanced courses. Division B Schools provided a more limited Science education with a three or four year Science course with nine hours instruction per week. 144 schools were in this category of which 69 were Endowed Grammar Schools who may have been unwilling to adapt their curriculum to qualify for the Division A award.

There was considerable resistance from various sources to this emphasis on the expansion of Science Education in schools and its influence on other curriculum areas. The Chief Inspector of Schools, HMI Buckmaster (Southern Division), stated “that while Science subjects were well taught he could not state this to be the case for English and other literary subjects” (Board of Education, 1902, 4). J.W.Headlam HMI, said, “that due to the encouragement afforded to Science, Greek had almost disappeared from the curriculum and that Latin was seriously threatened”. (A foreshadowing of the current position in the National Curriculum 1991) (Headlam, J.W. 1902.). The Head Masters’ Conference 1903 - claimed that the Board of Education had woken suddenly to the idea that science had been badly taught and stepped in to force the growth of Scientific feeling artificially by the use of increased grants. In 1904, Robert Morant , the Permanent Secretary to the Board of Education promoted his conception of a liberal education firmly in the Public School mode. Category A and B schools ceased to be distinguished, all secondary schools were to provide 7½ hours of Science and Maths per week at least 3 hours to be of science including both practical and theoretical work. This was criticised by the Thomson Committee (Board of Education, 1918,) as giving too little Scientific, practical and quasi ‘vocational’ experience, reflecting the classical literary academic curriculum of the traditional Grammar and Public schools. Chuter Ede criticising the previous level of science provision during a debate on the 1944 Education Act stated, “that the fall in provision was mediated by the proviso that a school could provide special courses for the instruction in at least two branches of science at Advanced Level to suit the special circumstances of the school and the locality.” This opened the way for many girls schools to partially or completely substitute laundry, cookery, housekeeping and household hygiene for science. The status of science diminished with the introduction of Morants 1904 code, as specific subjects no longer qualified for grants and science subjects with defined syllabuses were no longer required. These regulations remained in force up to 1918, the original Division A Schools continued to teach

science to a satisfactory level, whilst other grant aided schools, particularly those most closely allied to the public school image, tolerated rather than accepted and encouraged Science. Notwithstanding this situation, Cambridge University had a greater number of awards in science, for boys from grant aided schools than for any other subject. However, when the Carnegie trust in 1916 provided money for improving and extending opportunities for the study of Science in the Universities of Scotland, it was stated by Frederick Soddy, 1916, "that a bare quarter actually went into Science at Aberdeen, the remainder being diverted to Law, Economics and Languages." (Jenkins, EW, 1979, (17).

However, the experience of the First World War highlighted the widespread ignorance of Scientific knowledge of both officers and men (Shaw, N. 1916,) a former director of the meteorological department and Smithies, a chemical advisor noted that the lack of knowledge of basic meteorology and the information relating to gas , probably resulted in the majority of casualties during gas attacks. A Memorandum to "The Times", 2nd February 1916 stated that people were being destroyed due to their lack of knowledge of basic science. 'A Neglect of Science Committee' was set up which resulted in the establishment of the Thomson Committee in August 1916, chaired by Sir J.J.Thomson, President of the Royal Society, to examine the state of Science Education in Schools and Universities.

The Government already accepted that national interests were suffering from the neglect of science, argument ensued for more time to be available for the teaching of science in the school curriculum, a proposal bitterly contested by the Classics and Humanities lobbies. Richard Gregory chaired the committee set up by the British Association for the Advancement of Science (BAAS) on 'Science For All'. They pleaded the case for Science to be part of general education, unspecialised and without reference to one's prospective occupation or profession and not to be restricted to embryonic engineers, chemists and biologists. The

committee sought criteria to distinguish between things suitable and unsuitable for pupils at different stages of progress. The stages of progress were characterised as motives innate to the minds of children.

The Science Motives were, Wonder, Utility, and Systemisation. The systematising motive only gained dominance with "the full advent of adolescence". (BAAS Report, 1917,) |2|

A further influence, T.P.Nunn, first asserted in 1905 that the interests of children in science exhibited a rhythm corresponding to the rhythm of its history. This affected the sequence in which topics were supposed to be taught. Nunn was the Vice Principal of London Day Training College and then Director of the London Institute of Education from 1922 to 1936. He wrote extensively about the teaching of Mathematics and Science.

Nunn's ideas constituted a new learning theory. He stated that nature study and astronomy should be taught early to appeal to the "Wonder Motive", Archimedes' principle and the properties of fluids to coincide with interest in movement and ships:-"Utility Motive". He suggested a more humanistic approach, that Science Education should include less of the 'dry bones' and more of the 'spirit' of science.

In practice "The Science For All Movement", resulted in pressure on limited resources necessitating the reduction in the laboratory exercises undertaken.

Nunn's ideas were still accepted by the Spens Committee who drew up the Report of the Consultative Committee on Secondary Education (Board of Education, Spens Report, 1938,)

The Secondary Schools Examination Council was established in 1917, inaugurating the first School Certificate in 1918. This required passes in English,

Languages, Maths and Science. The Higher School Certificate selected subjects from only one group classics, modern studies or maths and science.

The Association of Public School Science Masters (APSSM, later to be called the Science Masters' Association - male only until 1967) produced the School Science Review and proposed the provision of science for all boys in secondary schools to include 5 hours tuition and one hours preparation per week, to include practical work and illustrated lectures.

1.1.4 The Development of General Science

In an effort to provide an adequate background for 'All' in Science whilst working within the time constraints of the entire curriculum, a General Science syllabus was devised to satisfy the science requirements of the School Certificate. This was envisaged as the sequel to the General Science frequently taught to eleven, twelve and thirteen year olds, and as a prelude to post certificate specialisation. Oxford and Cambridge Joint Board in 1921 were the first to ratify such a syllabus, which included Physics, Chemistry, Biology, Astrology, Geology and Meteorology.

However, General Science was not widely taken up, Physics and Chemistry still remained the most popular options. This was illustrated by the distribution of State Scholars in Science in 1926 and 1927.

Table 1.1

	1926	1927
Physics	11	7
Chemistry	19	9
Biology	5	7
Engineering	4	3
Other Science (General)	8	8
Total	47	34
Total Scholarships taken up	225	172

Further evidence of the limited uptake of General Science is provided by an analysis of the subjects followed by Science graduate trainee teachers, only 8 out of a total of 127 studied General Science.

From Jenkins, E.W. 1979

A Committee chaired by Richard Gregory was severely critical of the General Science Examination set by the Oxford and Cambridge Board, stating that "It relied on the recall of facts rather than the comprehension of principles. The questions set were more appropriate to a Physics or Chemistry paper and did not relate to the Science of everyday life." (Board of Education, 1925)

An additional problem was the shortage of teachers competent to teach all areas of the syllabus. There was limited development involving the science curriculum between 1919 and 1930 but then a series of economic crises prevented further development. Physics and Chemistry dominated the Grammar Schools' science teaching, although small inroads were made by General Science in Girls' Schools.

The Secondary Schools Examination Council in its 1932 Report stated that to matriculate students must present themselves either for Elementary Science requiring a time allocation of four lessons of 45 minutes per week or alternatively for Biology, Chemistry and Physics separately. This was unrealistic as very little Biology was taught in schools. Up till then a student could matriculate presenting an alternative group three subject, such as Arithmetic or Elementary Mathematics. London County Council in 1933 favoured the requirement of General Science as did W. Mayhew Heller speaking at the British Association meeting of 1932 (BAAS, 1932, 3) An article in Nature (1933 II) deplored the tendency of students to become too specialised too early under the mistaken belief that it was impossible to gain a University Scholarship in Science without the detailed study of Physics and Chemistry prior to the School Certificate Examination.

The Spens Committee of 1938 and the Norwood Committee of 1943 endorsed the proposal of the Science Masters Association, that all secondary school pupils should follow a broad course in Natural Science. Timetable constraints limited

the available time to four periods per week for four years, this time however, was inadequate for the SMA's proposed content. The SMA therefore recommended more teacher demonstration and less pupil participation as a more effective use of the time available.

Doubts were raised, by science specialists, as to the adequacy of General Science as a preparation for Sixth Form Studies; this situation bears an exact parallel with resistance by many specialist science teachers to the National Curriculum as propounded in 1989, where again doubts were raised about integrated science as a foundation for 'A' Level. The Spens Committee maintained its support for General Science and the uptake of Science continued to rise gradually.

Table 1.2.

School Certificate Entries		
	1936	1942
General Science Uptake	4,847	17,817
Physics Uptake	21,676	23,686

Little attention was paid to the teaching of Science to pupils not presenting themselves for School Certificate, consequently data relating to it in very many schools was scarce. To rectify this situation, The Board of Education carried out a detailed investigation:- it was found that most schools were teaching some science, but the time allocation varied enormously from one period to eight periods per week in different schools. The physical sciences dominated, few men being qualified to teach Biology.

1.1.5 Developments in Science Teaching and Examining

The General Certificate of Education, GCE, was initiated in 1951 and included a General Science Syllabus option. However, in the Grammar Schools General

Science was used as an introductory course as preparation for the study of the separate sciences at Ordinary 'O' Level. By 1960 the majority of GCE Boards had withdrawn their General Science Syllabus. Uptake of all three sciences rapidly increased over the next decade particularly Biology (as referred to in Section 1.1.10 of this thesis). GCE was entirely marked and moderated by the examination boards who were and remain independent of each other. Teachers were required to submit an estimate for each pupil for each examination subject.

The development of The Certificate of Secondary Education (CSE) was the outcome of the Beloe report of 1963 and the first examination papers were set in 1965. Unlike the 'O' Level examination there was both a full range of subjects and variety of mode of examination, Mode 1 syllabi entirely produced by the Board. Mode Three syllabi entirely produced by the school concerned but moderated by the Board and Mode 2 intermediate between the two. The Boards contained a very large proportion of practising teachers responsible for the style, marking and moderation of papers. The science examinations included a proportion of teacher assessment eg., 30% for Biology (the Midland Board) but there was considerable variation, some boards provided a practical examination others did not. The 'O' Level boards' teacher assessed component was exceptional although it was incorporated into 'A' Level Science examinations in 1976.

The raising of the school leaving age in 1979 necessitated the development of a suitable examination system to provide academic targets for the 50 to 60% of the population for whom 'O' Level was considered unsuitable. CSE examinations fulfilled this requirement. The learning of vast quantities of scientific facts became less relevant for CSE and to a lesser extent 'O' Level, this development resulted from both ideological and pragmatic considerations.

1.1.6 The development of the Nuffield Movement in Science.

In 1956, the Trustees of the Nuffield foundation, became interested in Science curriculum development stimulated by practising scientists, notably Lord Todd. The Nuffield foundation undertook to provide funds to sponsor curriculum development in science and Professor W.H.Dowdeswell became the organiser of the Biology Project. Teams of gifted science teachers were seconded and suitable courses were devised, the trials and pilot schemes were undertaken and financed by the Nuffield Foundation. The Nuffield movement lead to unparalleled development in teaching methods and learning in science. Syllabi were developed in the three sciences both at Advanced and Ordinary Level and Nuffield Combined Science gained tremendous impetus within the Lower School Curriculum. The aims of the classroom and laboratory were radically revised with the objective of encouraging reasoning and understanding in preference to unquestioning rote learning. Innovation was encouraged and investment was unparalleled. Ongoing discussion enabled the Nuffield Science Project teams to take note of changing views and to correct and change emphasis in the science curriculum, relating it to the prevailing school organisation. The Association of Science Education (ASE) formed in 1963 from the amalgamation of the Association of Women Science Teachers, founded in 1912, and the Secondary School Science Masters Association 1946, provided valuable input from practising teachers working with pupils within the schools. Nuffield Science sought to develop cognitive processes in Science, simultaneously reducing the emphasis on didactic instruction and to develop student initiative. Students were encouraged to participate in the initial organisation of the experiment, to perform the experiment themselves and in the case of the more gifted, extend the experimental objectives. Observations were made, results recorded and logical conclusions could be drawn. An enquiring attitude was fostered using the students' critical faculties to access results and evaluate their validity. The whole

ethos of the Nuffield Movement reflected back to the original objectives of the heuristic method of science teaching, as originally envisaged by H.E. Armstrong at the beginning of the century. The development of Nuffield Science coincided with a large financial input by the Department of Education to promote the evolution of the Comprehensive System for the State Sector of the education System. Buildings, equipment and consumable items were lavishly supplied, greatly facilitating the uptake of Nuffield Science, at least in the lower part of the school. Nuffield Science proved to be an excellent intellectual exercise and significantly raised the level of enthusiasm for the study of science among pupils of a wide range of intellectual ability.

Unfortunately disadvantages later became apparent. With the change in the economic climate, particularly with regards to the Education System, the expense of the Nuffield approach began to restrict its application. The central dogma of Nuffield is that the students' own experimental work should provide the information underpinning the learning process and that additional material should be available to facilitate extended investigations. In the trial schools where 'money was no object' this did not pose a problem, however, in less fortunate schools, Nuffield requirements far exceeded the financial provision for requisitions and shortages of equipment and consumable items hampered the full commitment to Nuffield Science. This statement is derived from the personal experience of the author working in various schools and attending courses over this period although she is unfortunately unable to corroborate the statement with actual financial data. Yet again, time limitation became a serious hindrance to the Nuffield method. The Combined Science Course and the 'O' Level syllabi required a large input of pupil time because of the emphasis on individual collection of data, its collation, explanation and evaluation of results as compared to the previous method of presenting experimental data and the associated principles as a 'fait accompli'. As the emphasis within the schools changed and other curriculum areas successfully competed for more time allocation, time for

the study of science became curtailed and Nuffield Science as originally conceived became less popular. The position of Nuffield 'A' Level Science was never as secure as the 'O' Level and Combined Science. Intellectually the syllabi were highly stimulating, promoting independent Scientific reasoning. However, the public perception, probably unsupported by evidence, was that there was insufficient factual content to provide the basis for specialist University study. Predictably, this was not a problem for the brightest students who were competent to identify and assimilate the additional knowledge for their chosen specialism. The more limited scholars, however, appeared to experience two problems. Some found the intellectual rigour required to achieve success in Nuffield 'A' Levels beyond their capability and the less content based syllabi disadvantaged them in further studies. Both of these difficulties might in fact have been endemic to the candidate rather than to the Nuffield method. At all age levels, whilst the practical work was enjoyed and appreciated, the intellectual challenge of sifting and evaluating results proved unnerving to some of the weaker or less confident candidates. They were unsure as to what was the 'correct' explanation and what they were supposed to 'know'.

The outcome was that the teaching of Nuffield Science in its entirety became uncommon. However, practically all subsequent science teaching schemes, examination syllabi and the style of examination questions incorporate the best of the Nuffield influence. For example; The 'circus' method is used to introduce children to a range of experiences relating to one topic, Pressure, Variety of materials in chemistry and classification of living things in Biology. The structured section of the 'A' Level Joint Matriculation Board JMB Biology paper requires understanding and reasoning related to the practical situation.

The work of the Nuffield foundation provided the spur for future curriculum development in Science.

1.1.7 Development of GCSE

With the steady increase of the state Comprehensive system it became practically and ideologically undesirable to retain the dual examination system, GCE and CSE running in tandem. It was unacceptable to separate pupils within one school and frequently within one class into two categories, those with 'O' Level potential and the rest, deemed to be suitable for the less prestigious CSE. In addition, it was impossible to undertake this screening process with any pretence of accuracy, the candidates occupying the region of separation could quite easily perform totally against expectation when entered for 'O' Level and obtain a fail grade, conversely, other candidates would be right at the top of the CSE range and might have been underestimated. At the beginning of the period when GCE and CSE became available, it was relatively common to double enter large numbers of pupils. This practice ceased to be acceptable because of the expense involved and also the examination load placed on the candidates. To overcome these problems, the GCSE examination system was devised. It combined GCE and CSE and was produced by the co-ordinated efforts of both the University dominated GCE boards and the teacher dominated CSE boards. It was designed as a broad based examination to suit 85% of the school population. To facilitate this, a wide range of lettered grades were awarded. The first three were supposed to maintain the original 'O' Level Standard. During the developmental stages there was a large input from practising teachers and University Departments of Education and the Nuffield ethos involving principles and understanding as opposed to rote learning and regurgitation was retained. Most science syllabi included a significant proportion of teacher assessment eg., 32% by the Northern Examining Association, NEA, assaying both practical and cognitive skills. It is the consideration of these cognitive skills which form the basis of this Thesis. This method of examination was intended to be a complete departure from the previous practice of student assessment. The intention was to produce a positive evaluation of the student's capabilities to fulfil certain criteria rather than to

compare the student with the rest of the examination population of that year on an examination paper standardised against previous years and award a comparative grade ie., the examination was to be criterion referenced rather than norm referenced.

A statement of Aims and Objectives prefacing the various syllabi both for separate Science and Co-ordinated/Integrated Science followed the same general tenure eg.,

Northern Examining Association Co-ordinated Science (Double Award).

Aims:-

To provide thorough, well designed studies of experimental and practical science, a worthwhile educational experience for all candidates whether or not they go beyond this level. In particular, candidates studies should enable them to acquire the understanding and knowledge of the concepts, principles and applications of biology, chemistry and physics and, where appropriate, other related sciences so that they may become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import, recognise the usefulness, and limitations, of the scientific method and appreciate its applicability in other disciplines and in everyday life; be suitably prepared to embark upon certain science - dependent vocational courses and studies up to and including 'A' Level in any of the pure sciences and applied sciences.

To develop abilities and skills that: are relevant to the study and practice of science; are useful in everyday life; encourage safe practice.

To stimulate: curiosity, interest and enjoyment in science and its methods of enquiry; interest in and care for the environment.

To promote an awareness that: the study and practice of science are co-operative and cumulative activities subject to social, economic, technological, ethical and cultural influences and limitations; the application of science may be both beneficial and detrimental to both the individual, the community and the environment; the concepts of science are of a developing and sometimes transient nature.

The criteria for Biology frequently included the promotion of respect for all forms of life. Few would find faults with these worthwhile ideals in theory, although in practice they are not necessarily easy to achieve. In addition to these aims a range of objectives were itemised and although variously stated displayed a common pattern between syllabi; the weighting allowance, which was to be credited to the assessment objectives were equally balanced from syllabus to syllabus. Knowledge and Understanding comprised 45% of the available marks with experimental skills and abilities and associated skills accounting for the other 55%. This allocation was very different from the 'O'Level distribution of marks.

The experimental skills and abilities included the following:

performing experiments

observing and measuring

reporting

finding patterns in result

interpreting results

designing and carrying out investigations to test hypotheses

the associated skills were:

information handling

interpretation and evaluation.

The NEA Biology syllabus, 1988, organised the teacher assessed skills into 32 individual entities which could be assessed separately on a pass or fail basis without intermediate possibilities. The candidates were allowed several opportunities to achieve each skill and so accumulate their mark score for the internally assessed portion of the paper.

A similar but not identical arrangement was used by other examination boards eg., Midlands Examination Group (MEG) but here the same skills were included with a mark range from 1 to 10. A prescribed number of occasions for assessment was required. This second method of assessment closely resembled the procedure used to internally assess 'A'Level practical skills for the Joint Matriculation Board for the syllabus first examined in 1976. The GCSE syllabus came on line in 1986 to be examined in 1988.

The relative advantages of the alternative methods of assessment are open to discussion, the assessment as part of a complete investigation is probably a more realistic reflection of the actual situation for practising scientists and later, in 1991 became the chosen procedure for assessment for the National Curriculum. However, the isolation of different skills to be monitored on a yes/no basis is more easily manageable for the assessor and is possibly of greater diagnostic

value if these processes are going to be specifically taught or of predictive value for the student's future line of study.

It was the assessment of individual cognitive skills as part of the teacher assessed practical component of GCSE that originally interested the author in this line of research. The fact that these abilities were monitored individually by NEA alerted the author to the variable range of complexity of the different attributes, the difficulties involved in predicting successes in the skills for individual students and the retention and potential for cross transfer of the abilities once successfully achieved.

The author elected to investigate the following attributes:-

recognising patterns in results

identifying anomalous results

drawing valid conclusions

identifying an uncontrolled variable and controlling it

formulating hypotheses and devising a suitable plan to test the hypothesis,

In addition, the author tested the ability of students to make predictions on the evidence available from previous data.

These particular skills seemed to embody the basic underlying tenets of scientific reasoning and a student who had mastered these principles should be well suited to pursue scientific study at a higher level.

Discussion in subsequent areas of the thesis involve the interaction of these attributes and their relationship to the age, sex, level of intellectual development and the context in which they are measured. The author became aware of the problems of a system of assessment, that claims to measure a cognitive ability.

Considerable variation in results occurs dependent on the current situation of the student and familiarity of the scientific material with which the student is working.

1.1.8 The Warwick Process Science Project

The Department of Education and Science and the Welsh Office had produced Science 5-16: A Statement of Policy 1985 stating that:-

“The essential characteristics of education in science is that it introduces pupils to the methods of science so that scientific competence can be developed to the full. The courses provided should therefore give pupils at all stages appropriate opportunities to:

- make observations
- select observations relevant to their investigations for further study.
- seek and identify patterns and relate them to patterns perceived earlier.
- design and carry out experiments, including appropriate measurements, to test suggested explanations for the patterns of the observations.
- communicate (verbally, mathematically and graphically) and interpret written and other material.
- handle equipment safely and effectively.
- use their knowledge in conducting investigations
- bring their knowledge to bear in attempting to solve technical problems.”

The Warwick Process Science Project, WPSP, based at the University of Warwick and co-ordinated by Dr.P.A.Screen was established with the sponsorship of Rank Xerox with the expressed objective of establishing and testing such a course of integrated science which would qualify students for a two-subject award at GCSE at the age of 16+.

A team of teachers mainly located in Community and Sixth Form Colleges in Leicestershire, were seconded to write and develop the material for a process-led curriculum. All science disciplines were represented and the teachers concerned contributed considerable experience of the needs of students of a wide range of age and experience.

It was the intention, subject to the availability of funds, of WSPSP “to extend the project to encompass the full age range from 5 to 16 years to provide a recognisable progression that forms a continuum, in accordance with the suggestions of the Statement of Policy of the DES and the Welsh office. (1985) In fact the 5 to 11 year olds section has not as yet (1993) come to fruition.

The process - led science curriculum was in direct contrast to the knowledge - led course followed by the majority of science students during the 60 to 70 years preceding 1985. This stagnation in science education was attributed to the shadow of externally imposed examinations which resulted in the need to teach facts ready for their subsequent recall, rather than processes. The opportunity for a significant reappraisal of the situation was presented by the introduction of new National Criteria for science syllabi by the DES and Welsh Office (1985) with the downgrading of the status of the recall of knowledge:- knowledge and understanding maximum 45% - with skills, processes, application and communication being apportioned the remaining 55%

The explosion of knowledge in science has made the teaching and subsequent recall of facts questionable, the ability to retrieve information from scientific literature and computer search facility is a more valuable tool. The rapid growth and continual updating of scientific theories makes a knowledge - led curriculum less relevant to science education at the end of the twentieth century and presumably in the future.

The Warwick Process Science Project aimed to target in on the 'primary or generic qualities' of science education, the processes' which will be of value when the 'facts' are forgotten or outdated (Screen ,P.A. 1984, 2). The objective was that the processes should be taught and experienced within the context of science. A certain basic knowledge needed to be acquired and the processes simultaneously taught during its acquisition would transfer to additional areas of scientific experience.

The processes were categorised as follows:

observing

classifying

inferring

predicting

controlling variables

hypothesising

The suggestion is that accurate observation enables pupils to draw inferences and classify data, and from this predictions could be made which could be subjected to a 'fair test' ie., with variables controlled, which could result in a hypothesis. This sequence also represents the hierarchical status of the processes. It was envisaged that communication by a whole range of methods, discussion, written accounts, displays of graphs and charts, photographs and video recordings, should be employed. Opportunities for group work were incorporated to enable the students to acquire the ability to become a viable members of a scientific team. Although Process Science encapsulated a great many objectives of considerable educational value, it did not appear to become established in the mainstream of science education. By 1987 schools using all or part of the Warwick Process Science Scheme remained, on the whole, restricted to Leicestershire with a small

extension into Nottinghamshire. On the whole, its use was for the 11,12 and 13 year olds.

The author, however, had the opportunity to test students who had received at least part of their science education by the process-led method to establish whether the processes had resulted in a transferable long term effect on the students' scientific thinking.

1.1.9 The National Curriculum for Science

The Education Reform Act (1988) provided the legal framework for a thorough review, evaluation and modification of the entire curriculum thus enabling the Government, through the auspices of the DES and the Welsh Office, to prescribe the minimum admissible level of content and tuition to which each child must have access in each subject area throughout the compulsory period of education.

The National Curriculum was laid out in considerable detail for all core subjects. Considering science in particular, by August 1991 the Science syllabus DES 1991 had been delineated into 4 different Attainment Targets (ATs) Comprising-
AT1 Scientific Investigation - which contained in essence, the scientific experimental method and mode of reasoning.

AT2 Life and Living Processes - Related to Biological Topics

AT3 Materials and their properties - Chemical, Geological and Meteorological topics.

AT4 Physical Processes - Physics - including astronomy.

The entire school population has been divided for the purposes of teaching and assessment into Key Stages, these key stages apply to all subject areas.

Key Stage 1 pertaining to children aged 5-7 years and relating to A.T. Levels 1-3 in their first years in school.

Key Stage 2 children aged 7-11 up to the end of their Primary School Education and relating to A.T. Levels 2-5.

Key Stage 3 encompassing the first three years of secondary education 11-14, and relating to A.T. Levels 3-7

Key Stage 4 to be the final part of the science education syllabus up to the end of the compulsory period of education 14-16 and relating to A.T. Levels 4-10

It will be noted that there is overlap in the expected levels of attainment within the four key stages in order to accommodate the range of ability of students, it is expected that the highest levels will be achieved by relatively few students. The students were to be monitored at the end of each Key Stage, the final testing to be linked, at least initially, to the GCSE examination system at the age of 16.

In response to wide spread criticism of the complexity of the delivery of the National Curriculum and also the National Standardized Attainment Tests (SATs) as applied in 1992, the Secretary of State appointed Sir Ron Dearing to undertake an enquiry and produce an interim report of the current workings of the National Curriculum. "The National Curriculum and its Assessment" (Dearing, R. July 1993).

In particular the Attainment Target Levels 1-10 were called into question. Section 4.13.

An approach which abandoned the concept of ten levels and developed programmes of study for each key stage in relation to which the pupil assessed

against specific end of key stage related criteria would overcome most of the problems identified in paragraph 4.13.

Sir Ron Dearing has made a series of recommendations which seem more acceptable to the educational community, however, no definitive decisions have as yet been taken.

The author was particularly interested in Attainment Target 1 which included the skills she had investigated within the context of GCSE.

The National Curriculum AT1 Sequence of Processes can be summarized:

Observation

Posing of questions and explanations

Further fair testing to answer the questions

Refinement of the hypothesis which is then tested to the greatest feasible level of accuracy commensurate with the problem.

The detailed statement relating to Levels of Attainment within AT1 are included in Appendix I.

The partial correlation of the attainment targets AT1 with the 9 skills under investigation are tabulated as follows:

Table 1.3

AT Level	Description	Skill	Description
4a	Ask questions, suggest ideas and make predictions	29	Formulate a hypothesis Make predictions
4b	Draw conclusions which link patterns in observations or results to the original question, prediction or idea	25 26	Recognise patterns in results and draw valid conclusions from the results.
3c	Recognise that their conclusions may not be valid unless a fair test has been carried out	27	Recognise an uncontrolled variable
6b	Considering the factors involved identify the key variables and how they can be controlled	28	Suggest an appropriate control.
5c	Evaluate the validity of their conclusions by considering different interpretations of their experimental evidence	30	Formulate several different hypotheses in a novel and complex situation.
8a	Use scientific knowledge, understanding and theory to generate quantitative predictions and a strategy for the investigation	32	Devise an experiment to test a hypothesis, planning the sequence of the experiment.

The National Curriculum attempts to provide a more accurately tuned assessment of the scientific investigation process than was provided by the GCSE list of skills.

Key Stage 4 comprises an extremely ambitious set of objectives at Levels 8-10, the cognitive ability to comprehend and achieve the highest levels of attainment within the context of an individually devised, experiment as prescribed by the National Curriculum Council, should test both pupils and teachers to their limits.

1.1.10 The Development of Biological Sciences

During the latter half of the nineteenth century the biological science taught in schools was mainly Botany and to a lesser extent Zoology, Agriculture and Horticultural Science and Animal Physiology. George Combe, the phrenologist believed the study of Animal Physiology to be acceptable (excluding the reproductive system) as a means of improving the health of the “Industrial Masses” by cross reference to humans. (Combe, G. 1857,)

The popularity of the study of Botany in schools during this period can be attributed to The Reverend Henslow, Regius Professor of Botany at Cambridge who wrote the book ‘Lessons in Elementary Botany’. His course required careful individual observation of flower specimens which was claimed:- would improve the students powers of logical thought and train the mind in observation of complex phenomena. (W.B.Carpenter FRS 1864 Evidence of the Clarendon Commission).

By the end of the nineteenth century Physiological Studies were beginning to replace Taxonomy. T.H.Huxley pioneered the inclusion of plant anatomy, morphology and physiology into the syllabus.

The Zoology syllabus of 1861 was firmly based on taxonomic considerations. T.H.Huxley argued for the study of selected types including dissection. The demand for zoology was small possibly due to its association with Charles Darwin’s unpopular ideas on Evolution propounded in ‘The Origin of Species’. (1859)

Huxley also encouraged the introduction of Biology into schools, to include Zoology, vegetable anatomy and physiology. His objective was “to give the

young mind some notion of what life is". (Huxley, T.H. 1893,) Biology was included as an examination subject for the Senior Certificate in 1885.

In 1899 The Agricultural Education Committee was established to encourage the study of agriculture and Nature Study became a compulsory part of the elementary School Curriculum. School Gardening degenerated into a source of cheap labour. Opposition to the study of Zoology and Biology was related to the study of reproduction, the subjects became acceptable to some opponents if reproduction was excluded. The original provision of Biology was for the benefit of intending medical students, however, with the expansion of dairy and agricultural research and the Pharmaceutical Industry, career opportunities expanded, as bacteriologists, mycologists and pathologists were needed. The Thomson Committee reviewing Science provision in boys' secondary schools in 1918, (HMSO 1918 Ref.3) found that nature study was provided for the lower forms with Botany and Zoology provided for a very few intending to study medicine. In secondary schools for girls, Botany was the dominant and occasionally the only science taught. In Public Elementary Schools only nature study was available. The Thomson Committee recommended the teaching of some Biological Topics but Physics and Chemistry were to be retained as the fundamental subjects. Biology was included in Group III for the School Certificate along with Chemistry, Physics and Mathematics, but was in fact only available with four of the eight examination boards, Botany was available with all eight boards. Biology suffered as it was a new subject without the support of a professional Institution until 1950, unlike the Linnean Society (Taxonomy) which dated from 1788 and the Botanical Society founded in 1836. Biology was disgracefully neglected by schools throughout the 1920's (Armstrong H.E. 1925, 2) only 3 out of 25 boys secondary schools taught any science besides Physics and Chemistry. In 1929, of 81% of secondary schools preparing their pupils for Higher School Certificate only 16% offered Biology. However, by 1938 as a

response to a succession of official and other reports stressing the value of a Biological Education, the provision of Biology in schools greatly increased. The British Association for the Advancement of Science (BAAS, 1928, 4) examined the position of Biology teaching in British schools found it compared unfavourably with both the USA and Japan, and recommended that Biology should be a fundamental subject in the curriculum of all Secondary Schools. They produced practical and realistic Biology syllabi. By 1931 all 8 examination boards examined Biology at School Certificate Level.

The Ministry of Agriculture and Fisheries expressed concern in 1929 over the inadequate supply of Biologists both for posts in Britain and in the Empire. Leaflets were published to acquaint teaching staff, pupils and parents with the available opportunities. The Chelmsford committee was convened in 1933 to investigate the shortfall in specialist Biologists in relation to demand, which lent support to those pressing for inclusion of Biology in the School Curriculum. The Board of Education also supported its inclusion as a means of facilitating improvement in the health and hygiene of the general population. Additional support was provided by the Chief Medical Officer of Health with the objective of improving knowledge about venereal disease and its transmission. In 1933, the British Social Hygiene Council, collaborated with the Education Authorities to promote Biological Education and started the publication of the periodical 'Biology'.

Various august scientists addressed the Science Masters Association on areas of biological developments of such general import that they needed to be included in the Science Curriculum for the benefit of the community. Lancelot Hogben (1942) expounded the need to include information relevant to human needs such as the value of vitamins. Alexander Fleming in 1945 gave an address to the SMA about the discovery and isolation of penicillin and J.G.Crowther at the same

conference propounded the idea that scientific knowledge should be harnessed for the benefit of mankind and that the social benefits of Biology were beyond dispute.

The Advanced Level Biology Syllabus content was considerably influenced by the requirements for exemption from the First MB examination of the Medical Degree. Biology taught in Grammar Schools tended to be academic in content rather than relevant and followed the dictates of the examination boards. In Secondary Modern Schools the Biology Syllabus was subject to modification to suit the teacher and/or his pupils. The notion existed that "the limited abilities of the Secondary Modern pupils would preclude them from the intricacies of the microscope or from quantitative experimental work". (Bonham, H.J. Advancement of Science 1949). The funds provided for Modern Schools as compared to Grammar Schools were inadequate to support properly organised laboratory courses. Between 1952 and 1962 the number of pupils sitting 'O'Level GCE Biology rose from 35,321 to 140,000. (Ministry of Education 1962 Statistics of Education 9) The GCE entries in Biology showed a marked sex bias towards girls, ratio of 2.75/1 Girls/Boys. There was far less bias towards girls in the uptake of 'A'Level Biology. Development in molecular biology as the result of cytochemical and crystallographic studies led to pressure for modernisation of the syllabus to include these aspects resulting in the production of a new 'A'Level syllabus by the Joint Matriculation Board in 1966. The new syllabus concentrated on fundamental Biological Principles as opposed to the previous study of types. Separate Zoology and Botany were withdrawn. At this time the Nuffield Teaching Project, 1962, and the American Biological Sciences Curriculum Study, were initiated. It took 100 years for school Biology to become comparable in extent and demand with other Sciences. (Jenkins, E.W. 1979, 18).

1.1.11 The Historical Aspect of Girls' Education in Science

In the period predating 1850, the education of girls was markedly different from that of boys. The Education they received, if any was provided, was in the acquisition of female accomplishments, as befitted the 'weaker sex'. The Schools Inquiry Commission (1868) delivered a grave indictment on the education of girls. It was found to be "wanting in thoroughness, foundation and system, with undue time given to accomplishments. The Physical Sciences were nowhere taught systematically and were commonly unintelligible." This report heralded a new era in the secondary education of girls. By the time of the Bryce Commissioners report 1895, they were able to survey a generation of progress in the secondary education of girls. The Girls Public Day School Trust Company was founded in 1872, its schools provided the models for the future school development in major cities. By the end of the century women had access to the majority of centres of higher education and could read for first and higher degrees. The Balfour Education Act of 1902, made the Local Education Authority responsible for the provision of education for both boys and girls. The provision of Science within the girls curriculum posed a problem, time was still allocated to accomplishments (drawing and music) and in addition many girls schools operated shorter days than boys' schools, in some cases mornings only. To facilitate this shortened week, Science and Mathematics lessons were curtailed to the minimum allowable (1904) three hours per week and lessons were more formal and intensive often in the form of lectures. The actual syllabus content to be taught to girls, became influenced by political considerations, with the objective of improving the Eugenic and Physical Level of the general population through the education of the mother:- the Social Darwinistic principle. This resulted in renewed emphasis on the traditional role of women to the detriment of theoretical Science Education. A new interdepartmental committee was established in 1904 to investigate the physical deterioration of the population.

This resulted in a system for the regular inspection of the teaching of domestic subjects. The instruction was to be in the simple practical mode, with no attempt to provide theoretical instruction as to the methods of cooking or the principles of digestion, beyond that necessary for the general understanding of the subject. It became acceptable to substitute instructions in domestic subjects partly or wholly for instruction in science.

The Girls Public Day School trust, which adhered to the principle that girls as well as boys would benefit from a sound intellectual education, indicated that it would prefer to dispense with the government grants than submit to the changes required by the board.

Arthur Smithells presented a paper titled 'School Training in the Home Duties of Women' to the British Association for the Advancement of science. (Board of Education, Special Report 1906,) He argued that Physics and Chemistry failed to appeal to any feminine interest, 'Applied Science of the Household' would be more applicable. Ida Freund a Chemistry lecturer at Newnham College stated that the term 'Domestic Science' was highly misleading as well as educationally disastrous, it would lower the already deplorable standard of education in many girls' schools. (Board Of Education 1913) required grant aided secondary schools to provide instruction in English, Arithmetic, History, Geography, Drawing, Singing and Physical Education - no requirement was stated either for Science or Domestic Science. The result of this rather imprecise recommendation was 'that a great variety of curricula and standards developed.' Manchester High School for Girls, under the headship of Sara Burstall provided two periods of General Elementary Science per week with some additional nature study and biology for the A Forms (the fast train). The B Forms were excluded from studying either Physics or for that matter Latin. She envisaged this second arrangement ie., B

Form with the emphasis on English, Modern Languages, Art and Handicraft, as the normal course of study for most girls attending secondary schools.

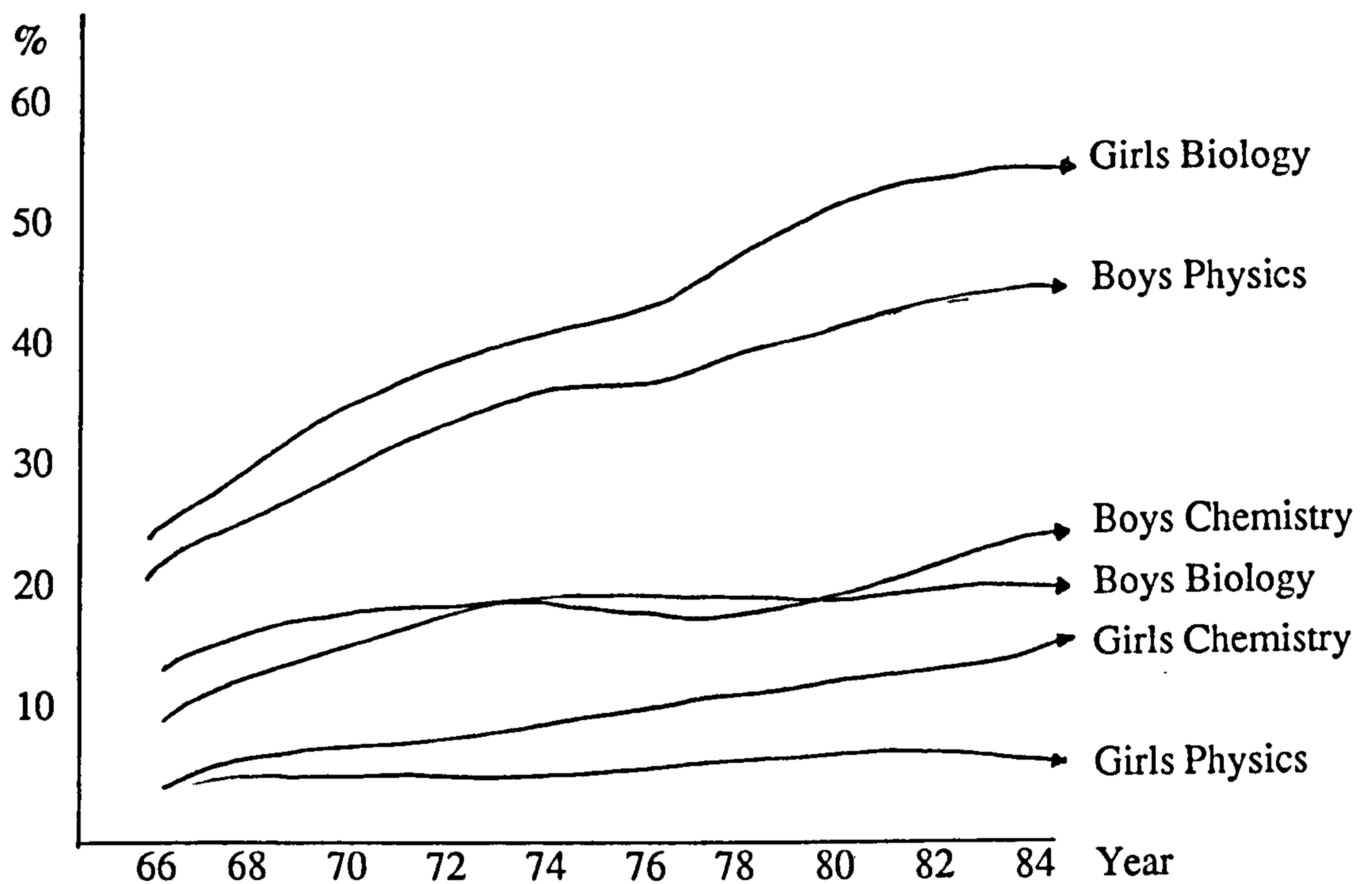
The Education Boards Consultative Committee Report on 'The differentiation of Curricula between the sexes' (Board of Education, 1923, 7), found that in some girls' schools there was no provision for the teaching of chemistry and considerably less provision for the teaching of maths than in an equivalent boys school. Often arrangements were made in co-educational schools for girls to discontinue the study of maths and to displace the systematic study of physics and chemistry with botany. The science curriculum of boys and girls was closely related to the resources available in terms of teaching staff and laboratories, both were expensive to provide. Many girls' schools were inadequately and privately funded, they had not taken advantage of the grants offered by the Department of Science and Art, which had done so much to stimulate the building and equipping of laboratories in boys' schools. (Board of Education 1904). There was the view of the Consultative Committee Report on Differentiation, that girls showed a 'comparative lack of scepticism and curiosity, the approach most suited to the study of Natural Sciences but showed a special aptitude for Biology, on the basis of their supposed diligence, neatness and the capacity to comprehend elaborate classification systems.' (Board of Education, 1923, 7). Miss Burstall subscribed to the view that a girls' school needed Biology Laboratories in preference to Chemistry Laboratories although she conceded that a wealthy school could provide special facilities for the study of science (Jenkins, E.W. 1979 19). By 1918, The Thompson Committee reported firmly established differences in the provision of laboratory equipment and practical teaching for girls and boys: those for the teaching of physical sciences were markedly inferior for girls. The committee also noted a serious problem of an adequate supply of teachers qualified to teach physics. The new School Certificate with the inclusion of science and maths in the Group III requirements, meant that a pupil could satisfy

the requirements with either Maths or Physics, either Chemistry or Domestic Science, and either Natural History or Botany. The most significant change in the science curriculum for girls was the replacement of Botany by Biology and the development of a General Science Course. However, the provision of the General Science Course did not necessarily imply the entry for Public examinations. Of the 137 girls' schools teaching General Science only 37 entered candidates for School Certificate. At degree level the discrepancy between men and women scientists persisted. The number of women holding State Scholarships and studying science was very small and two thirds of these entered the teaching profession. 1925-1926 14.6% of honours degrees in physics or chemistry were awarded to women, this figure had fallen to 10.5% by 1960-1961. The pattern of curriculum organisation with the options available discouraged or even prevented girls from studying Physics and Maths at Advanced Level. In 1962 only 40% of Girls' Grammar Schools taught any Physical Science in the 5th Year, this had a significant effect on the career opportunities available to girls. In 1957 the Ministry of Education recommended the provision of four laboratories for a two form entry boys or co-educational school but only three laboratories for a Girls' Grammar School of the same size (SSR no. 139 1958) further accentuating the discrepancy of laboratory facilities available to girls as opposed to boys.

1.1.12 The Research of Alison Kelly: Science for Girls

In the 1980's considerable discussion arose as to why there was a relatively poor uptake of science by girl students as opposed to boys. When the problem was examined more closely it was seen that in fact uptake of Physics was the problem.

Graph to Illustrate Science Uptake



The number of girls and boys passing 'O' Level or CSE physics chemistry and biology from 1966 to 1984 expressed as a % of the total number of school leavers.

Source - The Department of Education and Science, Statistics of Education.

In 1981 the first international conference on 'Girls into Science and Technology' took place with delegates from Western Countries. Following an expansion of the debate on this problem, Alison Kelly edited the book 'the Missing Half'. This book was then followed by 'Science for Girls' (Kelly, A. 1987,) The discussions put forward in the articles in the books centred around, the psychological aspects of science uptake by girls, suggesting that

girls from an early age were not expected or encouraged to succeed in science; and

that a patriarchal system operated within scientific education that discouraged girls whilst simultaneously reinforcing boys' efforts.

That the content and presentation of science was not 'girl-friendly'.

That some innate factor within the intellect of girls makes the conceptualisation of science by girls more difficult.

Valerie Walkerdine, in 'Science for Girls?' produced an interesting discussion, which although it originally related to Mathematics may be relevant to the problem in science. She noted that: the Cockcroft Committee considering Girls' mathematics:

Established first that girls were diligent, hard working and well behaved.

Found that girls performed significantly better in 11 out of 91 mathematical items.

Boys performed better in 14 out of 91 items.

Noted that when these results were analysed (Shuard, H. 1981.) the suggestion was made that the items in which the boys were more successful were the difficult ones, which required conceptualisation. these had a 49% pass rate.

The ones in which the girls were successful were the 'easy' skills requiring rule following and rote learning with a pass rate of 64%

Walkerdine takes issue with this interpretation and in fact several additional reviewers have concluded that the cognitive ability differences are unstable and small.

(Fairweather, H. 1976, MacCoby, E. and Jacklin, C 1980, and Hyde, J, 1981.)

Spatial ability was supposed to show the greatest difference at 4%, however, Hyde (1981) attributes this to sampling errors. Rosenthal, R and Rubin, D. (1982) have noted a reduction in differences in skills over the last 20 years. Notwithstanding this improvement, girls still opt for sciences less frequently than boys.

Another deterrent factor in the study of science by girls is considered by Alison Kelly to be competition for equipment and the teacher's attention when studying in a co-educational class, with boys monopolising the major proportion of both items. This situation has indeed been encountered in the author's own classes.

To offset this, single sex education or alternatively segregation for science classes has been suggested, in the report of the committee on 'Girls into Science and Technology', 1981.

The investigation attempted to establish whether there was a significant difference in the success rate of boys and girls in the different cognitive skills under consideration. As they were being investigated in the context of Biology, the negative attitude displayed by girls to science overall, should not interfere with their performance.

The author, in her investigation has attempted to compare the success of two groups of girl students, cross matched for IQ, one group from single sexed schools and the other taught in co-educational schools in mixed classes.

1.2 Theories of cognitive development in the Context of Science Education

1.2.0 The Development of Tests of Intelligence

Shelley and Cohen (1986) have discussed the development of psychological tests. The first historical records in 1879 of psychological tests were those originating from the research laboratory of Wilhelm Wundt in Leipzig. James McKeen Cattell was one of his students who later came to hold the Chair in Psychology at Columbia University and was one of the founders of the American Psychological Association. His published paper relates to physical and mental tests - Shelley and Cohen (1986).

Galton (1882) working in Britain compiled a range of tests which included measurements such as the circumference of the head but also more significantly, perceptual tests, intellectual exercises, mental arithmetic and anagrams.

Alfred Binet, working with Victor Henri in Paris published 'L'Etude Experimentale de l'Intelligence, (1911) which laid the ground work for the first intelligence tests.

Theodore Simon, (1905), produced the first intelligence scale, he realised that apparent intelligence increased as children matured and to allow for this, devised the concept of Mental Age as opposed to Chronological age. The American, Thorndike, claimed that some tests were more successful at predicting future educational success than others. "Currently there are far more tests and far more psychology available and far less confidence in either". Shelley and Cohen (1986).

During the First World War, the American Military made considerable use of Intelligence tests in an effort to match recruits to an appropriate niche. However,

IQ tests have also been abused to reinforce social and political prejudices, as exemplified by Arthur Jensen in the 1960's stating - that black Americans scored on average one Standard Deviation lower on IQ tests, equivalent to 15 IQ points, than white Americans. Thus ignoring the effect of culture differences, relevant to verbal reasoning tests and sampling differences. Gould (1981) and Kamin (1982).

IQ was defined as
$$\frac{\text{Childs Mental Age} \times 100 \text{ (According to the test used)}}{\text{Childs Chronological Age}}$$

Binet at the time of his death in 1911 had published one IQ Scale and one refinement of it. L.M.Terman working at Stanford continued the task and published the Stanford-Binet Tests. Piaget was employed on Binet's Tests and became involved in research on why children gave wrong responses to the tests or why they failed to be logical. The early efforts to refine the tests had tremendous effect on the development of child psychology, Cohen, D. (1983). In recent years great debate has occurred as to whether intelligence (as measured by the tests) depends mostly on heredity or environment. A consensus view (favoured by the author) is that both aspects are inseparably involved.

In Britain, the National Foundation for Educational Research (NFER) produces most of the tests available which may be administered by properly qualified individuals. However, popular books of IQ tests, suitable for adults are freely available for purchase by the general public, Eynsenck, H.J. (1966), and various coaching books are available for children (The Alpha and Beta series.)

The organisation MENSA claims to measure IQ's Internationally.

In America there is a large test creation industry, 8,000 tests are in active use. They are produced by such bodies as The American Psychological Association,

The Educational Testing Service and Western Psychological Services. However, endless debate continues as to whether IQ tests have any reliable predictive value of educational aptitude, or merely measure the ability of individuals to successfully undertake IQ tests.

1.2.1 A consideration of some definitions of intelligence

The question as to what constitutes intelligence has exercised the minds of educationalists throughout the twentieth century. Spearman, (1904) published an article in the American Journal of Psychology 'Intelligence objectively determined and measured.' He considered that intelligence consisted of G (General Intelligence) which he defined as the General Intellectual Ability and S, various specific intellectual skills. Since then numerous researchers have endeavoured to define Intelligence and measure it, although with reduced confidence and certainty as the years progress.

Thorndike, (1913) defined Intelligence as the 'Ability to make good responses from the point of view of truth and fact', the intelligent person would be able to come up with the right answers to difficult problems. He considered there were three different kinds of intelligence, abstract, mechanical and social. His intelligence tests categorised the components by which intelligence could be assayed as CAVD: Completion (of sentences), Arithmetic, Vocabulary and Direction. 17 levels of tests were produced, ranging from those suitable for 3 year olds to those applicable to graduates. Wilson (1969 1)

Terman, (1916) defined intelligence as 'The ability to think in abstract terms. He revised the Binet and Simon Tests of 1905 for use in America, Wilson, (1969 1) His scheme included definitions of abstract words, a search for a hypothetical ball in a square, counting backwards and vocabulary.

Henmon and Nelson, (1931) produced Test Material purporting to measure Achievement, Arithmetic, Computation and 'Information accumulated during the course of living'.

Stoddard, (1943) defined intelligence as: 'the ability to undertake activities characterised by difficulty, complexity and abstractness and to perform these activities with speed, economy of effort and adaptiveness to a goal, whilst retaining concentration and resisting emotional forces.'

Thurstone, (1947) developed a system of factor analysis to evaluate the responses to questions on addition, vocabulary, shapes, verbal fluency and similarities. He constructed the Primary Mental Abilities tests, PMA, one of which, the Scholastic Aptitude Tests, SAT, (for college entry) was widely used in the USA. Wilson (1969 2). Considerable care was taken to check the correlation coefficients of the various parts of the test. The reasoning section correlated well with the test as a whole; reasoning was assayed by arithmetic reasoning tests and series completion tests.

With Wechsler's verbal and performance scales (Wechsler, D. 1944) children needed to be verbally skilled to be assessed as gifted (130+) however, they may not be equally gifted at other intellectual tasks. The Wechsler Intelligence Scale for Children (WISC) was evaluated by Robeck, (1964) who found the subtests gave sufficiently stable results to allow differential diagnosis of individuals' cognitive difficulties, particularly with regards to reading problems.

Both the WISC tests and the Stanford-Binet Revised intelligence Scale required a high level of verbal fluency favouring children from privileged homes, Binet also required children to manipulate concepts well.

Wilson, (1969 3) showed there was great variability in results according to the test used.

J.M. Stephens, (1952) stated that intelligence is whatever the test measured. Rather than implying that such tests were therefore useless, he was calling for a more accurate statement by the test producers of the exact area of intellectual activity to which the test applied. Factor analysis can be used to establish exactly what cognitive skills the particular intelligence test measures. The difference in concept of the test makers regarding the nature of intelligence has influenced the choice both qualitatively and quantitatively of the items selected for tests and consequently the validity and suitability of tests for particular appraisal.

When using I.Q. scores to appraise an individual's ability and potential, more than one test score from differing tests is desirable even though the majority of tests are standardised to have a mean of approximately 100.

Tests that are semantically orientated putting a premium on vocabulary, memory and sentence interpretation, tend to predict success in the humanities and Social Sciences (Wilson, J.A.R. 1969, 4). Tests that stress structure and symbolism are more efficient in selecting students who will do well in the fields of mathematics and science, where convergent intellectual production is of primary importance. In more recent contexts where student scientists are asked to generate different hypotheses and research workers need to devise de novo lines of research, divergent thought patterns could also facilitate success.

J.P. Guilford, (1956 and 1967) devised for the United States Air Force 'Leadership Aptitude tests'. He analysed intellectual activity into four major areas.

Figural - the method of thinking for concrete, tangible (real) things
eg., the lie of the land, the cutting of pieces from a length of material, the arrangement of parts in an engine.

Symbolic (Abstract), use of letters, numbers, musical notation, chemical symbols and codes.

Semantic, meanings of words, the Scholastic Aptitude test gives a quantitative (symbolic score) and a verbal score.

Behavioural (a later addition) Empathic awareness of attitudes, needs, drives, moods and perception of others.

Guilford considers that five operations make up the process of thinking:-

Cognition - comprehension/understanding, discovery, awareness, rediscovery or recognition of information in various forms. This is the base from which all other operations develop.

Memory - retention, (storage) availability and recall.

Divergent Production - information available from cognition is transformed, combined and treated to generate new information.

Convergent Production - generating new information from given information with the production of 'an answer' the answer deemed to be correct by another. Multiple choice questions assay this type of production and it is much easier to evaluate than other types of thinking.

Evaluation - decisions made about the 'goodness' suitability, adequacy or success in terms of consistency, identity and goal satisfaction.

Interaction occurs between the operations during the ongoing process of thinking.

The product of thought in units, ie., Words, ideas, forms, symbols, verbal comprehension of feelings.

Thought patterns arrange and group items in different ways:-

Classes - items with something in common. The following groupings are very common components of intelligence tests. Relations that exist between units:- Analogies , opposites, similes etc.

Systems:- internal consistent groupings, the objective is to recognise the relationships.

Transformations:- modifications of arrangements, this last category should result in a range of answers.

Implications:- extrapolation or interpolations of information, extending the information you have.

A range of Intelligence tests is available for use and the problem is to select a suitable test for the assessment to be undertaken.

1.2.2 Choice of the Culture Fair Intelligence Tests

The Culture Fair Intelligence Tests were developed by R.B.Cattell in the late 1920's, influenced by the seminal work of Binet and Simon (1905). They were refined over an extensive period of time with the objective of producing tests that

were reliable and efficient but eliminated the verbal components which so favoured students from a privileged background whilst heavily penalising verbally deprived children. They were also unusable by people whose first language was anything other than the language in which the test was written. Cattell working at the University of Illinois incorporated the application of factor analysis as expounded by Spearman, working in England and Thurstone in the USA to assess the validity of the units and subunits of his tests against other tests assaying 'primary abilities'; verbal ability, spatial problem solving, numerical ability and even memory. He found that the tests which use no verbal skills at all correlated with the separate skills and also more significantly with general ability or General Intelligence; Spearman's factor G.

The tests were developed, refined and updated in 1940, 1949 and 1961. 72 items of the initial 159 were found to have adequate stability. Trials were extensively undertaken in the USA and additionally in Taiwan, New Mexico, Germany, Pakistan and Samoa. Adequate correlation was recorded in the cross culture tests and also in the test retest situation.

The culture fair tests consist of four subtests; - 1) series completion, 2) classification, 3) matrices and 4) pattern recognition, where patterns in differing variables have to be ascertained and finally increasingly complicated sets of conditions to be elucidated. The tests all allow only one correct answer and therefore favour convergent thought patterns, there being no credit given for originality. The tests are copyright to 'the Institute of Personality and Ability Testing' and are produced at Scale 1, 2 and 3. The author selected scale 2 as being suitable for use with pupils aged 7½ to 14 years and extended the range for high ability students of 12 years 9 months up to adulthood, by using scale 3.

The test producers do not make extravagant claims for their tests, recommending their use in order to give general assessment of intelligence and reasoning not for individual diagnoses. They alert the user to the many other factors interacting to predicate achievement. The author used the tests to give an approximate estimate of the subjects' general intelligence/reasoning power to look for correlation's with the Science Skills currently assessed at GCSE (1992)

The advantage of this type of test is that they are designed to be culture fair, they can be administered as a group test, the marking is totally standard and that the time required for their completion is short, allowing the testing of the 9 selected Biology Skills to be undertaken at the same session.

The tests are available from The Educational Testing Service and Western Psychological Services. However, endless debate continues as to whether IQ tests have any reliable predictive value of educational aptitude, or merely measure the ability of individuals to successfully undertake IQ tests.

1.2.3 Growth and Development in relation to Cognitive Skill

The age of a child has vital bearing on the cognitive levels that can be attained at any particular time. Perceptual skills will impede the child's ability to distinguish small letters and numbers and so his ability to conceptualise the principles of reading and number. Auditory perception and discrimination will restrict speech, communication and reading.

There is considerable variation within individuals as to the actual timing of developmental stages, the result of both genetic and environmental influences. However, according to the extensive research of Piaget and Inhelder (1956), a distinct sequence of stages has to be encompassed in order to achieve full

cognitive development. The work of Piaget is considered at length in this introduction (pages 62 - 78).

According to Freud, (1949) and Erikson, (1950) a child's growth and development, particularly cognitive and emotional, are influenced and sometimes impeded by physical changes and the concomitant hormonal and behavioural variations.

Guilford, (1967) working extensively on intelligence, diagnosed 120 different areas of intellectual development and attempted to devise systems of exercises to improve particular areas. He recognised the importance of both heredity and environment for the maximum cognitive growth.

The sequence he postulated is :-

Inherited responses (frequently reflex), sucking, blinking.

Imprinted responses (Also innate with as little variation as possible
(eg., Baby Birds following a moving object)

Conditioned responses (influenced by the environment)

Self-Directed Learning.

Wilson, (1969, '7) stressed the significance of the private world of the individual, each person's uniqueness resulting from varied experience with some overlap with others as the result of shared experience. Cognitive development involves the expansion of the private world to encompass parts of the private worlds of others.

The private world of the individual is changed by his or her learning and this in turn makes further learning more likely. Learning can occur at different levels

dependent on the presentation of the material and the student's prior experiences and his or her intellectual ability.

Wilson also sites pleasure and punishment centres in the brain motivating memory and recall.

Wilson, (1969, 7) proposed a neurological model, where associations are established between banks of neurones in the brain as a result of changes in RNA which codes for protein synthesis. The synthesised protein will facilitate or inhibit the establishment and consolidation of permanent storage systems and retrieval networks and the emergence of insights from associations. (The author in 1992 is less confident about the role of RNA and protein synthesis as a means of information storage. She also questions the position of DNA in this model if RNA is constantly altering.)

Pavlov, (1927) and Skinner, (1953) believed that initial learning was of the Association type. Rote learning of chronological dates, spelling and multiplication tables are all examples of this type of learning. The factual content of lectures is often retained by association learning.

The desired corollary to the initial, Rote learning, is conceptualisation taking in information, comprehending it, processing and incorporating the information into the student's own cognitive apparatus (assimilation).

Conceptualisation is far more difficult to engineer than rote learning. The student needs to perceive and comprehend the commonalties and relationships within the information and recognise inherent patterns. Conceptualisation is far more likely to be achieved if the student can derive, develop or discover the underlying concepts for himself. (The objective of the Nuffield Science Teaching Project).

The highest level of learning as defined by Wilson, (1969 8) is Creative Self Direction. The person selects and directs his own goals and pace of learning, motivation is internally generated, and at this point the individual is able to function as a free agent.

In the author's opinion, this highest level of learning is sometimes not achieved even by students who have successfully achieved University entrance. Their learning is still driven by outside influences, parents, teachers or an assumed career aim. In this situation, self motivated study may still be outside the reach of these students.

Thus the hierarchy of learning may be:

Association Learning -> Conceptualisation -> Creative Self Direction.

1.2.4 Piaget's Theory of Cognitive and Affective Development

Piaget's work on cognitive development in children extended over the greater part of the twentieth century, commencing in Paris where he worked with Binet at the Sorbonne operating a laboratory administering and standardising Intelligence Tests in a Board School. While working in Paris he became disenchanted with the standardised group tests and became far more interested in the incorrect answers children gave and their reasoning behind these answers.

He studied ontogenic changes from birth to adolescence in a large number of individuals. By extremely precise observation of these children performing a range of specific cognitive tasks, he sought to elucidate the pathways and sequence by which their reasoning powers developed.

He worked at the J.J.Rousseau Institute in Geneva and eventually established the Centre for Genetic Epistemology in Geneva, where visiting Scholars, interested in child development and drawn from many different academic disciplines could research into various topics, providing tremendous opportunity for cross fertilisation of ideas. He finally died in 1980 at the age of 84 still taking an active interest in research into cognitive development.

Initially Piaget's work was not recognised in the USA where behaviourists such as Thorndike, Hull, Tolman and Skinner held sway. They were exploring the idea of stimulus/response as the catalyst for learning, with reinforcement consolidating the process. They were at odds with Piaget's ideas of the existence of internal mental processes that established cognitive 'structures' (SCHEMATA).

Piaget considered, very reasonably, that development occurred from the less differentiated to the more differentiated, from the less sophisticated to the more

sophisticated. During this development, SCHEMATA are established in the brain which enables the next level of comprehension to be undertaken.

The sequence he proposed involved the following processes.

Construction of SCHEMATA

A generalised idea (plan) about something.

Assimilation. Additional information is provided from outside and enters the child's thought processes.

Accommodation. The child adjusts his thought pattern to encompass the new information.

Equilibration. The child mentally works on the information to fit in with his established schemata or adjusts or creates other schemata to comfortably include the new ideas.

Piaget considers each advance has to be accompanied by a period of Egocentrism while the child tests out the new ideas on a personal basis.

Piaget conceived the idea of a series of continuous stages in cognitive development through which each individual must pass before proceeding to the next stage. He considered the sequence to be invariant. However, the acquisition of one stage of cognitive reasoning does not ensure successful attainment of the next stage, although absence of a successfully mastered previous stage precludes progress to the next.

The stages with their approximate age ranges are listed below.

Stage	Age in Years
Sensory Motor	0-2
Preoperational (Prelogical)	2-7
Concrete operational (logical thought)	7-11
Formal operational	11 -> Not everyone achieves this stage
Propositional Operational thought	

This latter was a further extension of his stages and consisted of Logico deductive thought, the ability to apply logic to abstract problems. The person's schemata become qualitatively mature and can be applied to problems regardless of content.

At the time Piaget commenced his own research work, American behaviourists were undertaking research on children's learning under extremely formalised and controlled conditions. They tested hypotheses with control of variables and sophisticated statistical techniques were used to evaluate the results. Piaget's method was to use the Clinical Descriptive technique. Individual children were asked carefully selected questions and their responses precisely recorded, this in no way resembled the American experimental psychology and was therefore not acceptable at that time.

The problem with Piaget's early work was that he used intuition when interviewing the children and allowed the interview to develop in its own direction, so no two children were necessarily asked the same sequence of questions, and the experience received was therefore different. Piaget recorded his early work in the book:- "The child's conception of the world' (1929).

An additional problem was the very small sample size. Much of Piaget's extremely detailed work on young children aged 0-2 was performed on his own three children, the disadvantage of the small sample was considerably offset by the long term availability of his subjects. Piaget extrapolated his conclusions to propose that the general course of intellectual development, observed in his experimental subjects, would be the same for all persons.

His later experimental work was much more rigorously controlled and did in fact support his initial conclusions.

His work was recorded in further books written over the next 40 years:- 'The growth of logical thinking from childhood to adolescence (1956); 'Early growth of logic in the child' (1964); 'The mechanism of perception (1969). He eventually accumulated data on 1500 subjects by the technique of systematic observation, description and analysis of the child's behaviour.

The work was designed to discover the nature and levels of cognitive development that children use, not to produce developmental scales.

Piaget was initially trained as a Biologist not a Psychologist and he believed that biological acts were acts of adaptation to the Physical Environment.

Adapted from Wadsworth 1989.

That mind and body do not operate independently, mental activity is subject to the same laws as Biological activity.

That intellectual and Biological Activity are both part of the overall process by which an organism responds to the environment and organises its experiences.

Schemata are the cognitive or mental structures by which individuals adapt to and organise their experiences.

Schemata adapt and change with mental development, they are used to process and identify incoming stimuli. (A sort of mental card index file.)

As a child develops, his schemata become more generalised, more differentiated, more 'adult'. They never cease to develop and become more refined. (The author is not convinced that this last statement is universally applicable.)

The young child has a limited number of schemata available, the initial ones being reflex ie., sucking, but differentiation starts very rapidly eg., sucking which is milk producing as opposed to sucking that does not produce milk but provides comfort.

The schemata of the adult are a vast array evolved from the schemata of the child, as cognitive development occurs they become progressively more differentiated and less sensory. Their evolution is the result of adaptation and organisation due to assimilation and accommodation.

Schemata are constructed by the child and reflect the child's experiences. When assimilation of fresh information occurs, the person imposes his or her currently existing schemata on the new stimulus, trying to force it to fit. This results from an increase of information and is a quantitative change.

However, in all probability an exact schemata may not be available to fit the incoming information, in which case schemata may need to be adapted, or new

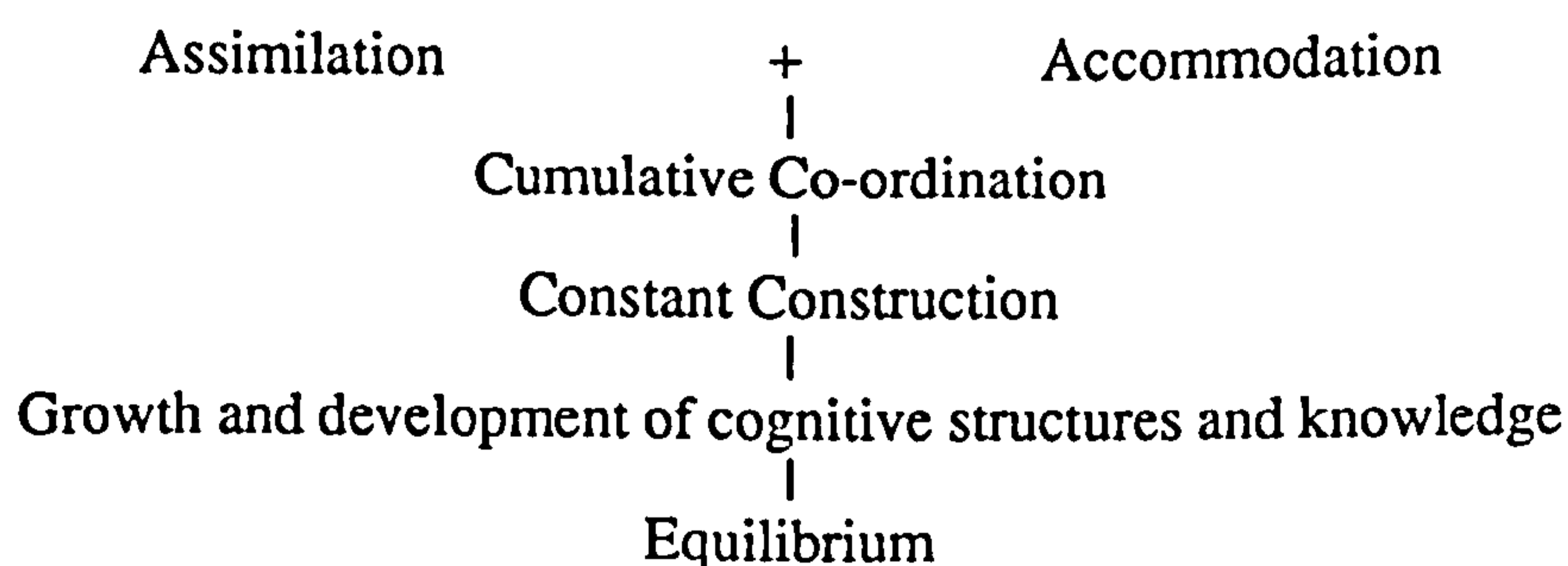
ones constructed, this process is known as accommodation, this is a qualitative change.

Both assimilation and accommodation are necessary for cognitive growth and development.

The relative amount of both assimilation and accommodation at any one time is important, excess assimilation without accommodation will result in too many unsorted stimuli which cannot be differentiated. Therefore no pattern recognition is developed. Whilst too much accommodation on the basis of too little assimilation will result in the person being unable to generalise from data received. The outcome will be an inability to draw conclusions.

Disequilibrium is an imbalance between accommodation and assimilation and results in cognitive conflict, equilibration is the process of bringing disequilibrium to equilibrium:- cognitive balance. A balance between assimilation and accommodation results in Equilibration. Better and better schemata are evolved as intellectual development proceeds.

THE SEQUENCE OF PROCESSES TO ACHIEVE EQUILIBRIUM ARE



The Internal Mechanisms that regulate the processes:

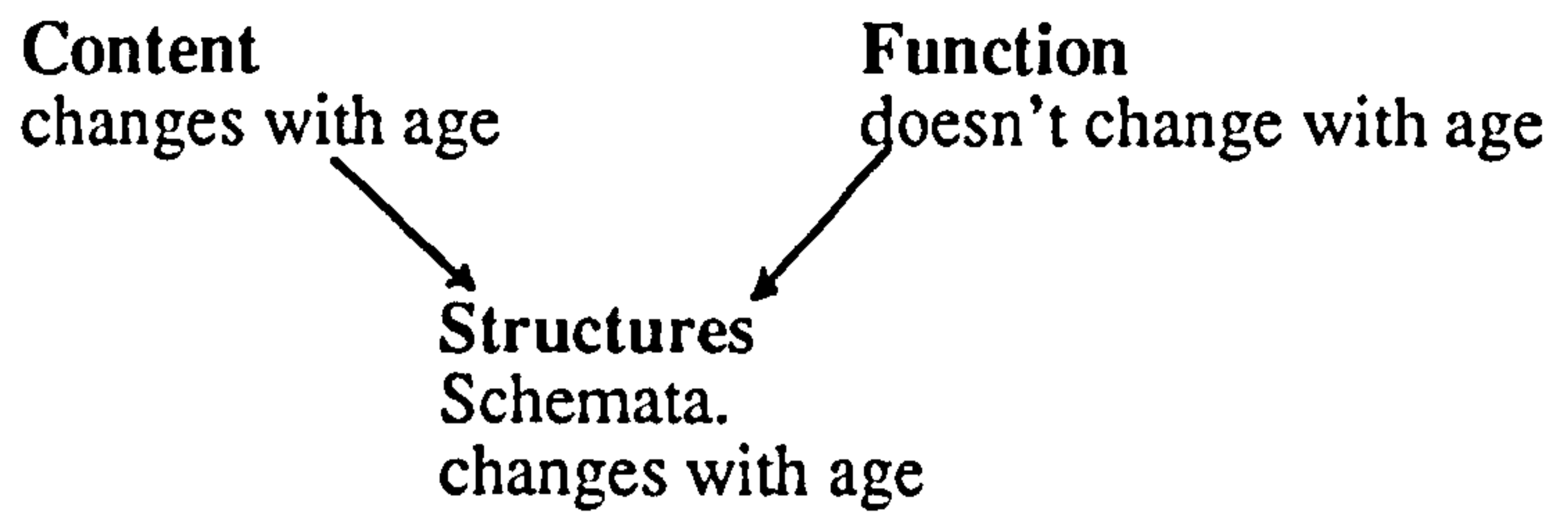
These are known as CONSTRUCTS. They are defined as concepts or things that are not directly observable but inferred to exist:- Intelligence, Creativity, Aptitude, Ability, Motivation, Instinct. Psychological research endeavours to classify the nature of these constructs and verify their existence. Disequilibrium, cognitive conflict results when expectation and prediction are not confirmed by experience.

Motivation activates behaviour to remove disequilibrium, Assimilation together with Accommodation results in Equilibration. i.e., Access to additional information with its appropriate processing will remove the cognitive conflict and achieve equilibrium (for the time being). This sequence is the drive and the basis of learning.

Piaget considers intelligence to be made of content, function and structure.

PIAGET'S CONCEPTION OF INTELLIGENCE COMPRISES

- | | |
|------------------|--|
| Content | What the child knows about, - observable behaviour, both sensory-motor and conceptual. It reflects intellectual activity and varies from age to age and child to child. |
| Function | Refers to the Characteristics of Intellectual Activity, Assimilation and Accommodation. They are stable and continual throughout cognitive development. |
| Structure | Refers to the inferred organisational properties, the schemata that explain the existence of particular behaviours. The change in structures are intellectual development, the schemata are the organisational properties of intelligence. |



Piaget's system requires that the child acts on the environment if cognitive development is to proceed. (The principle imbued in the Montessori system of Education and also the Nuffield Science Projects.) When the child is doing this he is taking in raw material to be assimilated into the schemata.

At first, the action of the child is direct (physical) ie., sucking, handling, later the action may be internal, ie., adding up a column of figures.

Mental and Physical actions are necessary but not sufficient for cognitive development.

PIAGET'S CONCEPTION OF KNOWLEDGE IS

Physical-size, shape, colour and weight. These require direct experience by the individual they cannot be fully comprehended from a second hand description or symbolic representation.

Logico Mathematic. The child invents this knowledge by thinking about experiences. The child acts on the objects to allow the cognitive construction to occur. (It is irrelevant whether the child counts beads of nutmegs.) However, groups of some kind of objects are essential. This knowledge also requires direct experience, it is not acquired by reading or listening.

Social-Arbitrary - the rules, laws, values, morals, ethics and language by which humans interact. These cannot be extracted from actions on objects, they must be constructed by interaction with other human beings.

A young child, 0-2, interacts directly with the environment on a sensory-motor level but does not possess the power of symbolic representation (Language). From the age of two onwards, the child becomes increasingly capable of representing action in the mind.

Piaget conceptualised development as a continuous coherent process with successive quantitative and qualitative changes in schemata each alteration being derived logically from preceding structures. The schemata being constructed, reconstructed or modified gradually to accommodate the assimilated experiences.

Piaget separated Cognitive Development into four main stages although not implying that children move from one discrete stage to the next discrete stage, rather that there is a gradual flow in development.

PIAGET'S STAGES OF COGNITIVE DEVELOPMENT ARE

- Stage 1 Sensory motor intelligence (0-2). the child does not internally represent events and think conceptually, although cognitive development occurs as schemata are constructed.
- Stage 2 Pre-operational thought (2-7). Development of language and other forms of representation, rapid conceptual development.
- Stage 3. Concrete operational thoughts (7-11). The child acquires the ability to apply logical thought to concrete problems.
- Stage 4 Formal Operational Thought. (11 onwards). The child's cognitive structures reach their greatest level of development and the child can then apply logical reasoning to all classes of problem.

Piaget's suggested age spans are normative as displayed by a typical or average child. These age spans are open to question as being rather optimistic as recorded from research work on the British child population. (Shayer, M. and Adey, P. 1981).

The ages at which stages occur vary with the nature of the individual's experiences and his or her hereditary potential. This accords with the idea of intelligence being related to both heredity and environment and intelligence as it is commonly assessed by tests is scored on an age related basis.

Piaget observed that the time for passage through the stages was variable. A 'bright' child progressing rapidly through, whilst some individuals never reach or complete the formal operational stage. However, the order of development is fixed.

Four broad factors interact in cognitive development, Maturation, Physical Experiences, Social Interaction and the general process of Equilibration. None alone is sufficient to promote cognitive development.

The inherited factors set limits for development at any one time through the process of maturation, and it is maturation which determines the range of possibilities at any specific stage, although it does not cause the actualisation of these schemata. Realisation of the child's potential depends on the child's own actions on his environment.

The balance (co-ordination) between maturation, experience and social interaction should result in equilibration. It allows new experiences to be successfully incorporated into the existing schemata, control of cognitive development is to a

large extent, self-regulating. Cognitive and affective development interact, eg., a child who 'likes' maths makes rapid progress and the converse is also the case.

The development of language has three consequences essential for cognitive development.

- 1 The possibility of verbal exchange with other people resulting in socialisation.
2. The internalisation of words allowing the development of thought itself supported by an internal language.
- 3 The internalisation of actions which can be tested intuitively by means of mental pictures and experiments.

Representational thought is carried out more rapidly than thought through movement because the former is not tied to the direct experience.

FACTORS INVOLVED IN COGNITIVE DEVELOPMENT

Transformation, a child at the pre-operational stage does not have the schemata to allow transformations ie., if something is moved and the child sees it move but still searches in the original place.

Reversibility, is the ability to follow a train of thought back to the original situation. This requires concrete operational skills and is not easily acquired. The child has to work through the problem logically, direct experience probably cannot be provided.

Conservation of a number, volume and mass needs to be actively acquired by concrete experiences, and appears to occur in a definite order, conservation of number first, followed by liquid volume, mass and finally solid volume. The

child needs to develop schemata that allows him to decentralise and concentrate on more than one characteristic at the same time. This is often achieved on reaching formal operational thinking and depends on decentering, transformation and reversibility. The child will have to learn to question his or her own thinking. This procedure requires considerable assimilation and accommodation, and teaching doesn't appear to help. One has to wait for the child to construct his own schemata.

Piaget defined an intellectual operation as 'an internalised system that is fully reversible'. (Piaget edited by Gallagher, J. and Reid, K. 1981)

At the concrete operational stage, when faced with a discrepancy between thought and perception, the child at the fully concrete operational stage makes cognitive and logical decisions rather than perceptual. He decentres his perceptions, attends to transformation and has attained reversibility.

The child at the concrete operational stage can perform seriation and classification on the basis of one criterion (dimension) eg., length or colour if all the objects are available for inspection. This attribute is required for a student to recognise patterns as needed for skill 25 in this project. However the information is provided in abstract form, increasing the level of difficulties with skill 25, 26 and 23.

Schemata for the formal operational (Logico hypothetical) stage are required for seriation and classification where all the required objects or events are not present, or several variables need to be considered, concrete operational schemata will not suffice. The child at the concrete operational stage cannot apply logic to problems that are hypothetical, purely verbal or abstract and, such a person cannot deal with multiple variables or extrapolate from data to make predictions. The ability to

Appendix I

*Statements of Attainment relating to Science Attainment
Target 1 of the National Curriculum*

APPENDIX I

The Statements of Attainment within Attainment Target 1 Scientific Investigation were categorised as follows:

ref: National Curriculum Council HMSO (Science in the National Curriculum 1991)

Level 1 - a Observe familiar materials and events.

Level 2 - a Ask questions (how, and why and what will happen if?, and make predictions.

b Make a series of related observations.

c Use their observations to support conclusions and compare what they observed with what they expected.

Level 3 - a Suggest testable questions, ideas and predictions based on everyday experience.

b Observe closely and quantify, by measuring using appropriate instruments.

c Recognise that their conclusions may not be valid unless a fair test has been carried out.

d Distinguish between a description of what they have observed and a simple explanation of how and why it happened.

Level 4 - a Ask questions, suggest ideas and make predictions based on some relevant prior knowledge in a form which can be investigated.

b Carry out a fair test in which they select and use appropriate instruments to measure quantities such as volume and temperature.

c Draw conclusions which link patterns in observations or results to the original questions, prediction or idea.

- Level 5 -
- a. Formulate hypotheses where the casual link is based on scientific knowledge, understanding or theory.
 - b. Choose the range of each of the variables to produce meaningful results.
 - c. Evaluate the validity of their conclusions by considering different interpretations of their experimental evidence.
- Level 6 -
- a. Use scientific knowledge, understanding of theory by considering different interpretations of their experimental evidence.
 - b. Consider the range of factors involved, identify the key variables and those to be controlled and/or taken account of, and make qualitative or quantitative observations involving fine discrimination.
 - c. Use their results to draw conclusions, explain the relationship between variables and refer to a model to explain the results.
- Level 7 -
- a. Use scientific knowledge, understanding or theory to predict the relative effect of a number of variables.
 - b. Manipulate or take account of the relative effect of two or more independent variables and refer to a model to explain the results.
 - c. Use observations or results to draw conclusions which state the relative effects of the independent variables and explain the limitations of the evidence obtained.
- Level 8 -
- a. Use scientific knowledge, understanding or theory to generate quantitative predictions and a strategy for the investigation.
 - b. Select and use measuring instruments which provide the degree of accuracy commensurate with the outcome they have predicted.
 - c. Justify each aspect of the investigation in terms of the contribution to the overall conclusion.

- Level 9 -
- a. Use scientific theory to make quantitative predictions and organise the collection of valid and reliable data.
 - b. Systematically use a range of investigatory techniques to judge the relative effect of the factors involved.
 - c. Analyse and interpret the data obtained in terms of complex functions where appropriate, in a way which demonstrates an appreciation of the uncertainty of the evidence and the tentative nature of conclusions.
- Level 10 -
- a. Use scientific knowledge and an understanding of laws, theories and models to develop hypotheses which seek to explain the behaviour of objects and events they have studied.
 - b. Collect data which is sufficiently valid to enable them to make a critical evaluation of the law, theory or model.
 - c. Use and analyse the data obtained to evaluate the law, theory or model in terms of the extent to which it can explain the observed behaviour.

The National Curriculum is not without its critics especially with regards to the loss of separate sciences from the curriculum of most children. Logii Bruce Lockhart (retired headmaster from Greshams College, the first school founded with the avowed purpose to instruct others in Science, comments in "The Guardian", 25th August 1992:- "A too conscious effort to please everyone by providing everything for everybody in the National Curriculum is doomed to end in teaching everything inadequately eg., watering down individual sciences to General Science and combining History, Geography and Social Studies does little except make progress in 'A'Levels more difficult.

Appendix II

Biology Trial Questions

*Biology Skills Question Booklet
as used for the Original Sample aged 15/16 Years*

*Additional Biology Skills Tests
as used for the Lower Age Ranges*

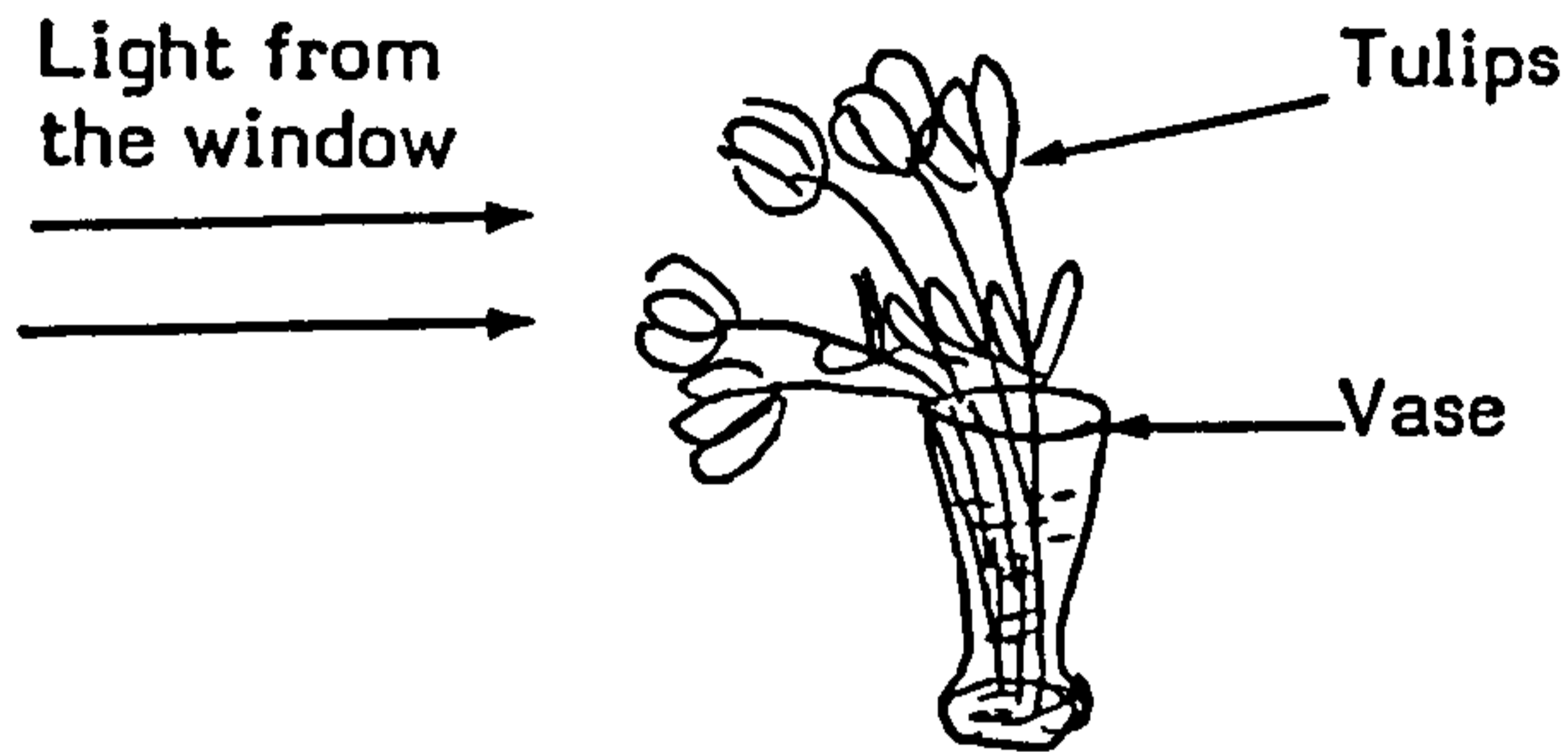
*'A' Level Trial Examination Paper
incorporating the Biology Skills*

Sample IQ Booklets, Scale 2 and 3

Biology to Trial Questions

1. FLOWERS

John bought a bunch of tulips for his mother. She was very pleased with them and put them in a vase in the front window. After one day the flowers were bent over towards the window.



The family started to discuss the problem of the flowers:

Dad said that the flowers had bent over because Mum kept the room too hot.

Mum said it was the light from the window that had caused the bending.

Can you suggest tests that John could try to really see whose idea was right.

Suggested tests:

Skell 32.. Planning an experiment to test a hypothesis

1. DOGS PREFER PEDIGREE CHUM

Mary Brown fed her dog (a black labrador) a meal of Pedigree Chum. The dog ate it with great enthusiasm, but unfortunately was then sick.

What does this test allow you to say honestly about Pedigree Chum ?

MORE ABOUT MRS. BROWN AND HER DOGS.

Mary Brown actually owns four dogs: one black labrador called Prince, two golden retrievers called Coffee and Chocolate, and a corgi called Snap.

Using these dogs can you devise a fair test to prove whether dogs do, or do not, prefer Pedigree Chum ?

Controlling Uncontrolled Variables. - Skills 27 and 28.

Mary's second attempt at a fair test worked as follows. She used all her dogs and fed them one meal a day of Pedigree Chum and one meal of Whofo. Her results were as follows:

Dog	Day 1		Day 2		Day 3		Day 4	
	Meal 1 Chum	Meal 2 Whofo	Meal 1 Chum	Meal 2 Whofo	Meal 1 Chum	Meal 2 Whofo	Meal 1 Chum	Meal 2 Whofo
Prince	All	All	$\frac{1}{2}$	All	$\frac{1}{2}$	$\frac{1}{2}$	UT	All
Toffee	All	All	All	All	All	All	All	All
Choc.	All	$\frac{1}{2}$	$\frac{1}{2}$	All	$\frac{1}{2}$	All	All	$\frac{1}{2}$
Snap	UT	All	UT	All	UT	UT	All	UT

All: All eaten $\frac{1}{2}$ = Half eaten, UT = Untouched

Would you consider Mary's second test a fair test of the advertiser's claim that 'Dogs prefer Pedigree Chum' ? Please give reasons for your answer.

Uncontrolled Variables. Skill 27

What other information would you need to be able to tell whether the second test was completely fair ?

1. SWEETS CAUSE TOOTH DECAY

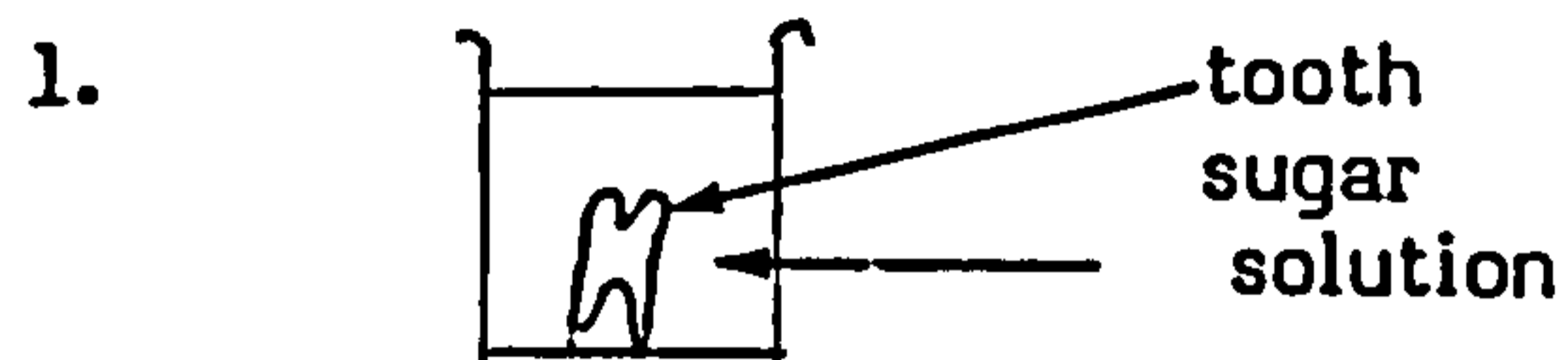
Johnathon is allowed to eat lots of sweets and has lots of fillings in his teeth. Michael, his identical twin, also has lots of fillings but neither likes nor eats sweets.

Tests on teeth

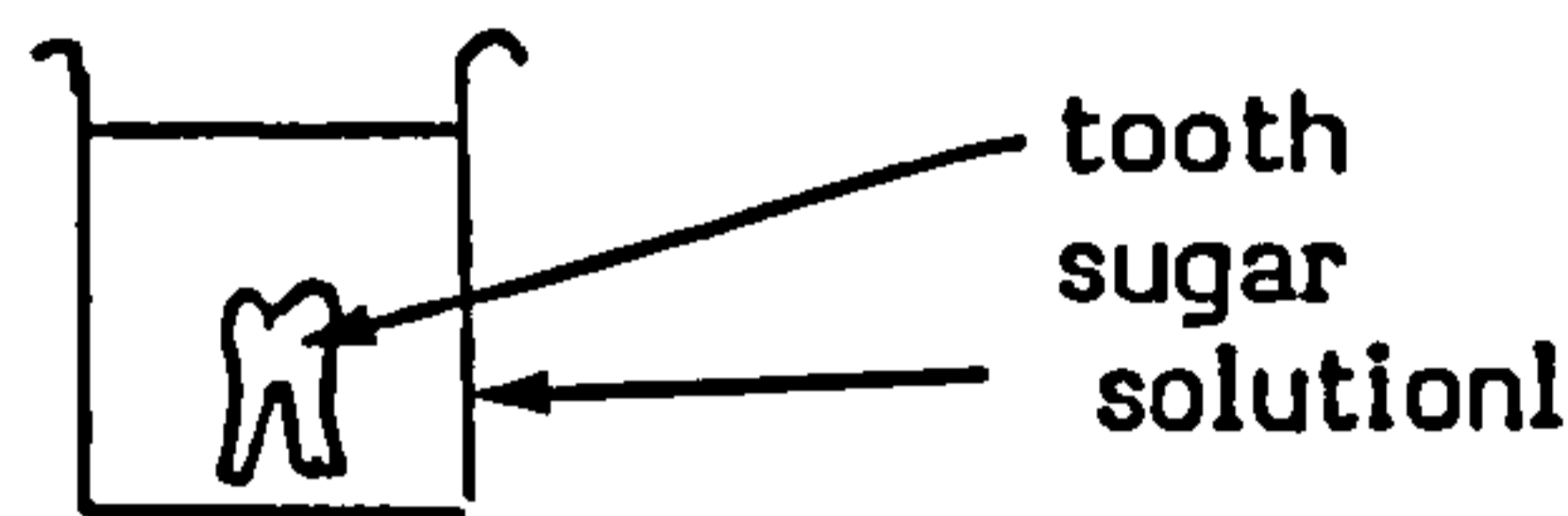
Both twins had undecayed teeth removed to help to space their teeth. They agreed that their teeth could be used for experimental tests in their science lesson.

The experiment was set up in three ways:

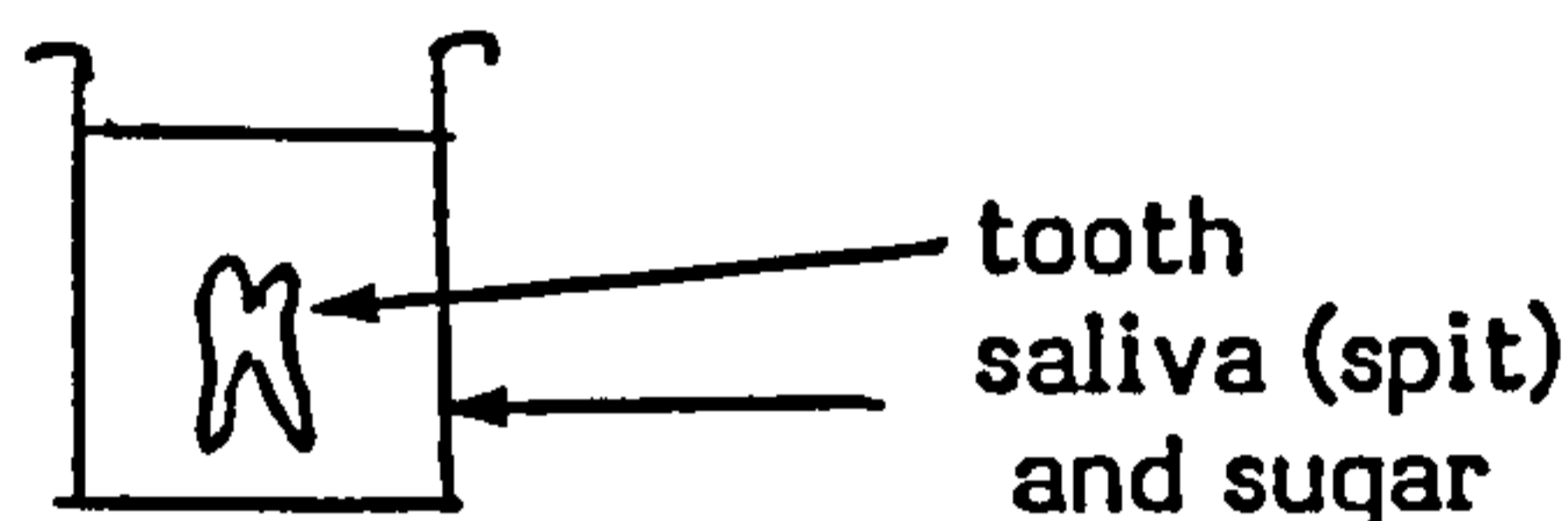
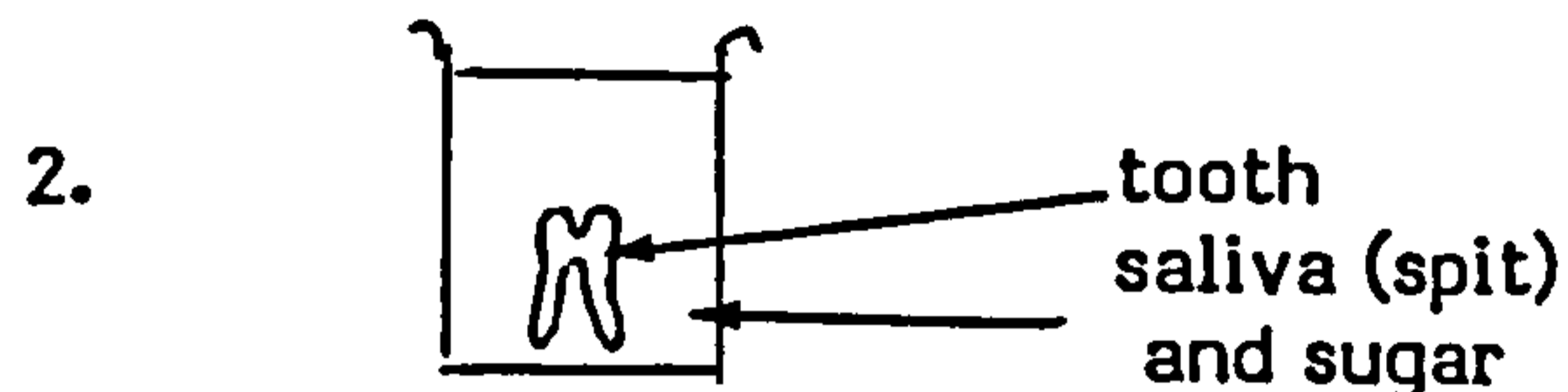
Michael's teeth



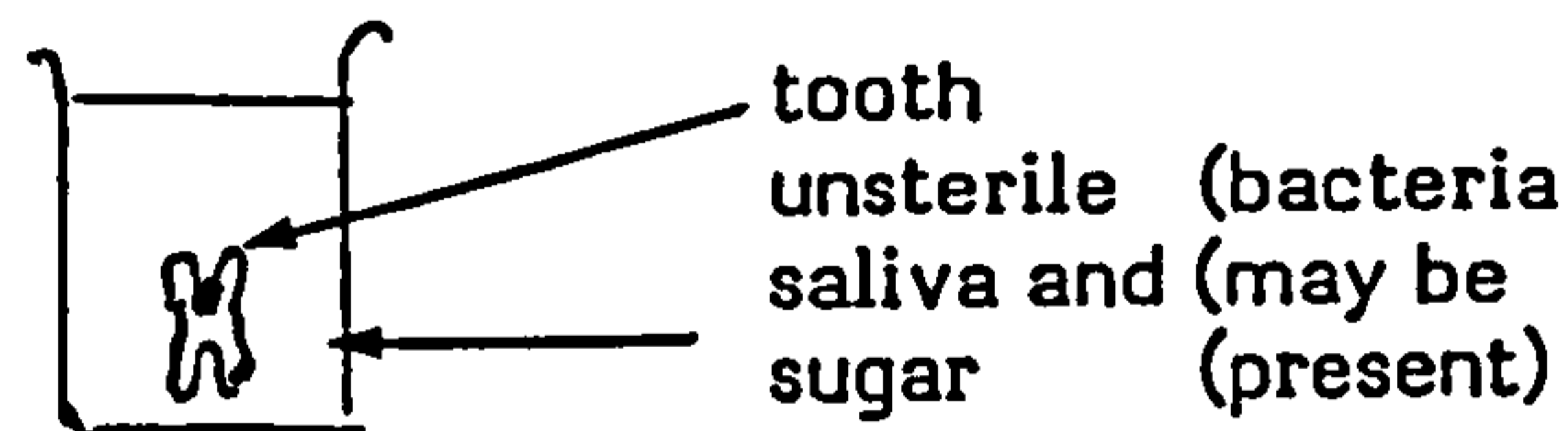
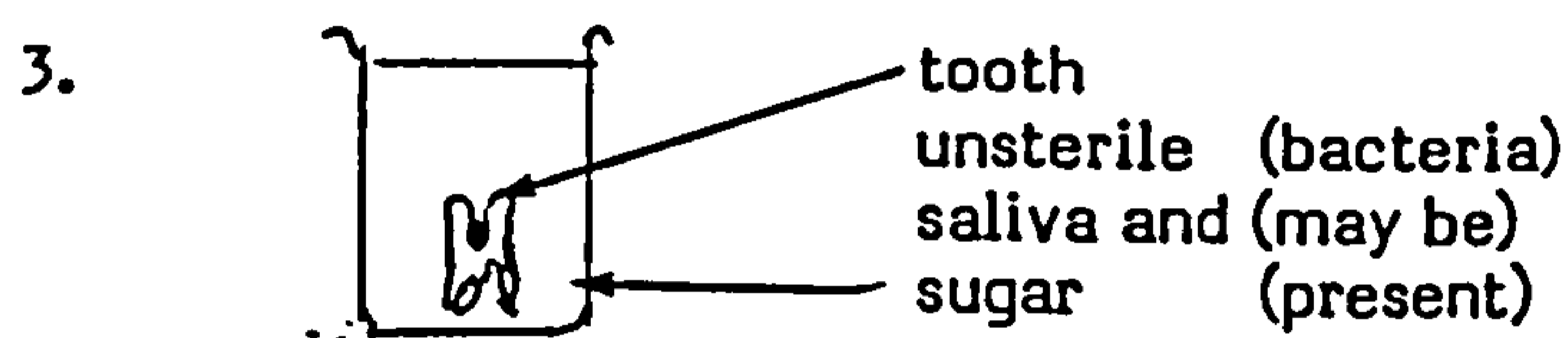
John's teeth



Neither tooth was decayed.



In Experiments 1 and 2 a weak antiseptic was used to prevent bacterial growth, but not interfere with the experiment. Neither tooth was damaged.



Both beakers were kept warm at mouth temperature. Both teeth were damaged.

Michael said that he was now sure that it was germs (bacteria) that damaged his teeth; John said he still wasn't sure.

What other conditions in Experiment 3, compared with Experiments 1 and 2, might have decayed the teeth?

Skill 21 and 28 Recognition and control
of uncontrolled variables

How would you set up an experiment to decide definitely whether the bacteria are the culprits in tooth decay?

Skill 32. testing a hypothesis

construct hypotheses, make predictions and plan procedures to test the hypotheses is assessed in Skills 29, 30 and 32 requiring logico deductive reasoning.

In fact the Culture Fair tests used in this project are largely of the multivariant type and so dependent on deductohypothetical - reasoning and will consequently only be within the capabilities of a person at the formal operational stage.

At this stage the person developed the reasoning and logic to solve all classes of problems without the need for direct physical experience.

After this, Piaget considered there is no further structural improvement, but an ongoing assimilation of material on which to use the structures. Changes in reasoning from there onwards are quantitative rather than qualitative.

Not all adolescents or adults fully develop formal operational thought. Elkind, (1962), Kohlberg, and Mayer (1972) and Schwebel and Raph, (1973) concluded that half American adults do not achieve full formal operational thought, Kuhn, et al (1977) found that a certain proportion of the adult population never advances much beyond concrete operational thought.

The person with fully developed formal operational thought uses hypothetical reasoning capabilities and can deal with complex verbal problems and solve problems relating to past, present and future situations on the basis of existing data. They can construct hypotheses and use them to solve problems or devise means of testing them. They can deal with verbal propositional problems and reason entirely symbolically. Several intellectual operations can be brought to bear simultaneously and systematically to solve a problem. Hypothetical reasoning goes beyond the confines of everyday experience to things of which he

has no experience. It transcends perception and memory (Brainerd (1978), allowing one to contemplate and reason about the unknown.

Deductive reasoning allows one to draw conclusions, deduce answers and make predictions; on the basis of existing data. Hypothetico deductive reasoning enables one to make deductions on the basis of abstract hypotheses (Brainerd, C. (1978). A further refinement at the hypothetico deductive stage is the ability to hypothesise on the basis of either a true or false premise, an ability completely out of the reach of children at the concrete operational level.

At this highest level, children can reason like scientists, as follows:-

Construct Hypotheses,

Devise Experiments,

Control Variables,

Record effects and

Draw conclusions in a systematic fashion.

Scientific thought requires one to think about a number of variables at the same time. They will be able to isolate variables and manipulate them while holding all the others stable and exclude irrelevant variables.

They are capable of empirical abstraction:- knowledge of the physical properties of objects by manipulation of the objects, and reflective abstraction which goes beyond the observable and results in mental reorganisation, internal thought based on, and extended from, available knowledge. Predictions would be included in this category. Analogies can be used.

Piaget divided this highest stage of thought into formal operational (which is less abstract) and propositional operational thought which is considerably more abstract (based on an abstract proposition.)

Adolescents have normally developed reasoning and logical abilities to a level equivalent to the adult population, they may however, have less schemata available for their use. The development of formal structures and Hypothetico deductive reasoning including combinatorial and propositional thought and reflective abstraction is the most important event in adolescent's cognitive development.

As previously stated, not all adults develop formal operational thought (Elkind, D. (1962), (Kohlbrg, L. and Mayer, R. (1972)), but Piaget considers all normal people have the potential to do so.

The development of formal operational thought may be more closely linked to schooling unlike concrete operational structures. (Gallagher, J. and Reid, D. (1981).

Piaget, (1967) in the "Psychology of Intelligence" states that "The structures necessary to the adult mind are not innate but must be assembled little by little, each structure presupposes a construction, each construction originates from a prior structure." Learning, according to Piaget requires construction and comprehension; rote memory is not considered by Piaget to constitute learning.

The age at which children develop schemata may vary with intelligence and Social Environment, (Piaget, J. and Inhelder, B. 1969). Piaget indicated that he

believed that the surroundings(Environment) became more important at higher levels of cognitive development ie. formal operational.

An interesting consideration, (Bringuier, J. 1980), is that a child remembers as he understands something, not as he has seen, perceived or lived something. A child's memory of an event may improve as its significance dawns on him, even though the event has not been experienced again.

Wadsworth (1978) describes how the use of 29 tasks derived from Piaget's work enables one to assess the level of cognitive development according to Piagetian Levels.

There is a wide distribution of levels of cognitive development at every age range eg.,

	Preoperational:- a few
Nine Year Olds	Concrete operational:-the majority
	Formal operational:- a few

Inhelder (1968) stated that true retardation displays as being slow from birth, the individual never progresses past concrete operational level, to reach the formal operational level.

Pseudo retardation is seen in others who progress slowly but finally reach the formal operational level.

Bovet (1976), showed that the developmental rate can vary during life both slowing down and accelerating. The slow stage may possibly be due to lack of stimulation.

Piaget did not observe any differences in cognitive development between sexes, although more definitive work on this area is needed.

The progressive cognitive development concept of learning depends on the amalgamation of the effect of both maturation and the environment. Mental development is the result of the interaction of the organism with the environment, a view first expounded by Plato.

The child can be viewed as a scientist, inquirer or explorer; critically instrumental in constructing and organising his world and in so doing bringing about his own cognitive development.

1.2.5 Science 5-13.

The project was sponsored jointly by the Schools Council, the Nuffield Foundation and the Scottish Education Office, and was based at the University of Bristol, School of Education. The scheme was devised with the objective of matching the science topics and the method of presentation to the cognitive level of the individual or group.

It's objective was to enable children between the ages of 5 and 13 years to learn Science through first hand experience, using a variety of methods.

The Project team aim to match the course content and progression to the capabilities of the children. This posed a number of problems for them:

- 1) Which ways of finding out about science are suited for children in this age range?

- 2) Children in the same chronological age probably having differing mental capacities, which also may be well or poorly developed.
- 3) Children of any age may have already been exposed to valuable exploratory experiences on which to build scientific concepts or may have been totally deprived of such opportunities.

The rationale is that Science as a discipline can help children to gather appropriate experience and help them to find their own answers from first hand investigation. These experiences can then be organised into a pattern personal to themselves.

The teachers aim to retain their perception of the individual natures and needs of the children, with the objective of developing the full potential of each child,

The Nature of Scientific Thinking

Hypotheses are suppositions put forward to account for known facts and serve as starting points for further investigations through which they may be proved or disproved.

Science is concerned with ordering experiences into a structure and extending that structure by making hypotheses, (looking for cause and effect) leading to generalisations. Difficulties will arise if the hypotheses and generalisations depend on abstractions when the children are not yet capable of abstract thought. Such teaching strategies will not be effective. The teacher will encounter difficulties because children within the same teaching group will be at different stages of development. Some older or more able students will be quite capable of dealing with abstractions whilst the rest of the group will not yet be ready, the teacher needs a method of establishing each child's stage of development.

When constructing a new curriculum the study team were aware of quotations from the Schools Council, (Schools Council Report, 1972).

“I have always thought that to define the aims of education in general terms is more or less meaningless, I am under no illusions that to define it precisely is downright dangerous”

“Translating into action any high sounding aims and objectives is difficult but these difficulties are minimal compared to the problems which the absence of such guides creates.”

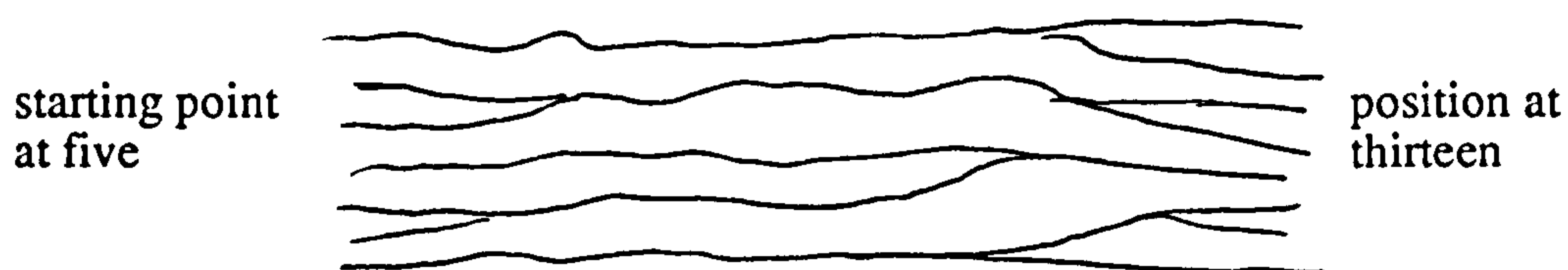
A position of some difficulty is established. The objectives, whatever they are, must not intervene between the teacher and the pupil. They must be present in the teacher’s mind but not so far to the fore that the teacher sees them rather than the children.

The position of Science 5-13 (Schools Council 1972)

- 1) Proposition: that Science is based on logical propositions. It is therefore best deferred until the children have developed some ability to think in abstract terms.
- 2) Until children reach the age of abstract thought they should be helped to gather experience of their surroundings and helped to organise these experiences into small areas of development that can be joined up later.
(In Piagetian terms, construct Schemata.)
- 3) Children should be able to work at their own pace and to their own level. They should be encouraged to develop attitudes of enquiry, objective judgement and to take personal responsibility.

During the chronological ages 5 to 13 enormous changes in a child's use of ideas and reasoning ability occur. Although the overall changes are gradual and continuous the mastery of ideas and concepts is in a general forward direction but with pauses and diversions.

Illustration below - developed from a Guide to Science 5 - 13 (1972)



Two or more ideas may interact to produce a more general idea.

One idea may divide to become more specific. This idea relates to Piaget's construction of increasingly meaningful schemata the idea of increase in both generalisation and specification of schemata.

The span of five to thirteen covers three Piagetian levels of development considered to occur as a continuum of development.

Five Years				Thirteen Years
Pre operational	->	Concrete Operational	->	Formal Operational

Science 5 to 13, endeavours to utilise (with small adjustments) these stages and identify and adapt various scientific activities, giving recommendations as to their suitability for different stages of development..

The Categories used in the science 5 to 13 Project are:

<p>Stage One Pre Operational Transitional to Concrete Operational</p>	<p>Stage Two Concrete Operational well established Mental Manipulation more varied and powerful</p>	<p>Stage Three Concrete and transitional to Formal operations Abstract thought established</p>
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Concrete operational thought, as characteristic of stage two development, leaves gaps when a person endeavours to investigate combinations of variables. The

working method available at this stage is tedious to apply as every combination has to be individually tested and no extrapolation abilities are available. The result is uncertainties and contradictions, therefore, the child eventually accommodates and makes the transition to formal operational strategies.

Stage three is characterised by the ability to handle abstract concepts, to extrapolate beyond experience, to extract principles and to deal with a full range of combinations of different variables.

All children appear to be ragged in movement from one stage to another - in one area of their experience they may progress more rapidly than in others. Progress from one mode of thought to another is considered to occur by the process of accommodation as defined by Piaget, (page 67 of this thesis). Accommodation results from the need to equilibrate the inconsistencies and anomalies encountered during the child's experiences. Adjustments are made that provide the threshold to formal operational thought. Some children appear not to acquire the mental ability to proceed to this stage. Recent work (Page 91 of this thesis) suggests that the number of adults not regularly functioning at the level of formal operations is much higher than originally supposed.

The part which experiences play, in bringing about the changes in a child's cognitive development, are evidently important. With appropriate experiences, the transition from one form of thinking to the next will take place more readily. Science 5 to 13 endeavoured to provide those experiences in a flexibly structured format matching learning experiences to the stages of development.

In planning a teaching sequence, two opposite problems are encountered:

If the material is insufficiently challenging the children will mark time and become bored.

Conversely, if children are expected to deal with concepts for which they have not as yet achieved the requisite level of cognitive development, they will also lose interest and resort to incomprehendingly following instructions.

The latter problem is greatest at the transition to Stage Three when formal operational thought is just beginning to be established.

Many children reach the secondary level of schooling without having established the ideas relating to conservation of quantity, the concept of cause and effect, the necessity for a range of accuracy of measurement and the ability to classify and categorise experiences.

The secondary school may presuppose erroneously the possession of these abilities and so progress in Science will be immediately blocked by their absence. To sensibly arrange a programme of work to suit children's capabilities it is necessary to know the child's stage of development and the activities and objectives suited to the various stages of development. All of this rationalisation has to take place within a class situation with all the children developing at their own particular rate.

The whole series of units was based on the discovery approach and provided an excellent foundation for the Nuffield approach for older students.

The idea of the discovery approach with investigations to be undertaken as near as possible to the time when the child initiates the idea, requires

great flexibility of time tabling and availability of resources. Each child needed to be treated as an individual, not the class as a homogenous body.

Children aged 11 to 13 are hopeful progressing from the stage of concrete operational to formal operational ie., Stage 2 to 3. The question is whether the teacher can identify arrival at stage three. Additionally, an individual child may vary at different times, using formal operational thought in areas familiar to him but reverting to concrete strategies when dealing with more complex or unfamiliar problems.

Formal thinking involves:-

- a) Making formal hypotheses,
- b) Sorting out variables
- c) Drawing conclusions and making generalisations.
- d) Thinking in abstract terms.

A hypothesis:- Is a testable assumption, an IF statement,
It should be capable of testing both by logical
argument and empirical testing,
The testing should involve dealing with variables in
isolation using appropriate controls.

A child working at the concrete level will have difficulty in separating the variables eg., In investigating the 'bendiness' of materials he may compare bendiness of a short fat rod of iron, with a long thin iron rod, or worse still, a short fat iron rod with a long copper rod.

The child at stage two is not systematic and will describe rather than explain his findings. The author finds that the latter mistake persists to some extent at all school ages.

The child at stage three is more likely to attempt to deduce the principle from the result of a particular problem and deal in abstract terms. They develop the ability to manipulate effectively mentally.

Very few children aged 11-13 have reached formal operational thinking, (A limitation that seems to have eluded the planners of Key Stage Three of the National Curriculum).

Mental manipulations required for formal operational thought need to be built up from experiences both inside and outside the classroom.

1.2.6 Cognitive skills in relation to the teaching and learning of Science.

The book, "Towards the Science of Science Teaching", by Shayer and Adey, published in 1981 discusses the level of cognitive skills needed for a proper comprehension of the Science Curriculum.

Children in science classes are expected to display certain Cognitive Skills, these expectations arise partly from the Science Teacher but also more significantly, from the Examination Boards as a requisite part of the GCSE skills to be assessed and more currently by the Department of Education and Science, as the criteria enshrined in Science Attainment Target One as part of the National Curriculum.

The last mentioned criteria are categorised (National Curriculum Council, 1991) in the Orders pertaining to Key Stage Three of the National Curriculum for Science to:-

- i) Plan, hypothesise, predict
- ii) Design and carry out investigations (including manipulating relevant dependent and independent variables.)
- iii) Interpret results and findings (observe patterns and draw conclusions.
- iv) Draw inferences
- v) Communicate exploratory tasks and experiments.

These 5 categories were consolidated from the original 17 Attainment targets and they were further modified as strands of Attainment Target One in the revised orders (National Curriculum Council, 1991)

Sc.1 Scientific Investigation

- 1(i) Question , Predict and Hypothesise
- 1(ii) Observe, Measure and Manipulate Variables
- 1(iii) Interpret results and Evaluate Scientific Evidence.

These requirements are directed at students aged 11-14 years, (Key Stage 3), drawn from the entire ability range.

Similar requirements were included in the skills required for GCSE, 9 of which form the basis for the author's investigation.

Shayer and Adey, (1981) questioned whether such demands are reasonable. They state that: "Many teachers find that there is a chasm set between the expectations expressed in curriculum objectives and the cognitive skills of many pupils."

The situation has not improved in 1992; the difference is that the curriculum objectives have now metamorphosed to curriculum directives (!) as defined by the Government within the documents of the National Curriculum.

According to Piaget (Piaget's Theory of Cognitive and Affective Development, Wadsworth, B.J. 1984) there is a gradual and continuous growth in a child's cognitive ability and with this growth an increased capability to perceive, process and use data. He implies a hierarchy in complexity in the possible ways that the data can be assimilated and accommodated (processed).

In the Secondary School Population ie., those of eleven years and upwards, the younger and less able pupils will be endeavouring to process data at the concrete operational level while the older and more able will be working at the formal operational level where the ability to handle abstractions and deal with multivariant problems becomes a real possibility. Piaget's stages further subdivided by Shayer and Adey, (1981,) are shown below.

Sensory Motor

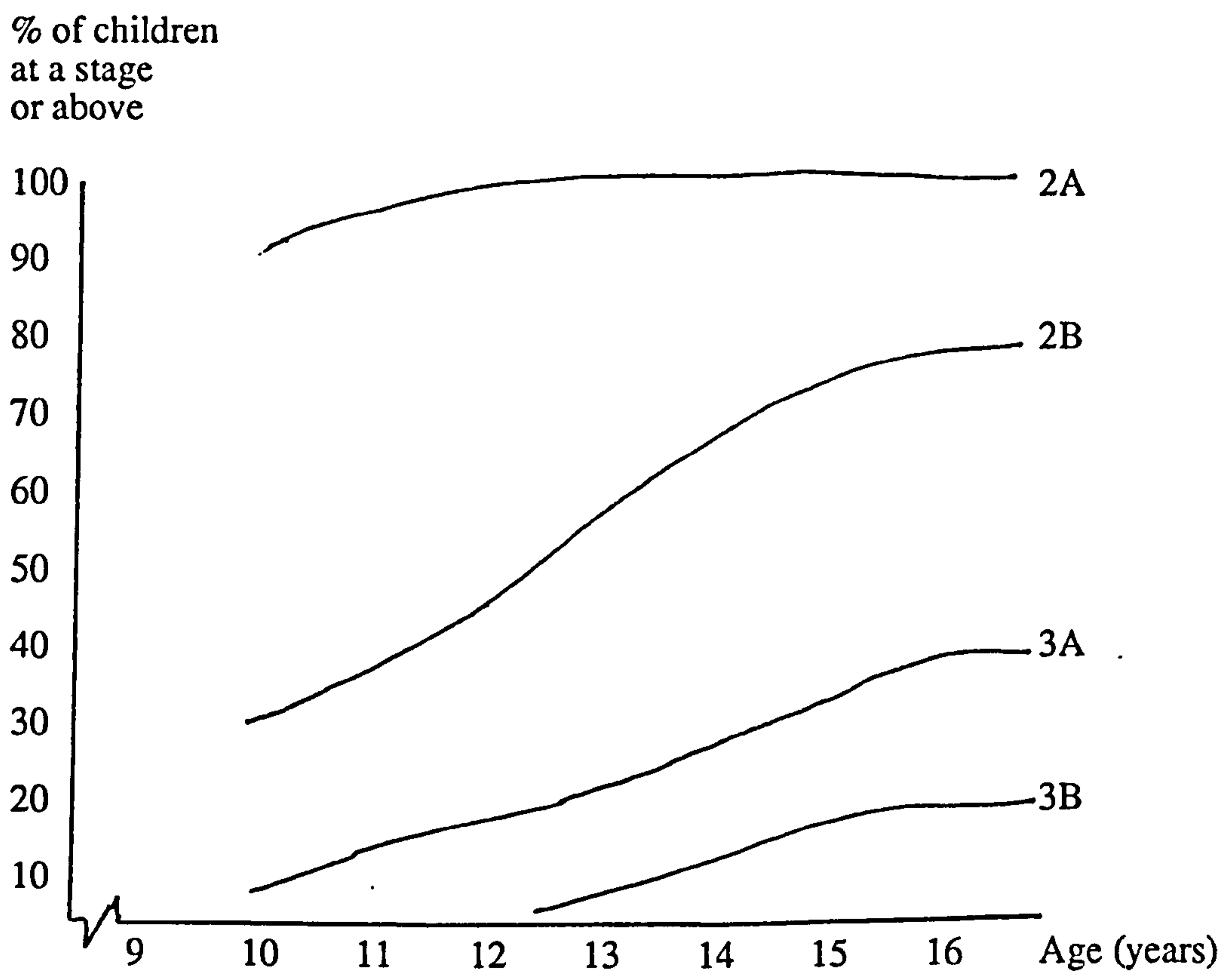
1A	Preoperational
2A	Early concrete operational
2B	Late concrete operational
2B/3A	Transitional
3A	Early Formal Operational
3B	Late Formal Operational

The suggestion is that if students displays concrete operational skills for one topic they will do so when faced with other topics.

According to Piaget's time scale an average eleven year old will be starting to operate at the formal operational level. According to the research work of Shayer

and Adey based on the assessment of their cognitive skills using Science Reasoning Tasks there is a huge discrepancy within the school population with regards to their cognitive development. Overall, only 30% of the school population had reached the early formal operational stage by the age of 16. See the graph adapted from Shayer and Adey, (1981,).

Proportion of children at different Piagetian stages in a representative British child population.



A further complication arises because of the different types of schools in the British Education System.

A truly comprehensive school not subject to 'creaming' is likely to have 20% of pupils in its third year at the early formal operational level, whereas in a highly selective school representing only the top 8% of the pupil population 60-85% are at early formal operational level or higher by the time they reach the 3rd form.

Only students at this stage can comprehend abstract models. This proved a problem for teachers attempting to follow the Nuffield Science curriculum and continues to cause difficulties for the more abstract skills such as, predicting, comprehending patterns of results and hypothesising about several variables, required for both GCSE and the National Curriculum.

The Association of Science Education did a great deal of work on curriculum development between 1960 and 1980, but their work was largely evolved from and developed in the selective sector.

The Nuffield courses were highly stimulating but were not well adapted for the whole range of target population. This may have been the result of testing on a non random sample of schools with too large a proportion of selective schools being represented. The courses were set to the chronological age of the class and did not allow for the level of cognitive development of the intended students.

“The most appropriate science course for pupils at the formal operational level is quite different to that required for the individual working at the concrete operational level, and teaching the same course but more slowly or with a larger number of steps doesn't assist the pupils at the lower level” (Shayer, M. and Adey, P. (1981) page 16.)

A child working at the early concrete operational level, is restricted in the possible options available to them. They can operate on the immediate properties of materials ie., floating or sinking and they can also sort things into classes based on a particular property eg., lightness, as compared to heaviness. However, if another dimension is considered, eg. shape, confusion rises.

It appears to take two years on average, to achieve the late formal stage and it is dependant on the student conceptualising the processes from the assimilation and accommodation of their own experiences (in Piagetian terms constructing their own schemata.) Until this is achieved they will be unable to handle multivariant problems.

Formal Operational reasoning is the pre-requisite to proceed from bivariant reality to multivariant, thus enabling the student to handle problems with three or more variables. This level was needed for a realistic appreciation of Nuffield Combined Science or to achieve Level 4 to 5 at Key Stage 3 in the National Curriculum Science Attainment Target One, as expected as the average level for the entire 13 year old population.

Shayer and Adey used 12,000 students on which to test and refine their battery of Science Reasoning Tasks (SRT's) to establish the cognitive levels of students, classifying them into the categories already defined (page 87). The tasks were organised as a class demonstration and each student completed a response sheet by means of selecting or providing the correct reply. A small sample were tested as part of the class group and also on the basis of individual Piagetian type interviews following his original protocols.

Both sets of results were subjected to statistical analysis and correlation between results produced by the two methods and consistency between SRT's was established.

The advantage claimed for the SRT's over a conventional IQ test is that SRT's provide an assessment of the individual's cognitive development as opposed to an age related figure standardised to the population norm. Additionally they tell you

more about the quality of a person's thinking and the strategies employed, implying a greater predictive value for success in the field of Science reasoning.

They are also useful to allow the teacher to select Scientific problems suited to the cognitive stages of their pupils.

From the analysis of the results the following conclusions were drawn.

- 1) That the ages of attaining the different stages are considerably higher for the average British School population than was found from Piaget's work.

At 9 years of age, 30% had reached concrete operational level.

At 12 to 14 years 20% had reached early formal operational level.

A levelling off occurred in cognitive development in the last two compulsory years of schooling whether the students had achieved formal operational level or not.

The implication from the levelling off at the ages of 14 to 15 and 15 to 16 years suggests that only 30% of the adult population can make use of theoretical models, or will be able to handle multivariant problems, which use cognitive strategies characteristic of formal operational thinking. This result concurs with the findings of Kuhn, et al (1973) in spite of Piaget's assertion that all normal adults will achieve complete formal operation eventually.

The Author tentatively suggests two ideas for the mismatch between the ages, Piaget's sample being considerably more advanced than the average British or average American population.

1) That Piaget's samples were in fact greater than average ability , a plausible explanation because he used his own children and those of his colleagues for a great deal of early work.

2) While the children were in fact research subjects, they were receiving a great deal of individual attention and the opportunity to talk about and evaluate their ideas so receiving more opportunity to equilibriate their schemata, an advantage unlikely to be available to the bulk of the British School Population.

Piaget's age ranges for the stages of cognitive development, approximate closely to that resulting from a school population produced by a selective examination at 11+.

In fairness to Piaget, he never intended his results to be used to provide norms for the ages at which cognitive levels were achieved, but rather to indicate that cognitive development was a continuum with an invariant sequence of development, with each stage forming the foundation on which the next stage is constructed.

Analysis of the results of the SRT's for an unselected British population is as follows:-

1.5% exhibit late formal reasoning by 12 years 3 months

7.1% exhibit late formal reasoning by 14 years 4 months.

Consequently, there will be an absence of the necessary formal operational thinking in adolescence which is needed for much of the Science Curriculum.

10% of the population have passed from concrete operational thinking to formal operational, prior to the onset of physical adolescence.

The 80 to 90th percentile more or less conforms to Piagetian timing of stages.

70th percentile are unlikely to develop beyond early formal thinking by the end of adolescence.

Below the 60th percentile people are unlikely to develop beyond concrete operational before attaining school leaving age.

These results bode ill for the National Curriculum encompassing Science for All and necessitating high levels of analytical thinking for Science Attainment Target One.

It also explains the Author's findings of the low success rate achieved by many of the students undertaking the Cognitive skills relating to the GCSE Biology Syllabus.

1.2.7 Thinking Science Cognitive Acceleration through Science Education. CASE project.

Philip Adey, Michael Shayer and Carolyn Yates working at Kings College London developed the CASE project, published by Macmillan in 1989. This contained a sequence of Science tasks within the programme designed with the specific objective of encouraging the development of thinking from the concrete operational level to the formal operational level.

Prior to the publication of the curriculum material in 1989, Shayer and Adey had used the CASE programme for two years between 1985 and 1987 as a carefully controlled trial involving 12 classes. Half the classes received special science activities as provided in 'Thinking Science' in place of some of their normal science lessons, the other half did not. The following results are recorded in a paper by P.Adey, (1992,).

At the end of two years, the experimental group showed significantly greater levels of cognitive development over that of the control group. However, there was no significant improvement in science performance at this stage. When both the groups sat their GCSE examinations two years after the end of the experimental intervention the target group's examination results were considerably better than those of the control group in Science, Maths and English Language. 50% of the CASE group obtained Grades C and above, compared to 25% of the control group.

The National Curriculum AT1 in Science at levels 5 and above requires formal operational thought to enable the students to comprehend multivariant problems. The average 16 year old is supposed to reach the level of the 6/7 border, (DES 1989 p8) so material which assists the development of formal operational thinking will be very valuable.

1.2.8 The Cognitive Development of the Pupil as a Scientist.

The Open University Press published Rosalind Driver's book "The Pupil as a Scientist" in 1983. This book endeavours to elucidate the pupils' cognitive development within the field of Science.

Very young children encounter every day natural phenomena and construct sets of expectations and beliefs in an effort to make sense of their experiences, eg., a baby dropping a rattle over the side of a crib very rapidly learns to expect it to be on the floor when he looks over for it. Similarly if he pushes a ball he expects it to roll away from him (and hopefully both items will be lifted or rolled back to him.) By the time a child receives formal Science teaching he may have established a firmly held set of beliefs which may well conflict with the accepted theories that the science teaching aims to communicate. This 'Prior Entry Phenomena' may prove confusing to the child and impede the assimilation of the accepted theory.

Little attention is paid to the ideas that the pupils themselves bring to the learning task, although these are a significant influence on what pupils can and do learn in the science lesson.

David Ausubel, (1968), commented on the importance of considering the child's preconceptions. They may be amazingly tenacious and resistant to extinction. It is important to know 'where the child is now' (the child's own ideas) in terms of scientific learning.

In some cases, the child's own intuitions about natural phenomena may well be in keeping with those they meet in the science lessons, in other cases the accepted theory may be counter intuitive.

Science curricula from 1960 to 1980 tended to develop along heuristic lines, particularly as exemplified by Nuffield Science. This change in the nature of teaching was from the transmission of a catalogue of facts to an attempt to present science as a consistent series of ideas.

Pupils' laboratory experiences organised on the discovery method were expected to lead to two outcomes. On the one hand the pupils were expected to explore phenomena themselves, collect data and make inferences based on this data, on the other this process was expected to lead to the currently accepted law or principle. These two outcomes may prove to be mutually incompatible resulting in frustration for both the student and the teacher.

From the authors observation, pupils rapidly come to recognise the rules of the game, and ask "Is this what I'm supposed to get?" Or alternatively, "Is this the right answer?" This is not quite within the spirit of the discovery method.

There are differing views of science. The Empiricists view is that all knowledge is based on observation. Linked with this, an Inductivist position:- as suggested by Bacon 400 years ago, That scientific laws are reached by a process of induction from the facts of observations - 'sense data'

This position relies on the principle that observations are objective and the facts immutable, this view accords with the heuristic approach and also a naive approach to the Discovery Method of Nuffield Science.

Observation is no longer seen as objective but is now seen to be influenced by the theoretical perspective of the observer. This is elegantly stated by Karl Popper, "We are prisoners caught in the frame work of our theories."

In the school science situation, with children in the role of observers, they observe the world through their own conceptual spectacles and they may have their own alternative framework. Great care is needed when using the discovery approach if students are expected to induce general principles from their results. The child may indeed arrive at a generalisation, but it may not be the one intended by the teacher.

Failure of a child to abstract and understand the currently accepted theories of science may be seen as the child's error in not observing accurately, or alternatively, not thinking logically about the pattern of results.

The underlying slogan of the discovery method is the phrase "I do, I understand". Regrettably, a not uncommon outcome is "I do and I am even more confused." (Driver, R. 1983)

One cause of confusion may be that, a pupil may have to comprehend a new principle whilst simultaneously abandoning an alternative framework which up to then has worked well for them. (Ausubel, D. 1968) as previously stated, found that preconceptions are amazingly tenacious and resistant to extinction. The unlearning of preconceptions may well prove to be the most determinative single factor in the acquisition and retention of knowledge.

Pupils commonly hold alternative frameworks and attempt to use them to explain new events. An interesting situation often found, is that younger children tend to use their qualitative judgement in predicting the outcome of an experiment and frequently give the correct response.

Older children may use additional information which is only partly assimilated and accommodated, they may therefore use it incorrectly and arrive at the wrong answer.

(An unfortunate example of the triumph of teaching over common sense.)

By mid adolescence, the student has established greater competence with hypothetical reasoning and will return to the correct answer.

Science Teaching is supposed to train people to be observant. However, different people looking at the same thing may perceive it rather differently, depending on their previous experience. An observer mentally checks his perceptions against his expectations and an inexperienced observer may have problems distinguishing relevant from irrelevant phenomena. Pupils may need an opportunity to explore irrelevant details to establish a better understanding of the problem, i.e., to eliminate the non-relevant information.

The Constructivist Hypothetico deductive view suggests that theories are constructions of the human mind which are tested and evaluated through experience of the processes. This view is encapsulated in the Piagetian concept whereby information is assimilated into existing schemata. Accommodation occurs to incorporate the information, adjustment occurs to the schemata or new schemata are constructed if required. This process requires time as the child has to check, test and evaluate the new ideas. Finally equilibration takes place and the new framework can be effectively used.

Alternative frameworks have to be built up over an extended period, which will take a considerable number of classroom activities to enable such a change to take place. An existing framework will not be rejected until there is an alternative, adequate and reliable construct to take its place. The constructivist's view of

science indicates that in order to understand conventional concepts and principles, they must be presented and then guidance given to help children to assimilate lines or principles, in what is possibly a new way of thinking about them. It is over optimistic to expect these principles to be 'discovered' from the basis of the student's practical work.

J.S.Bruner, (1963) suggested that it helps pupils to apply ideas to new situations if the connections between the ideas are made explicit by the teaching ie., it facilitates transfer. The difficulty is how to transmit these connections to the pupil. The connections are often crystal clear to the science teacher while being far from apparent to the pupil. (Driver, R. 1983) For new principles to be assimilated and accommodated these must not be too great a dissonance between the incoming information and the existing structure, otherwise equilibration is unattainable. However, if there is no dissonance between the input and existing cognitive structures no adjustment is necessary and there is no stimulation for cognitive development. Effective learning results from the stimulus of moderate cognitive dissonance, a 'reasonable' degree of difficulty and novelty for that particular student. Scientific thought is often considered to be of the convergent type resulting in one acceptable response, the role of imagination in science is rarely emphasised and yet it probably plays an important role in enabling pupils to grasp new ideas.

Opportunity is needed to test alternative explanations and this exemplifies the plural nature of scientific theory.

Two important ideas which one should aim to transmit during modern science teaching are:

1) Pluralism of Scientific Theories

The idea that theories are scrutinised, tested and approved or rejected by the community of scientists.

- 2) The Revolutionary nature of science - that progress in science is the result of major changes in scientists' theories as the outcome of additional and more sophisticated testing of the original concepts.

Initially, in Piagetian terms, in the pre-operational stage the child is egocentric, assuming that the change and the nature of the change is dependent on his own action. eg., something floats because of the way he put it down on the water.

At the concrete operational stage, the child constructs schemata as the result of his direct experience, testing out ideas practically. He can use simple logic to solve problems relating to up to two variables.

At the formal operational level (Hypothetico deductive), which develops around adolescence, the person can devise and test hypotheses relating to several variables and at this point can operate on the intuitive level alone without the need for direct experience.

The original concept as expounded by Piaget was that if a child could utilise formal operations for one problem this cognitive level would be equally well applied to other problems. Both Piaget and Ausubel assume that an individual organises and structures his own learning. Piaget focuses on content independent logical structures.

However, there appears to be evidence (Driver, R. 1983), that the familiarity or unfamiliarity of the material influences the students ability to fully utilise his hypothetico deductive logic, unfamiliar material being handle less competently. Another factor considered to effect a child's cognitive skill is the capacity of the working memory - the amount of information a person can keep available in the mind at one time - (Bryant, P.1974,) and this need not be age related.

Novak (1978) suggests that cognitive development is not a stage dependent process but is the result of a framework of specific concepts acquired during the person's lifespan. Case (1976) rejects the idea of age restriction on learning and suggests that the age and sequence in which tasks are successfully performed are simply a function of the complexity of the tasks and prior experience of the individual. This idea is raised as contradiction to Piagetian theory, however, it is not the results of Piaget's work which is being called into question but the interpretation of these results. Piaget himself did not suggest that his stages were rigidly age related, his idea was that the stages were definitely sequential and each stage lead the foundation on which the next stage of cognitive development could be built.

Ausubel postulates that knowledge is structured as a framework of specific concepts. He suggests two categories of learning:-

Rote learning, ie., learning by heart, understanding, is not a prerequisite for this process, as opposed to 'meaningful learning' which can only take place when the knowledge is related by the learner to relevant existing concepts.

The most important single factor in learning is what the child originally knows, if one can ascertain this one can then teach the child accordingly. (Ausubel, D. 1968).

When comparing the points of view of Piaget and Ausubel, Piaget focuses on logical operations whereas Ausubel concentrates on the structuring of content.

When teaching material is being produced, both points of view can be taken in to account, the content and structure should be complementary in the curriculum design.

The distinction from the curriculum development view point of Piaget's and Ausubel's concepts of learning can be crystallised as follows:

Ausubel's View: If learning new ideas depends primarily on what ideas the child already has, it should be possible, with a suitably designed sequence of instruction to teach any idea to any child at any age.

Piagetian viewpoint:- if there are structures of thought which only develop with age and experience it would be inappropriate to give instruction in those ideas at too young an age.

The author's experience leads her to believe that Ausubel's idea does not correspond to the observed situation:- Children appear to actually regress, they temporarily lose their ability to apply cognitive skills that they have already mastered, if the new material is perceived to be particularly difficult or complicated.

Science activities planned by Shayer, (1972) place emphasis on pupil's logical capabilities or level of operational thought. They require the child to be operating at the Formal Operational Level, using hypothetico deductive reasoning in order to, control variables, infer from data, impose quantitative models on observations, draw inferences and make predictions.

These activities are dependent on the individual's concepts of causality and legality, the recognition of the logical necessity of certain predictions. The same capabilities are needed in 1992 to fulfill the criteria of the GCSE syllabi and the requirements of the National Curriculum.

Questions involving Assertion/Reason discrimination, place strains on student's causality, legality concepts. Students frequently confuse cause and effect and also state that a particular outcome must be caused by a particular event when in fact the two are not linked.

They frequently ignore the results of an experiment (Legality) and resort to the causal framework.

In adults it has been found, (Wason, P. 1972), if the causal and logical tasks conflict, subjects tend to base their argument on causal aspects rather than logical reasoning.

The Policy Statement of The Association for Science Education, ASE, states that Education through Science should have the following Aims:-

1. Understanding of Scientific Concepts,
2. Development of cognitive and psychomotor skills,
3. Ability to undertake enquiries,
4. Understanding of the nature of Scientific enterprise.
5. Understanding of the relationship between Science and Society.
6. Development of a sense of personal worth.

Some of these aims conflict eg., Acquisition and understanding of scientific concepts and the use of students own enquiries. This conflict has existed for as long as science has had a place in the Educational Curriculum. (Board of Education 1918).

Curriculum developers in America have been incorporating the Process Aims since the 1950's. The National Science Teachers Association NSTA Curriculum Committee. (Theory into Action 1974) aimed to promote the skills of scientific

enquiry, the understanding of scientific principles and their application to everyday life.

The Australian Science Education Project, Science 5-13, also involves ideas requiring hypothetico deductive reasoning:- controlling variables, proportional reasoning.

Shayer and Adey have highlighted the mismatch between the logical demands and the level of thinking of most secondary school pupils in Britain. Pupils are being exposed to two types of learning at two levels simultaneously, observation of new phenomena and attempting to relate them to accepted theoretical interpretations (often also new to the pupil). Some pupils are prepared to suspend judgement, to learn rules or laws even though they cannot relate these phenomena to their own experiences, in the belief that at a later date they will make sense. However, most Secondary School pupils expect more immediate intellectual satisfaction. They need to make sense of the scientific ideas presented to them in a more immediate way. (Driver, R. 1984).

CHAPTER TWO

METHOD

2.1 INTRODUCTION TO THE METHOD

Sequence Of Work

The skills selected were all of a theoretical nature requiring cognitive skills and were all capable of being tested by written questions with written responses.

They were as follows:-

- 23 Recognition of anomalous results
 - 25 Recognition of patterns within a sequence of data.
 - 26 Drawing valid conclusions.
 - 27 Recognition of an uncontrolled variable.
 - 28 Control of the uncontrolled variable.
 - 29 Devising a hypothesis to explain a complex set of results.
 - 30 Devising three hypotheses to explain a complex set of results.
 - 32 Devising an experiment to test a hypothesis.
- Making predictions on the basis of previous results.

All but the last of these skills were present in various forms in all the NEA syllabi and also in the MEG and SEA syllabi. In addition, they are included within the National Curriculum for Science. (1989).

2.2 Testing Sample Questions

During 1988, a variety of questions were compiled to test the different skills. The questions were constructed in such a way that prior tuition of the topics was not

necessary to allow the students to successfully undertake the questions; the questions tended to be open ended with several different acceptable responses.

The questions were tested on volunteers of all ages at King Henry VIIIth School. The responses were marked and the questions altered to eliminate ambiguity. Unsuitable questions were discarded.

The questions were then assembled into different sample booklets so that each booklet contained the full range of skills. The booklets were then tested on further groups of volunteers to establish the best combination of questions that resulted in unambiguous responses and could be completed within an acceptable time period. The author envisaged a combination of a question booklet together with an Intelligence test that could be completed within 60 to 70 minutes, a common duration for a Science Lesson which should not be too exhausting for the candidates.

An open ended question was included at the back of the booklet:- Sample Booklet to investigate conditions which the candidates considered would adversely affect their performance. Appendix II, Biology Skills Question Booklet.

During 1989, the question booklets were tested on a GCSE fourth form class under timed conditions, the skills passed were credited towards the students' school based practical assessment.

The booklets were then duplicated ready for use in the participant schools.

(Appendix II)

2.3 Selection of Intelligence Test

The author appreciates the fact that 'Intelligence' as such is almost impossible to define and is only one of a battery of attributes that are required to facilitate effective study. However, the author wished to have some objective measure of the students' ability to reason, therefore some form of Intelligence Test appeared to be the best option available.

The requirements of the test were as follows.

- 1) That it should not be influenced by the teaching the student had received.
- 2) That the possession of a wide English vocabulary should not favour the student, the author was expecting many students from different ethnic groups to be included within the sample.
- 3) That the test could be undertaken by a whole group simultaneously and did not require individual administration. This eliminated tests with oral responses.
- 4) That the test should be relatively short. This enabled the student to complete the IQ and the Biology Question paper at the same session without undue exhaustion.
- 5) That the test should have been adequately standardised on a large test population.
- 6) That the test should be applicable to a wide age range, including adults.

The author examined many tests and selected Cattell:-Culture Fair tests supplied by the Institute of Personality and Ability Testing. (IPAT inc.) Champaign, Illinois. (Appendix II)

The test is supplied in the form of a booklet, a multiple choice answer sheet and full instructions for the administration of the test.

It was also supplied in two categories. Scale 2 is appropriate for children of 8 years and above, it can be used with older children and most adults.

Scale 3 provides greater refinement in the higher intelligence ranges, it is therefore suitable for students when selection for entry has already taken place and also for older students where ceiling effects with Scale 2 could be anticipated.

The author pre-tested both Scale 2 and Scale 3 tests on a small sample and found very close correlation to within one IQ point. The test however gave considerably lower results than the Moray House Verbal Reasoning Test but did, to a large extent, display the same order of ability. Not surprisingly, there were some anomalous results which can be explained because the Moray House test relies largely on verbal ability which is eliminated from the Cattell test.

Precise instructions were given for the test administration of the Cattell test (Appendix II). Both Scale 2 and Scale 3 tests needed 12½ minutes working time, plus time for explanation.

2.4 Selection of Schools

Twenty Schools in the area were approached (See appendix V, letter of introduction) and invited to participate. The following schools agreed to participate:

School	Type	Co Ed / Single Sex	Science Teaching Method
Cardinal Newman	Coventry LEA	Co Ed	Traditional
Stoke Park	Coventry LEA Community College Comprehensive	Co Ed	Traditional
Tile Hill Wood	Coventry LEA Comprehensive	Girls Only	Traditional
Woodlands	Coventry LEA Comprehensive	Boys Only	Traditional
Judge Meadow	Leicester LEA Community College, Comprehensive	Co Ed	Process Science
Rufford	Nottinghamshire LEA Comprehensive	Co Ed	Process Science
Wreake Valley	Leicester LEA Community College, Comprehensive	Co Ed	Process Science
Coventry School Bablake	Independent Selective	Co Ed	Traditional
Coventry School King Henry VIII	Independent Selective	Co Ed	Traditional
St.Josephs Covent	Semi Selective Independent	Girls Only	Traditional

2.5 Administration of the IQ test and the Biological Skills Test Booklet

Appropriate arrangements were made to test the students during their science lessons, One hour five minutes being the shortest time available and one hour fifteen minutes being the longest time period. The day of the week and the time of day when the tests were administered could not be controlled because of the constraints of both the students' and author's timetables.

In two cases, for logistical reasons, the IQ test had to be administered at a separate session from the Biology question paper, however, the overall time allowed was not outside the range indicated above. The students concerned were the 19 from Rufford School and 22 of the 38 candidates from St. Joseph's Convent. The overall results from these two schools did not appear to be affected by this variation in procedure.

It was necessary to administer the IQ test to the very precise specification of the Test producer to maintain its validity; it was always administered before the Biology Question Paper.

The Biology Question Paper was answered at the pace of the student within the allotted time available.

After completion, both the IQ papers and the Biology Question Papers were marked by the author; the Biology papers were returned to the students when the results had been recorded, these were therefor available for the students GCSE assessment. The IQ results were not released. All Biology questions were marked to the NEA criteria for use by the author, however it was necessary to present the results in different forms to make them useful to students using different syllabi or different GCSE boards.

2.6 Processing of Results.

The results were fed in to the computer at the University of Warwick. IBM 4381 on SKY. Using the programme SPSSX (Statistical Package for Social Sciences.), language SPSS.

The ten skills were cross tabulated against all the other variables, the responses relating to interference factors were also cross tabulated against the other variables.

The percentage pass rate for each skill was calculated and also computed for each skill with reference to each variable.

2.7 Criticism Of The Procedure

The combination of the IQ paper and the Biology Question Paper appeared to be overpowering to some of the candidates. Some, in fact, did not attempt all the questions, possibly due to disinclination, exhaustion or a fall off in concentration, few people actually ran out of time.

However, all the questions were thoroughly sampled when the results of the whole test population were considered.

Skills 27 and 28 appeared to be much easier for the students than the other skills. The author suspected that this result might be caused by the fact that these questions were at the beginning of the paper, to check this the papers were assembled in a different order and tested on another batch of students; the high success rate for skills 27 and 28 was maintained.

Skills 30 and 32 were tested towards the end of the paper and had a low success rate. This difficulty was offset by the fact that these skills were tested on two occasions on the paper. When these skills were presented at the beginning of a reassembled paper, they were still often wrongly answered or not attempted, presumably students perceived these questions as being beyond their capabilities.

The open ended question on the last page of the booklet, included to endeavour to establish factors which adversely affected concentration and presumably success in problem solving, was not effective. Many people gave no reply. Other students who recorded very poor responses to the Biology Question Paper claimed always to be able to concentrate well. Only very able mature students appeared to recognise and analyse working situations thoroughly. The responses that were received were so varied that a meaningful analysis was scarcely possible.

2.8 Further Lines of Development

The author wished to investigate the correlation of the eight GCSE skills under investigation with the final GCSE grade achieved by the candidate.

A letter was written to the Research Department of the JMB which holds the data bank pertaining the NEA, GCSE results. Unfortunately, no records are retained relating to the school based practical assessment which would enable one to investigate the performance of individual candidates in each skill.

In order to pursue this line of enquiry the author analysed the individual practical assessment records of pupils from the three schools presenting single subject NEA Biology over a period of three years, together with the final result of the pupil.

The schools involved were Coventry School, King Henry VIIIth, Coventry School Bablake and Stoke Park School.

The directive relating to the practical assessment of NEA Biology states that students should be allowed additional attempts (number unspecified) at skills, if they are unsuccessful on the first attempt. The author therefore noted whether each candidate had finally achieved each skill and also whether the skill had been passed on the first attempt. This was possible because the date when each skill is passed is recorded, so passes at later dates than other candidates implies either initial failure, or occasionally absence. The later situation is identifiable from the teachers' records.

2.9 Additional means of monitoring the skills

Most GCSE and A Level written papers now include a proportion of questions which test the skills that have been tested under non examination conditions by teacher assessment. These skills form the basis of this study.

The Author therefore used the last two years GCSE 'Trial' examination papers to establish whether the candidates who had already passed a skill continued to use this ability successfully when it was included as part of an examination paper. However, it was not possible to find suitable questions to sample all the skills. Only skills 26, 27, 29 and 30 were actually sampled.

The IQ's of the students were established by reference to the Verbal Reasoning Test used as part of the school entrance examination. However, as previously stated the Moray House test used, gives a higher IQ rating than the Cattell test when both sets of data are available for an individual.

An additional fault in this piece of work occurred when skill 27, involving an uncontrolled variable, was tested on the examination paper because only a very specific response was accepted on the mark scheme to qualify for the mark.

2.10 Expansion of the tests to include additional age groups

With the development and publication of the National Curriculum, the same skills were in fact included within AT1 for Science. The author therefore decided to expand the study to include pupils around the ages of seven, eleven and fourteen years, ie at the end of Key Stages One, Two and Three.

An additional series of questions were produced, (Appendix II) tested and then administered to pupils in the third year of King Henry VIIIth School. The intelligence test was also given.

Very similar questions, incorporating the same skills, and the IQ tests were administered to the eleven year old pupils in King Henry VIIIth Junior School. In addition, pupils from Earlsdon Junior School were permitted to answer the Biology Skills Questions.

Pupils around the age of seven were tested at Davenport Lodge School, Kenderdine Montessori School and Cheshunt School. It was not possible to administer an IQ test as the Cattell test is only applicable for age eight years and above and alternative tests would not have been comparable. The questions testing the Biological skills were equivalent to those given to the eleven year olds but were explained orally to the pupils. Help was given when the child knew the response he or she wished to make but was unable to write it.

14 year old pupils from the third forms of Coventry King Henry VIII were tested using similar but slightly more complex questions which still sampled the same skills. (Appendix II) They were tested for IQ rating using the Cattell tests Scale 3. Further expansion of the work was undertaken to include students of around seventeen years. The author tested the Biology Advanced Level Students at King Henry VIII. It was noticed that the Joint Matriculation Board 'A' Level examination paper had begun to include questions incorporating the skills under consideration. The author used relevant questions from the structured paper in the Trial Examination and also set a compulsory structured question on the Option Paper testing all the skills. In addition to this, the author had access to the skills achieved by the students at GCSE, whether resits were required for any skill and also the final 'A' Level Grade. All but two of the students agreed to undertake the IQ test.

On completion, the author had results relating to the nine skills from pupils of a similar IQ range at the following ages:-10 to 11 years, 13 to 14 years, 15 to 16 years and 17 to 18 years.

The 7 year old results were not compared directly because of the lack of an IQ result.

CHAPTER THREE

RESULTS

RESULTS

3.0 Introduction To Results

The results are divided into three sections.

Section 1: Relates to the main test sample who undertook the IQ paper and the original Biology Skills test paper.

Section 2: Uses information derived from student record cards and GCSE and 'A'Level examination results

Section 3: Involves extension of the tests to include additional age ranges.

The Graphs which relate to the Results Table included in this Results Section are displayed in Appendix IV.

Section 1

The original population of 247 individuals used for this study was drawn from 10 schools. They were tested under standard conditions and their results recorded, analysed and cross tabulated using the computer programme SPSS on the University of Warwick Computer working on SKY.

Appendix III, comprises the computer printout of these results.

The results were cross tabulated to display the interaction of the various criteria. During this procedure, 3 cases appeared to be missing. The explanation of this anomaly is that three candidates completed the Intelligence Test section but failed

to complete any of the Biological section and so were missing from all the skills results.

Additionally the section of the paper which the author intended to use to assay the factors which respondents themselves considered to be influencing their performance was completed by so few candidates that the author decided that this data was too limited to be of value to the study It was therefore omitted.

The data was systematically analysed and percentage pass rates for each skill calculated using the computer cross tabulations. Appropriate tables and figures were constructed to display this data. IQ appeared to be very significant when the success rate for different skills were considered, (Table 3.3). Page 123. The author therefore prepared tables with candidates cross matched for IQ to eliminate the effect of this variable and so allow other variables to be compared more accurately.

Section 2

The author wished to explore the correlation of the success in the nine individual skills, with the final GCSE Grades achieved by a relatively large sample of students. The objective was to try to establish whether any of the skills could be of predictive value for overall success in Biology at GCSE Level.

As stated in the method, the necessary information was not forthcoming from the Joint Matriculation Board. The author therefore abstracted the information from a large sample of student record cards together with the students' final grade. In addition to this she received the grades achieved by the candidates in the original sample and cross tabulated and compared all this data.

This procedure was repeated for students studying 'A'Level Biology. Their original facility at the nine selected GCSE skills was recorded and compared to their final 'A'Level Grade, with the objective of establishing any existence of correlation.

Section 3

The author constructed additional tests (Appendix II) and administered them to three younger age groups, 5 to 7, 10 to 11 and 13 to 14 years. The older age range of 17 to 18 years was also investigated. The objective was to study the order of acquisition of the skills and their retention or loss during the period of formal Scientific Education.

3.1 Results Section 1 - All graphs and statistics are displayed in Appendix IV

3.1.1 Consideration of the percentage success rates for the 9 skills and the mean IQ to pass each skill (Tables 3.1 a and b, 3.2 and 3.3 also graph 3.1) (Appendix IV Page 16)

The skills that were tested are listed below using the numbering system adopted by NEA for GCSE Biology.

List of Skills

Skill 23	Identifying Anomalous Results
Skill 25	Recognising Patterns
Skill 26	Ability to draw Valid Conclusions from Data
Skill 27	Identification of an uncontrolled variable
Skill 28	Suggestion of an appropriate method of control of the uncontrolled variable.
Skill 29	Formulating one hypothesis when data involves a single factor varying in two distinct situations.
Skill 30	Formulating several hypotheses (three) in a novel and relatively complex situation involving factors which may interact.
Skill 32	Devising an experiment to test a Hypothesis and planning the Sequence of the experiment.
Prediction	Making a prediction requiring abstract reasoning. This last ability is not a skill included in the NEA Biology Syllabus and is consequently not numbered.

This numbering system is used throughout the results section.

Using the entire sample the percentage success rate correct to one decimal place for the nine skills was computed and displayed (table 3.1 and graph 3.1). The mean IQ to pass each skill was computed (appendix III pages 13-20) Table 3.2.

Table 3.1a

Table to show the percentage success rate in the nine skills for the whole sample

Skills	% Success
23	30.7
25	66.0
26	61.5
27	89.8
28	70.9
29	57.0
30	9.8
32	15.6
Prediction	27.0
Mean	49.3

Table 3.1b

Table of Skills listed in order of facility.

Entire Sample	All Comprehensives	Traditional Comprehensives	Process Science	Selective Schools
27	27	27	27	27
28	28	28	28	25
25	25	25	26	26
26	26	26	25	28
29	29	29	29	29
23	Pred	Pred	23	23
Pred	23	23	Pred	Pred
32	32	32	32	32
30	30	30	30	30

Skills 27 and 28 proved to be significantly easier for the students with a pass rate of 89.8% and 70.9% respectively. Skill 30 was particularly difficult with a success rate of 9.8%.

The author was concerned that this result may have been due to the order of the paper. The question to assay skills 27 and 28 was on the first page, undertaken when the candidates were neither tired nor short of time. To check this the author

re-tested the paper with skills 27 and 28 last on the paper (table 3.2). The outcome remained substantially the same.

Table 3.2

The percentage pass rates in the nine skills with the order of the paper reversed.

The test was carried out on two further samples of students both taken from a selective school (School 4)

Skill	Sample 1 % Pass Rate	Sample 2 % Pass Rate
23	62	40
25	70	80
26	88.8	75
27	88	95
28	81.5	90
29	62	75
30	22	20
32	29.6	5
Prediction	62	55
Number of Candidates	27	20
Mean % pass rate	62.9	59.4
Mean IQ	115.4	116.2

Both samples were taught by the same Biology teacher, under very similar conditions. Sample 1 was a form studying all three sciences. Sample 2 studied Biology only, or in a few cases Biology and Chemistry.

Table 3.3

Table of Mean IQ to pass each skill

Skill	Mean IQ	Description
23	114.1	Recognising anomalous results
25	109.7	Recognising a pattern in data
26	109.5	Drawing valid conclusions
27	107.3	Recognising an uncontrolled variable
28	107.4	Controlling the variable
29	109.4	Devising one hypothesis to explain data
30	124.0	Devising three different hypotheses
32	111.7	Planning an experiment to test the hypothesis
Pred	114.0	Making a prediction from data

Skills 25, 26, 23 and predictions are interdependent.

Skills 27 and 28 are also interdependent.

Discussion of the Results

The possible explanation for the high facility of skill 27, recognising an uncontrolled variable, is that this required a qualitative answer with several possible correct responses. Skill 28, providing a suitable arrangement to eliminate the uncontrolled variable, required a more specific response and showed a greater failure rate. The lowest mean IQ was exhibited by students passing skills 27 and 28, mean IQs of 107.3 and 107.4 respectively (Table 3.3)

Skill 25, recognising patterns in data, showed a lower pass rate - 66%, The mean IQ of successful candidates being 107.3. This skill involved the candidates in the theoretical analysis of the data to derive some significance from it.

Skill 26, drawing valid conclusions from the results had a success rate 61.5% but showed a very similar mean IQ for successful candidates (109.5). This anomaly may be due to the fact that science students are customarily expected to draw conclusions from their results and are therefore more familiar with this procedure. Additionally, Skills 25 and 26 would appear to the author to be interdependent.

Students need to establish the pattern or patterns in the result in order to draw valid conclusions.

Skill 23, identifying anomalous results, proved particularly difficult with a 30.7% pass rate and a mean IQ to pass of 114.1. To achieve this result the candidates had to analyse the results, ascertain the patterns displayed and then recognise the single result which did not conform to the established pattern. Three procedures were therefore required, thus giving three opportunities for error. This may explain the degree of difficulty for this skill.

Skill 29, devising one hypothesis to explain some scientific results involving several variables had a pass rate of 57%. The mean IQ of candidates being 109.4. Many candidates seemed unwilling to tender an explanation when dealing with unfamiliar material.

Skill 30, formulating several hypothesis, appeared to be well beyond the range of the majority of candidates. The pass rate was 9.8% and the mean IQ of the successful candidates was 124. This skill requires the generation of three mutually independent hypotheses to explain results involving several variables. In the teaching situation, skill 30 had proved particularly difficult for many students, even in the selective schools and under examination conditions was only successfully completed by 51.3% of 'A'Level candidates at the age of 17 to 18. (Table 3.33, Page 176).

Skill 32, devising an experiment, was passed by 15.6% of the candidates with a mean IQ of 111.7. It required the construction of a plan to test their hypotheses. Obviously, if they had been unable to generate a hypothesis, they could not devise a plan to test it and frequently the plans constructed did not in fact test the

explanation the student had suggested. Many candidates never attempted this section.

Realising the difficulties involved in skills 29, 30 and 32 the author had provided two possible opportunities within the paper to achieve these skills; nevertheless the success remained very low.

Prediction:- Students were asked to make a prediction about the outcome of an experiment if a condition was altered in a specified manner. 27% were successful with a mean IQ for this skill of 114. Very many candidates were unwilling to suggest ideas in an unfamiliar situation.

The percentage success rate for each skill was calculated for the sample and divided into the following subsets: All comprehensives, traditional science comprehensives, process science comprehensives and selective schools. The order of facility in the different skills is displayed in table 3.16, Page 121. In all cases skill 27 proved the easiest and skill 30 the most difficult. The order remained practically consistent for skills 27 to 29 with some alteration in the order of prediction and anomalous result recognition.

The mean IQ for success in each of the 9 skills exceeded the mean for the population tested, 106.5, and considerably exceeded the accepted mean of 100 taken to be the figure for the general population to which all IQ tests are standardised.

It is worth noting that the questions to test the skills in no way required a quantitative statement as a reply, which would have increased the level of difficulty. This is required for Levels 8, 9 and 10 of AT1 of the National Curriculum for Science.

3.1.2 Analysis of the results from Appendix III, (page 32) the sample population divided into sets and sub-sets.

Graphs and Statistical Analysis are contained in Appendix IV

The population sample compared all the candidates educated in comprehensive schools as opposed to those educated in selective schools. The results are displayed in Table 3.4 (a) and (b).

Table 3.4

Table a

Results for all the pupils at comprehensive schools within the sampled population

Skill	Number of correct responses	% of correct responses
23	21	14.7
25	71	50.0
26	71	50.0
27	118	83.1
28	93	65.5
29	64	45.1
30	2	1.4
32	15	10.6
Prediction	23	16.2

These results are for 142 candidates, their mean IQ = 101.8

% success for all skills = 37.4

Table b

Results for the pupils from selective schools

Skill	Number of Correct Responses	% of Correct Responses
23	34	50.7
25	58	86.6
26	54	80.6
27	64	95.5
28	50	74.6
29	50	74.6
30	19	28.4
32	14	20.9
Prediction	33	49.3

These results are for 67 candidates mean IQ = 121.2

% success for all skills = 61.4

This raw data showed the pass rate for selective school pupils to be higher for all the nine skills and to make this information more meaningful, this comparison was repeated later using students crossmatched for IQ.

School 7 which is semi selective, was not included in either set. (Table 3.5)

Table 3.5

Semi Selective Girls School

Skill	% Pass
23	52.6
25	84.6
26	65.8
27	97.4
28	78.9
29	65.8
30	7.9
32	23.7
Prediction	26.3
Population	38
Mean % Pass of all skills	55.8
Mean IQ	105.7

The mean % pass rate for this sample for the 9 skills proved to be between the other two sets. These candidates (37 girls) were exceptionally successful at skill 27, recognition of an uncontrolled variable.

The Comprehensive School population was then divided into two subsets, those taught entirely by traditional methods and those taught for part of their Science education by a process led rationale. The results are shown in (Tables 3.6 a and b Graph 3.2). (Appendix IV, Page 17).

Table 3.6 a

Tables of results to compare the success rates for Comprehensive Schools teaching Science by traditional methods with those where Process Science methods have been used for at least part of the Science course.

Traditional			Process Science	
Skill	Number of correct responses	%	Number of correct responses	%
23	12	14.5	9	15.7
25	41	49.4	30	52.6
26	40	48.2	31	54.4
27	73	87.9	45	78.9
28	57	68.7	36	63.1
29	37	44.5	27	47.3
30	1	1.1	1	1.7
32	8	9.6	7	12.3
Prediction	16	19.3	7	12.3
	Sample Size = 83		Sample Size = 57	
	% success for all the skills	38.1		37.5
	Mean IQ of the sample	102.4		100.8

Table 3.6 b

Table to show the direct comparison of success in each skill in Traditional Science Teaching Schools compared with Process Science Teaching Schools.

Skill	Traditional % Success	Process Science % Success
23	14.5	15.7
25	49.4	52.6
26	48.2	54.4
27	87.9	78.9
28	68.7	63.1
29	44.5	47.3
30	1.1	1.7
32	9.6	12.3
Prediction	19.3	12.3
Mean	38.1	37.5

The overall pass rate for schools using the traditional method only, was slightly higher - 38.1%, than the schools using some process science - 37.5%, and there was some fluctuation in both directions for success at the different skills. When tested for statistical significance using the Chi squared test with Yates correction

(Appendix IV Page 4), there was a probability of 0.9 that this resulted from chance only. This does not confirm the hypothesis that specific teaching of data analysis as distinct process, actually improves skills related to data analysis. However, the author did observe that the process led students were more successful at analysing patterns, drawing conclusions and isolating anomalous results (but still below the level of statistical significance), so some advantage may have accrued from this input. Inexplicably they were particularly weak when making predictions. A process particularly included in the Process Science methodology.

The two single sexed comprehensive schools that drew from the same catchment area were compared. (Table 3.7).

Table 3.7

Comparison of the results from two single sex Comprehensive Schools in the same catchment area.

Skill	Boys's School % pass rate	Girls' School % pass rate
23	5.5	15.0
25	50.0	35.0
26	44.4	54.2
27	77.8	100
28	77.8	85.0
29	38.9	20.0
30	0	0
32	0	0
Prediction	18	20
% success for all skills	32.8	34.9
Mean IQ of the sample	99	102.8

The girls' performance overall was better but still at a level below statistical significance. The girls again excelled at recognising an uncontrollable variable (skill 27). The boys' school sample were better at data analysis, (skills 25 and 26), making a prediction and suggesting a hypothesis, (skill 29) but worse at

recognising anomalous results, (skill 23) and controlling variables, (skill 28). Overall it is not possible to draw conclusions.

The % success rate was compared for males and females, firstly using the entire sample and then subsequently using subsets derived from the selective school population and a group of the population in the IQ 115-125 range (irrespective of school).

This last refinement was included so that a relatively large sample of girls of IQs below 95 would not skew the results. The range 115 to 125 was chosen because this encompassed the full range for success in all the skills.

3.1.3 Analysis of the success in the different skills when 38 males and 38 females are considered separately.

Table 3.8

Table to illustrate the skills passed as the percentage of the candidates with males and females considered separately.

Skill	% pass rate males	% pass rate females
23	24.7	34.2
25	62.3	67.0
26	61.3	60.2
27	83.2	92.5
28	70.3	69.9
29	59.4	54.1
30	11.1	8.9
32	12.9	17.2
Prediction	30.7	24.0
	45.8	47.3

The Mean IQ of the sample is 106.5

47.5% of the Male sample have an IQ of 106.5 or over

41.8% of the Female sample have an IQ of 106.5 or over

Girls achieved a slightly higher success rate when the whole sample was considered and exceeded the boys performance in skills 23, 25, 27 and 32. Boys performed better at 26, 28 and 30 and making a prediction.

If the sample from the selective schools only was considered, consisting of 39 boys and 29 girls (Table 3.9a, Graph 3.4). Females continue to out-perform the males in skills 23, 27 and 32. The males in this sample were better overall and also performed better in skills 25, 26, 28, 29, 30 and at making a prediction.

Table 3.9

Tables to show % of subsets of males and females passing each skill

a) Selective Schools' Population

Skill	% Pass Rate Males	% Pass Rate Females
23	50.0	51.6
25	94.4	77.4
26	0.6	77.4
27	86.1	96.8
28	77.8	74.2
29	83.3	74.2
30	15.2	11.0
32	19.4	29.4
Prediction	55.5	35.5
Mean	62.4	58.6

Significantly, the selective school population contained more boys in the sample, of which more were in the very high IQ range. This may explain the greater success of the boys at skill 30 which showed the mean IQ of successful candidates to be 124. Males also were more successful at making predictions where the mean IQ of successful candidates was 114. However, girls performance exceeded boys', when recognising anomalous results which also needed a mean IQ of 114.

When the final GCSE Grades were compared (Graph 3.6), (Appendix IV, Page 20) predictably the males achieved more higher grades due to the large number of high IQ males within the sample.

The author then selected the results from a specific IQ range only. The range chosen was 115 to 125, chosen to cover the complete range required for the skills.

(Table 3.9 b) Graph 3.5. (Appendix IV, Page 19)

b) Students within the IQ range 115-125

Skill	% Pass Rate Males	% Pass Rate Females
23	60.0	55.6
25	80.0	83.5
26	86.7	72.2
27	86.7	94.4
28	60.0	77.8
29	60.0	94.4
30	22.8	11.4
32	20.0	38.9
Prediction	46.7	38.9
Mean	58.1	63.0

Skill	23	25	26	27	28	29	30	32	Pred
Mean IQ for success	114.1	109.7	109.5	107.3	107.4	109.5	125.3	111.7	114.0

All the students within this range from all the schools were included and their results analysed separately for each sex. Unfortunately there were only 35 people in total, 22 girls and 13 boys.

Within this range female performance exceeded male in skills 25, 27, 28, 29 and 32. The females also had a better overall pass rate for the 9 skills.

The GCSE grades for this subject are shown (Graph 3.7, Appendix IV, Page 20), 8 girls and 3 boys in this subset achieved Grade A.

To sum up, girls always exceeded the boys' performance when recognising an uncontrolled variable (27), or planning a sequence to test a hypothesis (32).

Boys always exceeded the girl's performance when drawing valid conclusions (26) or when constructing the three mutually exclusive hypotheses (30). Males also performed better than females in all three subsets when asked to make predictions. Overall the differences were relatively insignificant, neither sex being at a significant disadvantage.

The relative mean % success rate for the skills was compared statistically for males and females using the Chi squared test. The probability that the difference was due to chance was high at the 0.50 to 0.70 level. (Appendix IV, Pages 1 & 2)

3.1.4. Discussion of the results of the skills tested for Students of Asian origin as opposed to students of non-Asian origin

The author wished to examine this particular dichotomy because in the school where she teaches GCSE, there are a significant number of students of Asian origin who are very highly motivated and also very high achievers.

Table 3.10

Analysis of the % pass rate of the nine skills for students of Asian origin as compared to non-Asians.

Skills	Students of Asian Origin % Pass Rate	Non-Asian Students % Pass Rate
23	26.3	31.6
25	52.6	68.4
26	55.5	62.6
27	78.9	91.7
28	71.1	70.9
29	50.0	58.3
30	10.5	9.7
32	15.8	15.5
Prediction	18.4	28.6
Mean	39.2	48.6
Number of candidates	38	206

However, the results of this survey Table 3.10 indicated that the students of Asian origin had a significantly lower success rate in the majority of skills and 9.4% discrepancy in the mean success rate.

Within the sample there were five students of Asian origin with very high IQ's, 131 and above and these were the ones who passed Skill 30.

A large number of the students of Asian origin tested had IQs below 100.

In order to try to eliminate the discrepancy due to IQ in the sample, the author compared the results of the students of Asian origin and the Non Asian students cross matched for IQ.

The results of each candidate of Asian origin were examined and tabulated, another set of results were systematically compiled to compare with the results of the students of Asian origin. The procedure used was that for each member of the

first set another non-Asian was selected of the same sex, from the same group in the same school and as close as possible to the same IQ score. The objective was to eliminate, as far as possible, the discrepancy possibly due to a difference in IQ, any influence of the school, the teaching group and the sex of the candidate.

When controlling all these variables it was only possible to cross match 23 pairs of candidates. Their results are displayed in table 3.11 and Graph 3.8 and 3.9.

(Appendix IV, Page 21)

Table 3.11

Table of results with a set of students of Asian origin cross matched for IQ, School, teaching group and sex. IQ range 81-144. Mean 103.2

Skills	Students of Asian Origin % Pass Rate	Non-Asian Students % Pass Rate
23	30.4	34.8
25	65.3	65.3
26	56.5	73.9
27	87.0	82.6
28	78.3	33.4
29	52.5	33.4
30	21.7	21.7
32	17.4	26.1
Prediction	17.4	26.1
Mean	47.4	44.3
Number of candidates	23	23

The cross matching appeared to eliminate the higher rate of passes from the scores of the students of non-Asian extraction. In fact the success rate for the students of Asian extraction now exceeds that of the non-Asians. The probability that the differences were due to chance were high at the 0.7 to 0.8 level. (Appendix IV, Page 3) The GCSE Grade distribution for the above candidates is displayed in Graph 3.9. (Appendix IV, Page 21)

The difference in success rates for different skills when compared statistically using the Chi squared test or the Fisher test (See appendix IV Page 3) when the candidates were crossmatched for IQ, showed very low significance levels with

regards to sex, teaching method being of Asian origin or being taught in a single sex situation. The probability that the difference in results was due only to chance rather than gender was at 0.5-0.7 level, was due to chance rather than to being of Asian Origin was at the 0.7-0.8 level, was due to chance rather than to the teaching method used was at the 0.9-0.95 level. None of these factors show any statistical significance.

However, being taught in a selective school, or studying all three sciences both showed a positive correlation with success in the skills. These last two factors remained significant when the samples compared were also cross matched for IQ.

3.1.5 Intelligence Quotient

The IQ for all the candidates in the original sample had been assayed using the Culture Fair Tests, as described in the method. They were cross tabulated using the SPSSX programme and are displayed (Appendix III page 33) with reference to each skill. From this a Table 3.3 was derived.

Table of Mean IQ to pass each skill

Skill	Mean IQ	Description
23	114.1	Recognising anomalous results
25	109.7	Recognising a pattern in data
26	109.5	Drawing valid conclusions
27	107.3	Recognising an uncontrolled variable
28	107.4	Controlling the variable
29	109.4	Devising one hypothesis to explain data
30	124.0	Devising three different hypotheses
32	111.7	Planning an experiment to test the hypothesis
Pred	114.0	Making a prediction from data

Additionally, the author analysed these results to produce a sequence of Graphs as follows, these are displayed in Appendix IV, Pages 22-30)

Graph of IQ Distribution

3.10

3.11

3.12

3.13

Population

Entire Sample

Boys and Girls separated

All Comprehensive Schools

Selective Schools

3.14
3.15
3.16 - 3.25

Process Science Schools
Traditional Science Schools
Schools 1-10 respectively

The Author received the result in the GCSE examination, either in Biology or in Integrated Science, for the majority of the candidates at the end of their two year course. A few candidates did not enter the examination for various reasons therefore no result was available

Table 3.12 and Graph 3.26 (Appendix IV, Page 31) compare the Grade achieved by the candidates with the mean IQ of those achieving each Grade.

Table 3.12

Table of Grades achieved in GCSE and mean IQ of the candidates with each grade.

Grade	Number of People	Mean IQ
A	44	117.5
B	38	111.4
C	56	109.3
D	32	101.7
E	28	97.6
F	17	91.2
G	9 (8)	89.7 (85.0)

The figures in brackets for Grade G show the figures adjusted by omitting a candidate with an IQ of 127.

The results achieved appear to show a direct positive correlation with IQ.

3.1.6 Analysis of the IQ range of the sample

The IQ range was analysed for the whole population tested, for boys and girls considered separately, for the comprehensive schools as a group and for the selective schools as a group. Also for comprehensive schools teaching Process Science as opposed to Comprehensive Schools teaching Science by the traditional method and for each individual school. The results are shown in the graphs 3.10 to 3.25. (Appendix IV, Pages 22-30)

The whole population showed an IQ range from 57 to 158, the distribution was skewed above the theoretical mode of 96 to 105 because of the over representation of the higher IQ levels in the selective schools.

When boys' and girls' IQs were separated, both groups had the same mode 95-105, but the girls' sample contained more candidates below the mode 29.5% with 43.2% above. Boys had only 21.8% below the mode and 43.2% above.

The mean figure for all comprehensive schools was 101.8 with a slightly greater number of candidates below 100 than the norm.

The mean for the schools teaching Process Science was 100.8, the mean for the comprehensive schools teaching science by the traditional method was 102.8.

The most selective schools, Schools 2 and 4 had a mode of 125-135 with a mean of 120.3 and 121.8 respectively.

Comprehensive Schools 9, 3, 1 and 8 showed normal distributions with the mode in the range of 95-105.

Their mean IQs were 99.2, 102.8, 108.4 and 99 respectively. School 5 had a much lower IQ range with a mode at 85-95 and a mean of 89.8.

School 6 had the mode at 95 to 105 with a mean of 108.2. School 10 had a widely spread distribution with a mean of 109.6

3.1.7 Analysis of success in the different skills and the final grade achieved for the different subsets in each case cross matched for IQ.

The author considered that the IQ, as measured by the Culture Fair tests, appeared to show a considerable correlation with regards to the skills passed and the grades achieved. She wished to measure the effects of the other factors under consideration, therefore a series of tables and graphs were prepared for these different criteria, but in each case the samples were selected to crossmatch the candidates for IQ as closely as possible.

The criteria considered were:-

Single sexed Education as compared to Co-Educational Education.

Selective Education as compared to Comprehensive Education.

Studying three sciences as compared to not studying three sciences.

Being of Asian origin as compared to not being of Asian Origin, as discussed previously in these Results Tables 3.10 and 3.11 and Graphs 3.8 and 3.9.

(Appendix IV, Page 21)

The difference in performance with regard to sex has already been explored in tables 3.8 and 3.9 and Graphs 3.3 and 3.7. (Appendix IV, Pages 18-20) No further comparison at the age level of this sample were performed.

Traditional Science Education as compared with Process Science Education had been investigated only within the Comprehensive Schools sample table 3.6 and Graph 3.2. (Appendix IV, Page 17) These two subsets comprised the same IQ range.

Unfortunately when crossmatching for IQ is undertaken the sample size is greatly reduced but the author considered the elimination of the effect of IQ to be sufficiently important to make the constraint on numbers unavoidable but acceptable. The Fisher method of statistical analysis had to be used on this data

because of the small sample size. The statistical analysis is contained in Appendix IV.

3.1.8 Comparison of the relative achievement of boy students taught in a single sex comprehensive school as compared to boys in co-educational comprehensive schools.

In order to make this comparison the author endeavoured to compare the results of boys from the only single sexed boys' comprehensive school with a sample of boys cross matched for intelligence from co-educational schools. In fact it proved impossible to adequately cross match the sample because the boys' school had three boys of particularly low IQ of which there were no comparable matches in the main sample.

Table 3.13

Results of success in skills for boys in a single-sexed comprehensive school cross-matched by IQ to boys in co-educational comprehensive schools.

Skill	% Pass in single sexed boys's school	% Pass for boys in co-education schools
23	11	5.5
25	50	55.5
26	44.4	44.4
27	88.9	88.9
28	66.7	50
29	38.9	50
30	0	0
32	0	5.5
Prediction	11	22
Mean	34.5	35.5
Mean number of passes / boy	3	3
Mean IQ	94.6	99.8

Grade Distribution

A	0	2
B	0	1
C	3	3
D	2	6
E	5	6
F	4	0
G	4	0
Number of boys	18	18
IQ Range	83-127	86-118

When the results were compared, allowing for the miss match and the small sample, there was little significant difference in the results of the skills test. 0.8-0.9 probability that the difference was due to chance. (Appendix IV, Page 6) However, when the results of the GCSE examination were published, the boys' school sample was very significantly lower, even the boys of high IQ obtaining low grades.

From these extremely limited results, it does not appear that boys' performance at GCSE Biology is improved by single sexed education, rather the reverse seems to be the case.

3.1.9 Discussion of the results of girls' education in a single sexed comprehensive school as compared to girls' education in a c-educational comprehensive school.

Table 3.14 Graph 3.28 (Appendix IV, Page 33)

Table 3.14

Results of success in a single sexed girls' comprehensive school compared with the success rate of girls matched for IQ in co-educational comprehensive schools.

Skill	% Pass in single sexed girl's school	% Pass for girls in co-education schools
23	15.8	21
25	36.8	68
26	63.2	63.2
27	100	78.9
28	84.2	36.8
29	10.5	63.2
30	0	0
32	0	10.5
Prediction	10.5	21.0
Mean	35.7	40.3
Mean number of passes / girl	3.3	3.5
Mean IQ	100.8	101.1

Grade Distribution

A	0	2
B	3	3
C	3	4
D	6	4
E	3	4
F	1	1
G	2	1
U ?	1	0
Number of girls	19	19
IQ Range	84-127	84-127

The sample of girls that could be crossmatched was only 19 pairs. When the skills were tested there was considerable fluctuation in the percentage pass rate for the individual skills, the overall mean % pass rate was slightly higher in the co-educational comprehensive sample and the Final Grades were slightly better. The

small sample involved unfortunately adversely effects the significance of any results.

A comparison of the results in the skills tested and the final grades was made between girls from a girls only semi-selective school and girls from a mixed selective school. They were cross-matched for IQ.

Table 3.15

Comparison of the results from a semi selective girls' school with girls from a co-educational selective school cross matched for intelligence. Table 3.15 Graph 3.29 (appendix IV, Page 34)

Skill	% pass for selective girls school	% Pass for girls from selective co-educational schools
IQ Range	105-139	104-140
23	57.1	50
25	92.9	71.4
26	78.6	85.7
27	100	100
28	85.7	64.3
29	92.9	50
30	7.1	7.1
32	7.1	21.4
Prediction	57.1	35.7
Mean	64.2	53.9
Mean number of passes / girl	5.9	4.9
Mean IQ	110.1	109.8

Grade Distribution

A	4	5
B	3	5
C	5	4
D	0	0
E	2	0
Not Taken	2	0

A comparison of the results in the skills tested and the final grades was made between girls only semi-selective school and those from a mixed selective school cross-matched for IQ.

From this table of results it appears that girls of similar IQ in an all girls school are considerably more successful at achieving passes in these skills in the classroom situation at the beginning of their course. The probability that the difference in the mean % success rate is due to chance is at the 0.10 to 0.20. However, at the end of the course when the examination is taken the results achieved by girls in a selective coeducational school are considerably better.

It was only possible to cross match fourteen pairs of candidates because the girls only school had a large number of students who were below the entrance level for the selective coeducational school. Moreover the girls from the coeducational school who were crossmatched were mostly the weakest candidates admitted to the school and were probably the least confident.

Conclusions relating to single sex education in science.

When students educated in single sexed schools are compared with those educated coeducationally with regards to the nine selected skills and to the final GCSE grades achieved, there is no evidence at all of improved performance in the single sex school by the end of the GCSE course. Rather the reverse is the case although not at a significant level. This runs counter to the suggestion by Alison Kelly that single sex education benefits girls in science. The original evidence for this involved many of the GPDS Trust Schools. Girls Public Day School Trust Schools. The girls in these schools are of extremely high academic calibre and it would be very difficult to produce a comparable population drawn from co-educational schools. (Ref. Kelly A, 1981 and 1987). The very small sample

available from the single sexed boys comprehensive school also appeared to show less successful results than boys educated in co-educational schools.

3.1.10 Education in a selective school compared to a non-selective school. The candidates were cross-matched for IQ.

Students from selective schools were compared with students cross-matched for IQ and sex from non-selective schools, with regards to their success in the initial nine skills and also their final grade achieved at GCSE.

Table 3.16

Comparison of the % success in skills and the final grade achieved, between the two sets of students, cross matched for IQ, one set educated in non-selective schools, the other set in selective schools.

Skill	Non-selective % pass rate	Selective % pass rate
23	36	52
25	64	92
26	58	88
27	92	92
28	60	72
29	40	76
30	0	12
32	0	24
Prediction	20	58
Mean %	41.1	62.8
Mean IQ	118.3	118.2 range of IQ 101-154
Number of Students	25	25

Grade Distribution

A	5	11
B	2	9
C	8	5
D	3	0
E	2	0
F	3	0
G	1	0
Y	1	0

The results (Table 3.16, Graph 3.30) (Appendix IV, Page 35) show a considerably higher rate of success for students educated in selective schools when these

specific GCSE skills were tested towards the beginning of the GCSE course. Probability that the results are due to chance only is low .01-.001 level. (Appendix IV, Page 5) When the actual GCSE grades are obtained at the end of the GCSE course there is an extremely large difference in favour of the selective schools for pupils carefully paired for IQ with students in non-selective schools. Again the probability that this result was due to chance was low at the 0.01-0.001. Unfortunately this study did not attempt to monitor attitude and work patterns of the candidates, nor social factors.

3.1.11 The effect of the study of all three sciences on the % success in the nine skills and also the final grades achieved.

Students studying the three sciences were compared to those who were not studying three sciences in comprehensive schools, in a semi selective school and a selective school, also all those available in the whole sample, in all cases cross matched for IQ tables 3.17-3.20 and Graphs 3.31 to 3.34. (Appendix IV, Pages 36-39)

Table 3.17

A comparison of the pass rate in the selected skills and the final GCSE grades between two sets of students, both from non selective schools and cross matched for IQ, one set studying three separate sciences, the other set studying integrated science.

Skill	% pass rate for set studying separate sciences	% pass rate for set not studying separate sciences
23	20	20
25	30	90
26	40	70
27	80	80
28	70	60
29	90	60
30	0	0
32	30	20
Prediction	20	20
Mean pass rate	37	42
Mean IQ	106.9	106.9 range of 97-139
Number of Students	10	10

Grade Distribution		
A	1	1
B	2	1
C	3	4
D	4	2
E	0	1
F	0	1

The available sample of students studying separate sciences in the non-selective schools in this study was unfortunately so small that any trends are by definition suspect. There was no very obvious difference between the overall success rate at the skills tested, probability being that the difference is caused by chance 0.5 to 0.7, although the integrated science group scored marginally higher. In both groups there were great fluctuations in results. The GCSE grades were marginally higher in the separate Science Group. Table 3.17, Graph 3.31. (Appendix IV, Page 36)

Table 3.18

Comparison of the results achieved in a girls only semi selective school between students studying the three sciences separately and those studying either Biology only or Biology and Combined Science, the sample is crossmatched for IQ.

Skill	% Pass for students studying 3 sciences	% pass for students not studying 3 sciences
23	43.7	73.3
25	87.5	86.7
26	75.0	60.0
27	100	100
28	87.5	66.6
29	68.8	73.3
30	6.3	6.6
32	6.3	6.6
Prediction	50.0	46.7
Number of students	16	15
Mean	58.3	57.6
Average number of passes	5.1	5.1
Mean IQ	108	108

Grade Distribution

A	6	0
B	3	7
C	5	5
D	0	0
E	0	2
Did not enter	2	1

From this table of results there is an insignificant difference between the girls' success rate for the skills tested at the beginning of the course. The probability being that the difference is caused by chance is high at the .95-.90 level. By the end of the course when the girls sat the examination, the students offering three sciences are considerably more successful.

Table 3.19

Comparison of the results achieved in a co-educational selective school between students studying the three sciences separately and students studying Biology only.

The candidates were cross matched as closely as possible for IQ.

Skill	% Pass for students studying the 3 sciences	% Pass for students not studying the 3 sciences
23	61.9	42
25	90.5	76
26	71.4	81
27	95.2	85
28	90.5	52
29	95.2	62
30	28.6	0
32	42.9	9.5
Prediction	66.7	33.3
Mean	71.4	49.0
Number of Students	21	21
Mean IQ	118	118 Range 101-140

Grade Distribution

A	12	4
B	5	6
C	2	9
D	2	2

The difference in results Table 3.19 and Graph 3.33, (Appendix IV, Page 38), between the two sets of students both in the skills when they were tested towards the beginning of the two year course and also the final grade achieved at GCSE after two years, is highly significant. The probability that it is due to chance is at the .01-.001. The students studying the three sciences are a great deal more successful even though the two sets are cross matched for IQ.

The students studying three sciences are more successful in the skills even at the beginning of their course, the probability that this difference is due to chance is at the 0.10-0.20 level. They achieve significantly higher grades at the end of the course even when the variable IQ is eliminated. As shown in Table 3.20, Graph

3.34 (Appendix IV, Page 39), the probability that, obtaining a Grade A when studying 3 Sciences, is due to chance is .01 to .001. (Appendix IV, Page 11)

A comparison of the percentage pass rate in the selected skills of two sets of students cross matched for IQ, one set comprised all available pupils that could be crossmatched who were studying all three sciences, the other set were not studying three sciences.

Table 3.20

Skill	% Pass for students studying three sciences	% Pass for students not studying three sciences
23	51.1	48.9
25	77.7	84.4
26	66.7	73.3
27	93.3	91.1
28	84.4	60
29	93.3	66.7
30	15.6	2.2
32	28.9	15.6
Prediction	53.3	35.6
Mean	62.7	53.0
Number of Candidates	45	45
Mean IQ	113.1	112.6

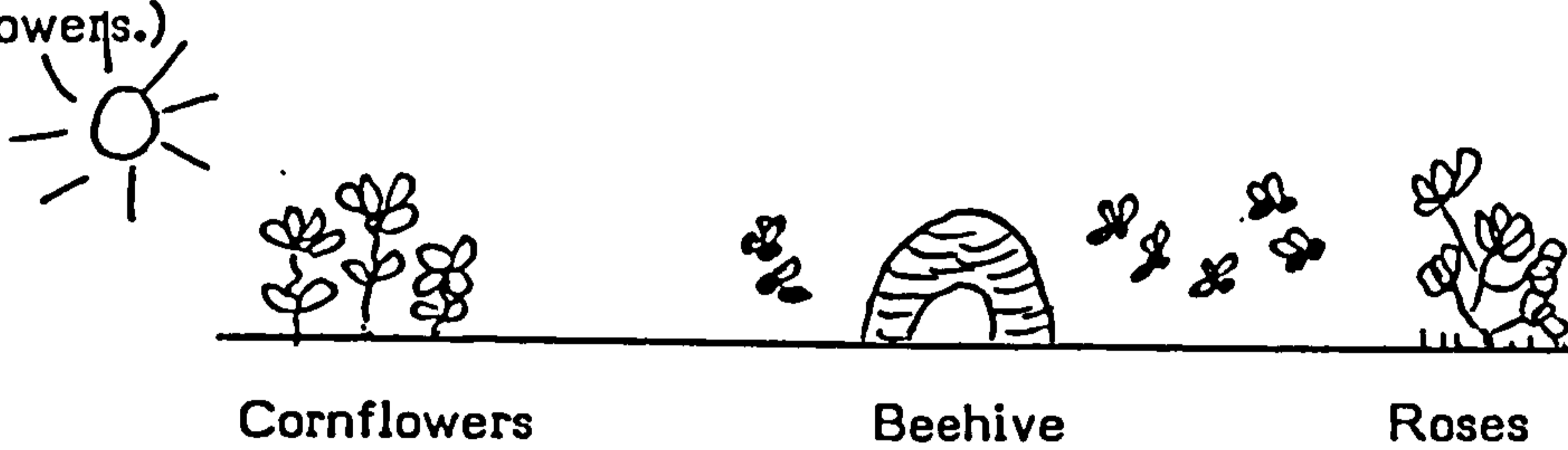
Grade Distribution

A	19	5
B	10	14
C	10	18
D	6	4
E	0	3
F	0	1
G	0	0

1. INSECTS

Entomologists (people who study insects) have been interested in whether bees can see and respond to different colours.

To test whether bees preferred blue or red, they arranged their beehive so that it was equidistant from a group of red flowers (roses) and a group of blue flowers (cornflowers.)



The result of the experiment was that most bees flew towards the roses.

Another entomologist stated that this experiment was not a fair test.

Can you suggest several different reasons why this may not have been a fair test ?

Reasons:

Skill 27 Uncontrolled variables.

Can you make up a fair test to see whether bees prefer the colour blue or the colour red ?

Brief plan of your test

Skill 28 Controlling uncontrolled variables.

2. SWEETS CAUSE TOOTH DECAY ?

Johnathon is allowed to eat lots of sweets and has lots of fillings in his teeth. Michael, his identical twin, also has lots of fillings but he neither likes nor eats sweets.

Using this evidence only, do you think children are likely to need more fillings if they eat a lot of sweets. Please explain your answer.

Skill 26 - Ability to draw (or not to draw) valid conclusions

John and Michael, the twins, are in Class 4. The class decided to survey the members of the class to find out about their sweet eating, milk drinking and teeth cleaning habits, and also the number of fillings each person has. The results are shown in the table below.

TEETH - CLASS 4

Name	Number of fillings	Likes and eats sweets	Drinks milk	Cleans teeth twice daily
Michael) the	10	x	x	/
John) twins	9	/	x	/
Anthony	1	/	/	x
David	10	/	x	x
Mark	0	x	/	/
Frances	8	/	x	/
Catherine	1	x	x	x
Carole	2	/	/	/
Jane	3	/	/	/
Gillian	3	/	/	/

If you were a dentist, what recommendations would you make about eating sweets, drinking milk and cleaning the teeth? Use evidence from the table only to support your recommendations.

Skill 25 Pattern recognition.

1. Do you think it is more important to drink milk or clean your teeth to prevent tooth decay? Support your answer using evidence from the table only.

Skill 26 Drawing valid conclusions using
skill 25 Pattern recognition

2. Is it more important to drink milk or not to eat sweets? Give your evidence from the table only.

Skill 25 Pattern recognition.

3. What patterns can you see in the results table? Please pick out results from the table that do not follow the general pattern and say how they seem to differ from the pattern.

Skill 23 Recognition of anomalous results.

3. RABBITS

Phillip found that when he kept his rabbit in its hutch, which is fairly small, the rabbit ate less bran and dandelion leaves than when it was able to use both its run and the hutch. The run was on the lawn in the middle of the garden. However, when the run and hutch were moved to another part of the garden, that was warm and sunny but had little grass, the rabbit ate less bran than when it was on the lawn, but more bran than when it was in the hutch. It also needed more dandelion leaves than when it was either in the hutch or in the hutch and run on the lawn.

Please suggest three different explanations of the rabbit's different feeding requirements.

1. Skill 30 devising three hypotheses to
explain results (this includes Skill 29)

2. _____

3. _____

4. Choose the explanation that you think is most likely and plan an experiment to test whether your idea is correct.

Skill 32 devising a plan to test a hypothesis.

5. How would you expect the rabbit's eating requirements to change if the hutch and the run were placed in a very grassy sheltered warm place in the garden? Please say why.

Making a prediction

2. SOME EFFECTS OF TAKING EXERCISE

A group of six pupils were asked to exercise by jogging for 15 minutes. Their pulse and breathing rates were monitored during the exercise and for 15 minutes after they had finished running. The results are shown below:

PULSE RATES

<u>Time (mins)</u>	<u>Liz</u>	<u>Shelagh</u>	<u>Helen</u>	<u>Mark</u>	<u>Adam</u>	<u>Saydur</u>
0	65	67	62	67	65	64
5	70	77	69	75	67	69
10	73	78	70	79	68	75
15	73	78	70	79	70	76
<u>Stop</u>	73	78	70	79	70	76
5 (at rest)	69	75	70	75	68	76
10 (at rest)	66	70	69	67	65	73
15 (at rest)	65	68	68	67	65	71

BREATHING RATES

<u>Time (mins)</u>	<u>Liz</u>	<u>Shelagh</u>	<u>Helen</u>	<u>Mark</u>	<u>Adam</u>	<u>Saydur</u>
0	23	22	20	23	24	23
5	24	23	21	23	24	24
10	26	24	23	24	25	26
15	26	24	23	24	25	26
<u>Stop</u>	26	24	23	24	25	26
5 (at rest)	29	27	24	26	25	26
10 (at rest)	30	28	25	23	24	28
15 (at rest)	27	25	25	23	24	28

Please examine both tables carefully, and then using information from these two tables only answer the following questions:

PULSE RATES

1. What generally happens to the pulse rate during exercise ?

Skill 25 Pattern recognition.

2. What generally happens to the pulse rate when the person rests after exercise ?

Skill 25 Pattern recognition

3. Do any of the students show different patterns from your answers 1 and 2 ? Please state the name(s) of the student(s) and how they differ.

Skill 23 Recognition of an anomalous result.

BREATHING RATES

Please answer the previous questions above, but this time in relation to breathing rates.

1. _____

2. _____

3. _____

4. How do the patterns of pulse rate during exercise and subsequent rest, and the pattern of breathing during exercise and rest differ ?

3. BLUEBELLS

Bluebells are usually found growing in deciduous (trees which shed their leaves in winter) woods, where they produce leaves from an underground bulb and flower in early spring. They are not usually found in evergreen woods, which shed a few needle-like leaves throughout the year but are never without leaves.

Please suggest three different explanations for the presence of bluebells in one type of wood but not in the other.

1. Skill 30 devising three different hypotheses
to explain a set of results.

2. _____

3. _____

4. Please choose the most likely explanation (in your opinion) and plan an experiment to test whether your idea is correct.

Skill 32 planning an experimental procedure
to test a hypothesis.

5. The Forestry Commission has some areas where deciduous woodland and evergreen woodland grow next to each other. What would you expect to be the effect on the bluebell population if many of the evergreen trees were replaced by deciduous trees? Please explain your answer.

Making a prediction.

3. BACTERIA

Some bacteria are killed by some antibiotics, others are not. Unfortunately some bacteria become used to some antibiotics (become immune) and are no longer killed if they have a chance to get used to the antibiotic gradually.

Mary had a sore throat which Dr. Davies diagnosed as being caused by bacteria. He was not sure, however, which strain (type) or strains of bacteria were causing Mary's sore throat. He decided to use the antibiotic Penicillin, but not too strong a dose in order to avoid side effects.

RESULT

At first Mary's throat improved greatly and far fewer bacteria were present.

After three days there was no further improvement and the bacterial count increased.

After one week Dr. Davies doubled the Penicillin dosage but Mary's throat remained sore and the bacteria continued to multiply.

Please suggest three different explanations for the pattern of bacterial growth.

1. Skill 30 making three different hypotheses
to explain a set of results.

2. _____

3. _____

4. Please choose the most likely explanation and devise a test to check your explanation.

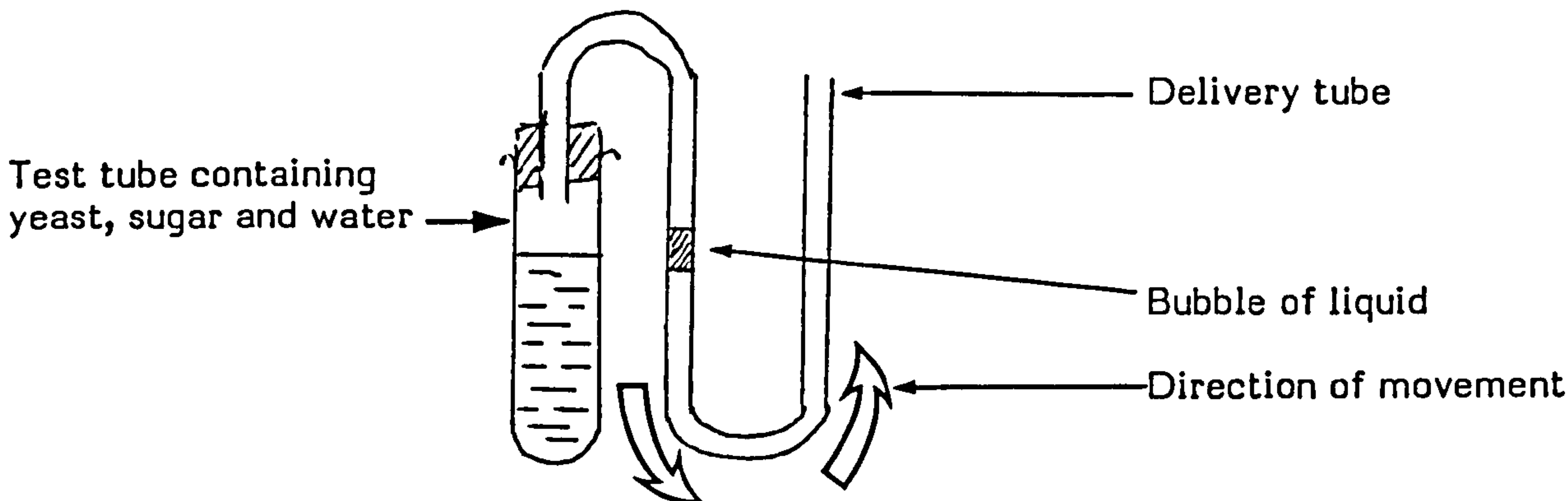
Skill 32 planning an experiment to test a
hypothesis

5. How could the doctor have treated Mary's throat to improve the chances of curing the throat infection using antibiotics? Please explain your answer.

Making a prediction

3. ANAEROBIC RESPIRATION

When mixed with sugar and water, yeast respire and give out carbon dioxide. It does not use any oxygen. If the yeast, water and sugar are placed in a test tube, with a delivery tube leading from the tube as shown in the diagram, the bubble of liquid in the delivery tube is pushed away from the test tube for five minutes, but then slows down and stops.



Please suggest three different explanations for the movement of the bubble.

1. Skill 30 devising three different hypotheses to explain a set of results.

2. _____

3. _____

4. Please select the explanation you think most likely and plan an experiment to test your idea.

Skill 32 devising a plan to test a hypothesis.

5. Had an additional substance been put in the test tube to absorb carbon dioxide, but not to stop the yeast respiring, what result would you have expected in the experiment? Please explain your reasoning.

making a prediction

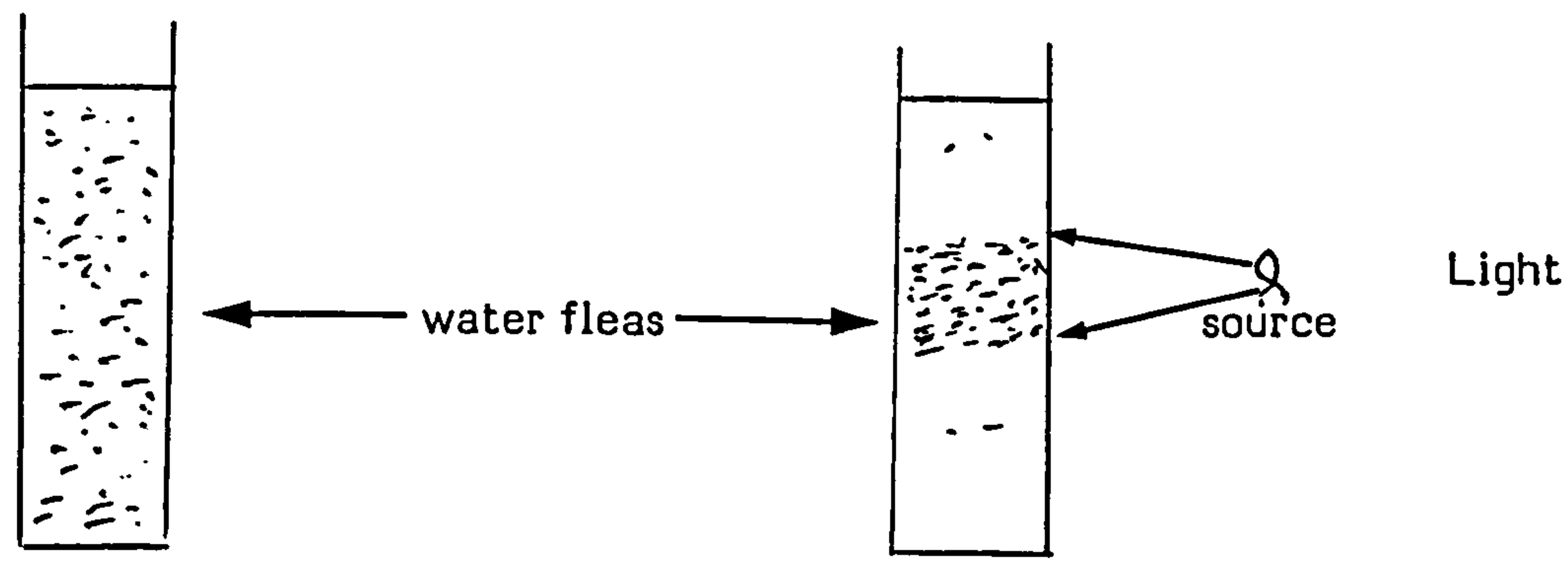
3. WATER FLEAS

A group of students were watching a cylinder of pond water in which many small water fleas (Daphnia) were swimming. The fleas were evenly dispersed through the water in the cylinder.

A narrow beam of light was directed on to the cylinder so that the middle region of the cylinder was more brightly illuminated. After a few minutes most of the water fleas were swimming around in this brightly lit region. (See the diagram)

Cylinder at the start of the experiment

Cylinder when brightly lit in the middle region



Please suggest three different explanations for the result of this experiment.

1. Skill 30 devising three different hypotheses to explain a result

2. _____

3. _____

4. Choosing the explanation that you think is most likely, plan an experiment to test whether your ideas is correct.

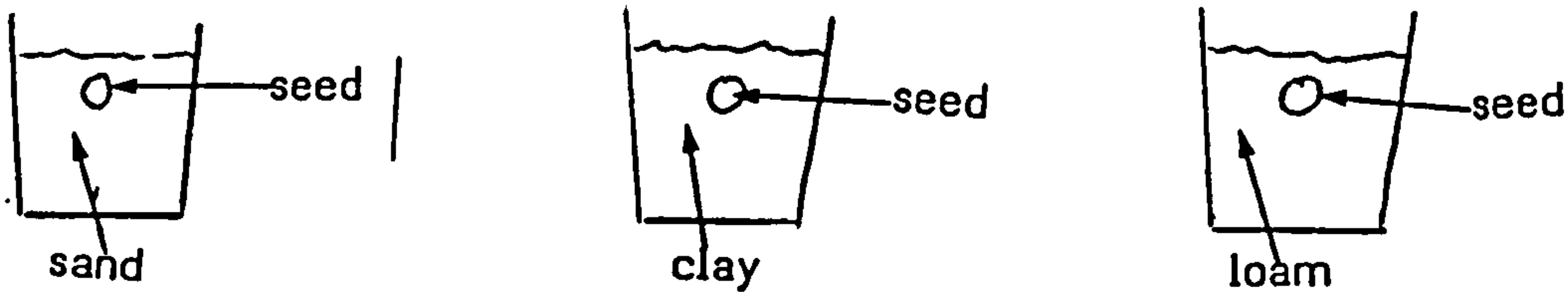
Skill 32 devising a plan to test a hypothesis

5. What would you expect to happen to the distribution of the Daphnia if the cylinder was brightly lit throughout its length? Please explain your reasoning.

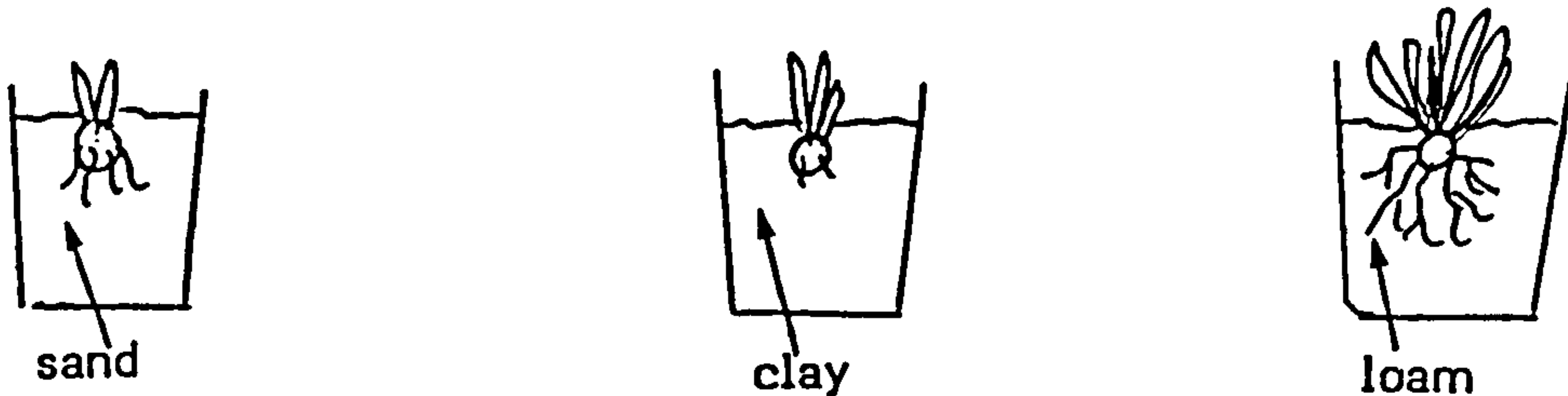
Making a prediction

1. GERMINATION OF SEEDS AND THE YOUNG PLANTS THEY PRODUCE

An experiment was set up as follows. Three pots of the same size and material were taken; one was filled with sand, one with clay and one with an in-between type of soil called loam. An identical seed was planted at the same depth in each pot; all the seeds were watered with the same amount of nutrient solution, and all were kept at the correct warm temperature for seed germination and seedling growth; all three had the same light available and the same air around them.



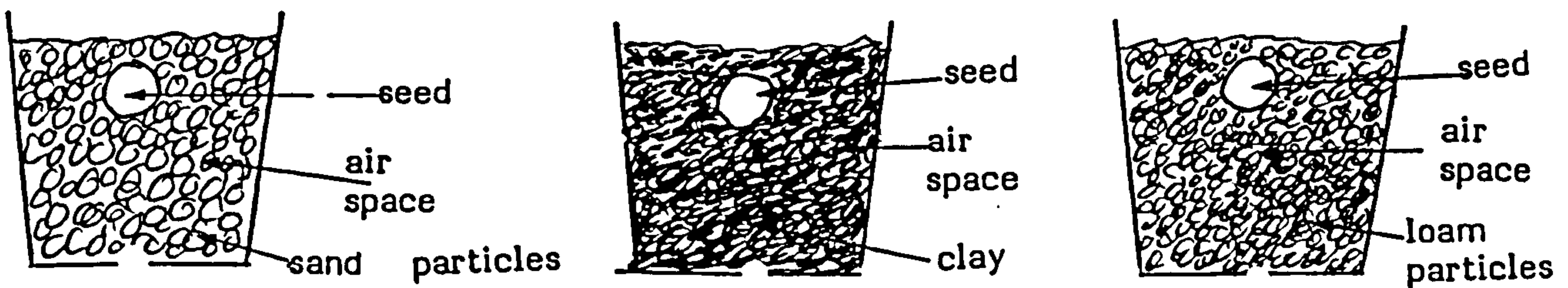
Results



What deductions can you make from the results shown above ?

Skill 25 observation of patterns in results.
and Skill 26 Drawing conclusions.

A closer look at the pots:



Each pot had been treated in the same way.

Can you suggest at least three reasons for the difference in growth of the seedlings ?

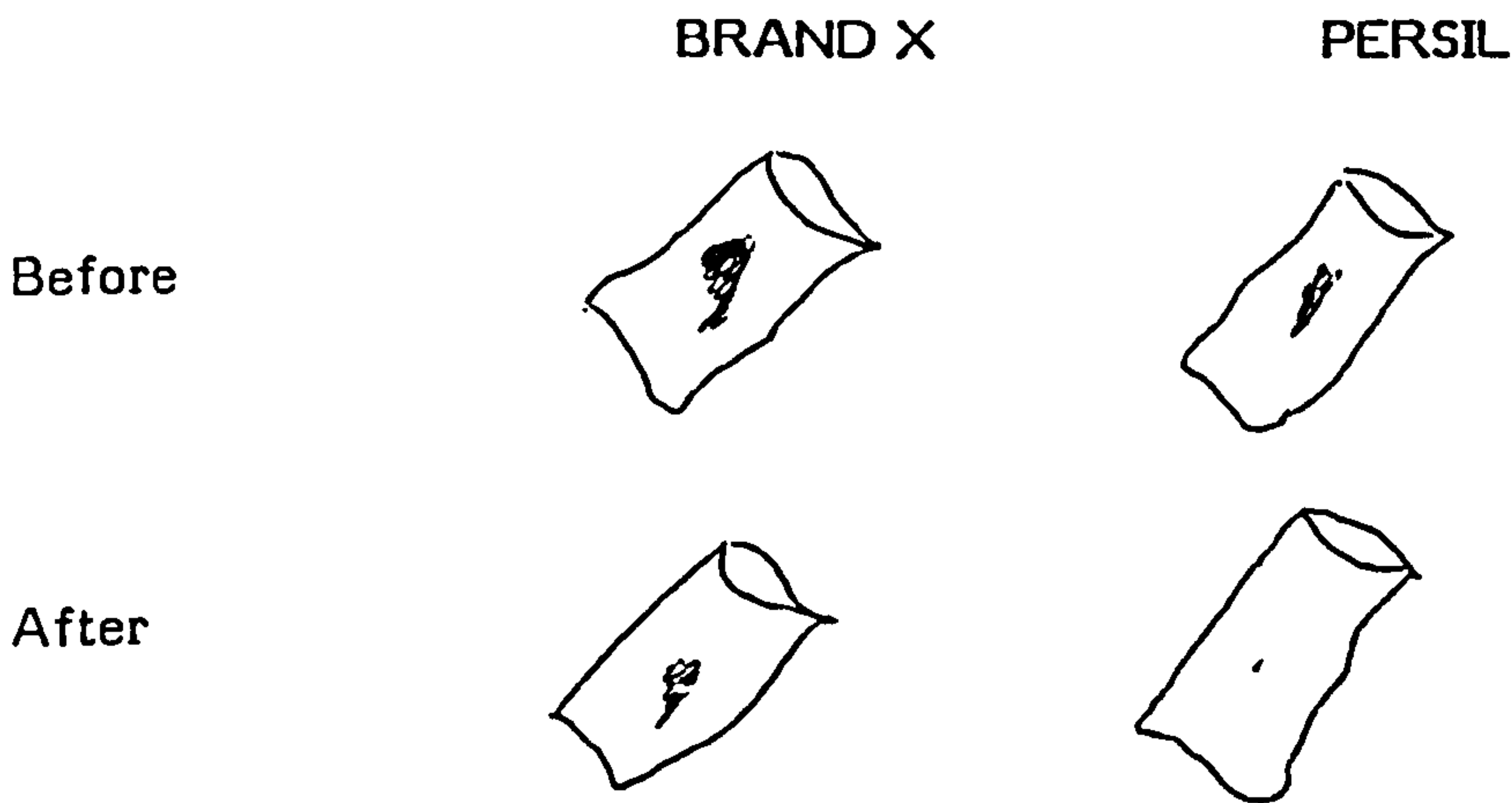
1. Skill 30 three different hypotheses to
2. explain a result.
3. _____

Can you suggest some experiments to test each of your chosen reasons to see which is/are most important in determining seedling growth ?

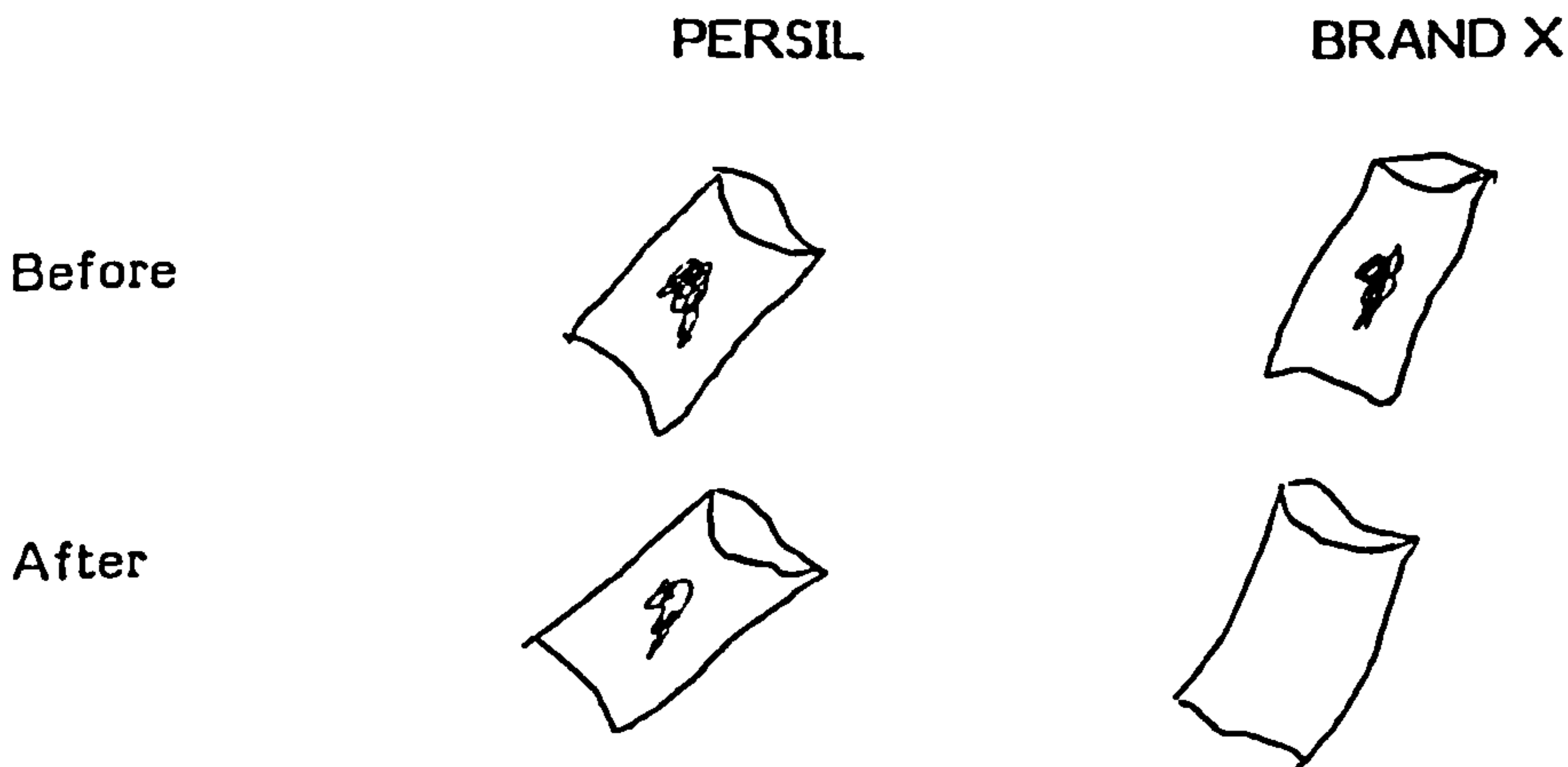
Skill 32 devising an experiment to test
a hypothesis.

2. PERSIL WASHES WHITER

Mrs. Smith washed a pillowslip with blood on it in her regular powder, Brand X, but it did not come clean. She then washed it in Persil and it did come clean.



Mrs. Smith wasn't sure that her test of Persil was fair so she decided to improve it. She washed a pillowslip with blood on it in Persil, and a pillowslip with egg on it in her original washing powder, Brand X. This time Brand X produced a cleaner pillowslip.



What deductions can you make from these tests about Persil and Brand X as successful washing powders?

Skill 26 drawing conclusions from results
also skill 25^o pattern recognition

Mrs. Smith then tried a really complicated washing powder test. Using Persil, Brand X or both, she also used different types of stains and either hot or warm water.

Please use only the results in the table to answer the following questions:

What patterns, if any, can you see concerning:

1. Persil and Brand X's cleaning power ?

Skill 25 and Skill 26

2. Using hot water as opposed to warm water ?

Skill 25 and Skill 26

3. Using both powders and the order you use them ?

Skill 25 and Skill 26

4. The three different types of stain ?

Skill 25 and Skill 26.

Can you suggest, with supporting evidence, the temperature Mrs. Smith probably used for her first wash ?

Using deductive reasoning

Biology Skills Questions

Question Booklet

Explanatory Note Relating to the Biology Skills Booklet

The response Integrated Science on the first page was used by pupils who were studying any science course involving all three sciences.

The following syllabi were represented.

NEA Integrated Science Modular
NEA Double award science syllabus A
NEA Co-ordinated science Double Award. Syllabus B
NEA Combined Science
MEG Double subject science. Syllabus C and D
MEG Combined Science

The teacher concerned specified the precise syllabus.

Please fill in the following details:

Name:

School:

Date of Birth:

Male or Female:

Please circle the correct response:

Do you study	Biology	Yes	No
	Chemistry	Yes	No
	Physics	Yes	No
	Integrated Science	Yes	No
	Process Science	Yes	No

The following booklet contains questions which if successfully answered show competence in the following skills for NEA (Northern Examining Association):

Skill 23 **Identifying anomalous results.**

Skill 25 **Recognising patterns.**

Skill 26 **Ability to draw valid conclusions from data.**

Skill 27 **Identification of an uncontrolled variable.**

Skill 28 **Suggestions of an appropriate method of control.**

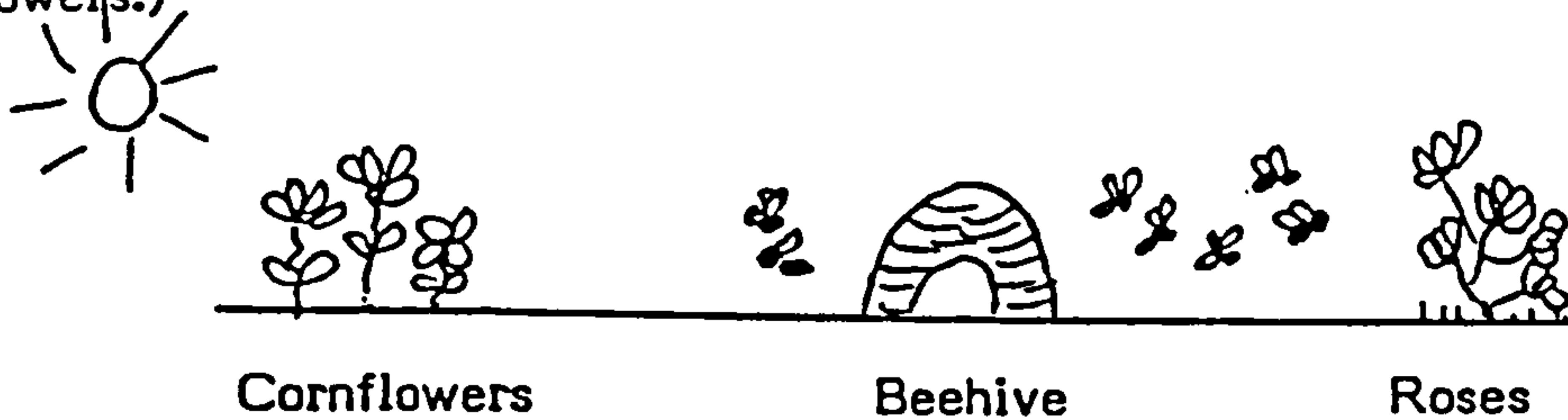
Skill 30 **(Including Skill 29)**
Formulating several hypotheses in a novel and relatively complex situation involving factors which interact.

Skill 32 **Planning the sequence of the experiment.**

1. INSECTS

Entomologists (people who study insects) have been interested in whether bees can see and respond to different colours.

To test whether bees preferred blue or red, they arranged their beehive so that it was equidistant from a group of red flowers (roses) and a group of blue flowers (cornflowers.)



The result of the experiment was that most bees flew towards the roses.

Another entomologist stated that this experiment was not a fair test.

Can you suggest several different reasons why this may not have been a fair test ?

Reasons:

Skill 27

Can you make up a fair test to see whether bees prefer the colour blue or the colour red ?

Brief plan of your test

Skill 28

2. SWEETS CAUSE TOOTH DECAY ?

Johnathon is allowed to eat lots of sweets and has lots of fillings in his teeth. Michael, his identical twin, also has lots of fillings but he neither likes nor eats sweets.

Using this evidence only, do you think children are likely to need more fillings if they eat a lot of sweets. Please explain your answer.

Skill 26 realising you need more evidence to draw conclusions.

John and Michael, the twins, are in Class 4. The class decided to survey the members of the class to find out about their sweet eating, milk drinking and teeth cleaning habits, and also the number of fillings each person has. The results are shown in the table below.

TEETH - CLASS 4

Name	Number of fillings	Likes and eats sweets	Drinks milk	Cleans teeth twice daily
Michael) the	10	x	x	/
John) twins	9	/	x	/
Anthony	1	/	/	x
David	10	/	x	x
Mark	0	x	/	/
Frances	8	/	x	/
Catherine	1	x	x	x
Carole	2	/	/	/
Jane	3	/	/	/
Gillian	3	/	/	/

If you were a dentist, what recommendations would you make about eating sweets, drinking milk and cleaning the teeth? Use evidence from the table only to support your recommendations.

Skill 25 Pattern recognition.

1. Do you think it is more important to drink milk or clean your teeth to prevent tooth decay? Support your answer using evidence from the table only.

Skill 26

2. Is it more important to drink milk or not to eat sweets? Give your evidence from the table only.

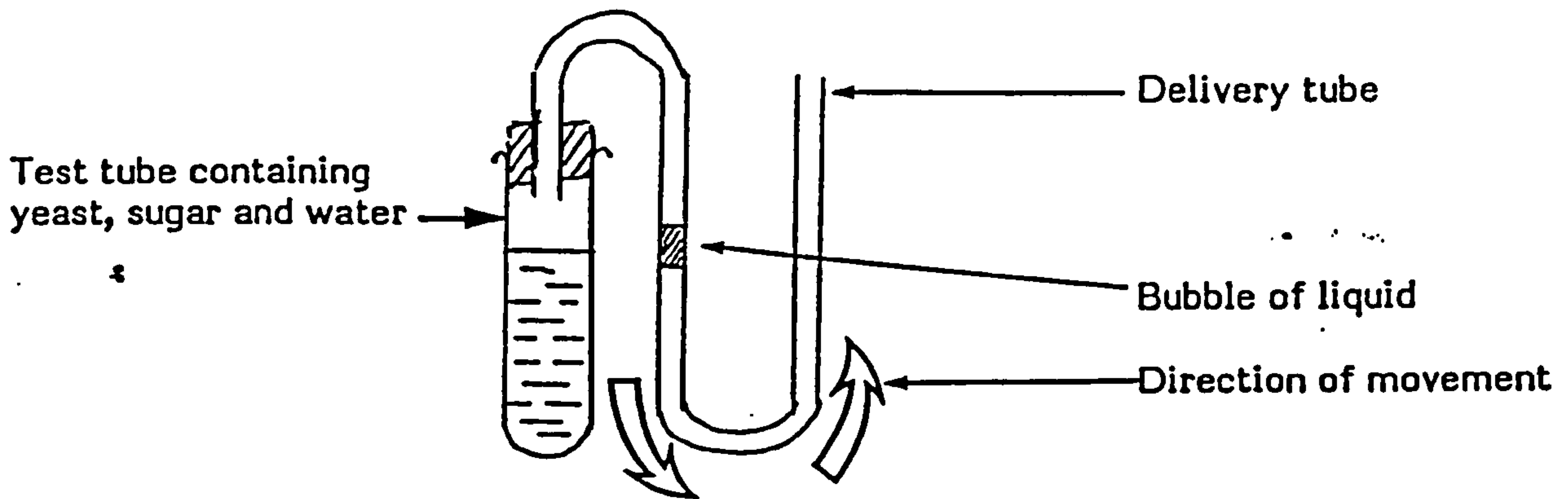
Skill 26

3. What patterns can you see in the results table? Please pick out results from the table that do not follow the general pattern and say how they seem to differ from the pattern.

Skill 25 and Skill 23.

3. ANAEROBIC RESPIRATION

When mixed with sugar and water, yeast respire and give out carbon dioxide. It does not use any oxygen. If the yeast, water and sugar are placed in a test tube, with a delivery tube leading from the tube as shown in the diagram, the bubble of liquid in the delivery tube is pushed away from the test tube for five minutes, but then slows down and stops.



Please suggest three different explanations for the movement of the bubble.

1. Skills 29 and 30

2. _____

3. _____

4. Please select the explanation you think most likely and plan an experiment to test your idea.

Skill 32

5. Had an additional substance been put in the test tube to absorb carbon dioxide, but not to stop the yeast respiring, what result would you have expected in the experiment? Please explain your reasoning.

Prediction.

3. BACTERIA

Some bacteria are killed by some antibiotics, others are not. Unfortunately some bacteria become used to some antibiotics (become immune) and are no longer killed if they have a chance to get used to the antibiotic gradually.

Mary had a sore throat which Dr. Davies diagnosed as being caused by bacteria. He was not sure, however, which strain (type) or strains of bacteria were causing Mary's sore throat. He decided to use the antibiotic Penicillin, but not too strong a dose in order to avoid side effects.

RESULT

At first Mary's throat improved greatly and far fewer bacteria were present.

After three days there was no further improvement and the bacterial count increased.

After one week Dr. Davies doubled the Penicillin dosage but Mary's throat remained sore and the bacteria continued to multiply.

Please suggest three different explanations for the pattern of bacterial growth.

1. Skills 29 and 30

2. _____

3. _____

4. Please choose the most likely explanation and devise a test to check your explanation.

Skill 32

5. How could the doctor have treated Mary's throat to improve the chances of curing the throat infection using antibiotics? Please explain your answer.

Prediction

Thank you for answering the questions in the booklet.

A personal question:

Please can you tell me whether you are usually able to think clearly when you attempt to answer questions ?

Write your answer

Yes

No

If your answer to the question above is No, please will you list any things that may sometimes cause you to think less clearly.

Thank you.

Lesley A. Dunham

Additional Biology Skills Test
for lower age ranges

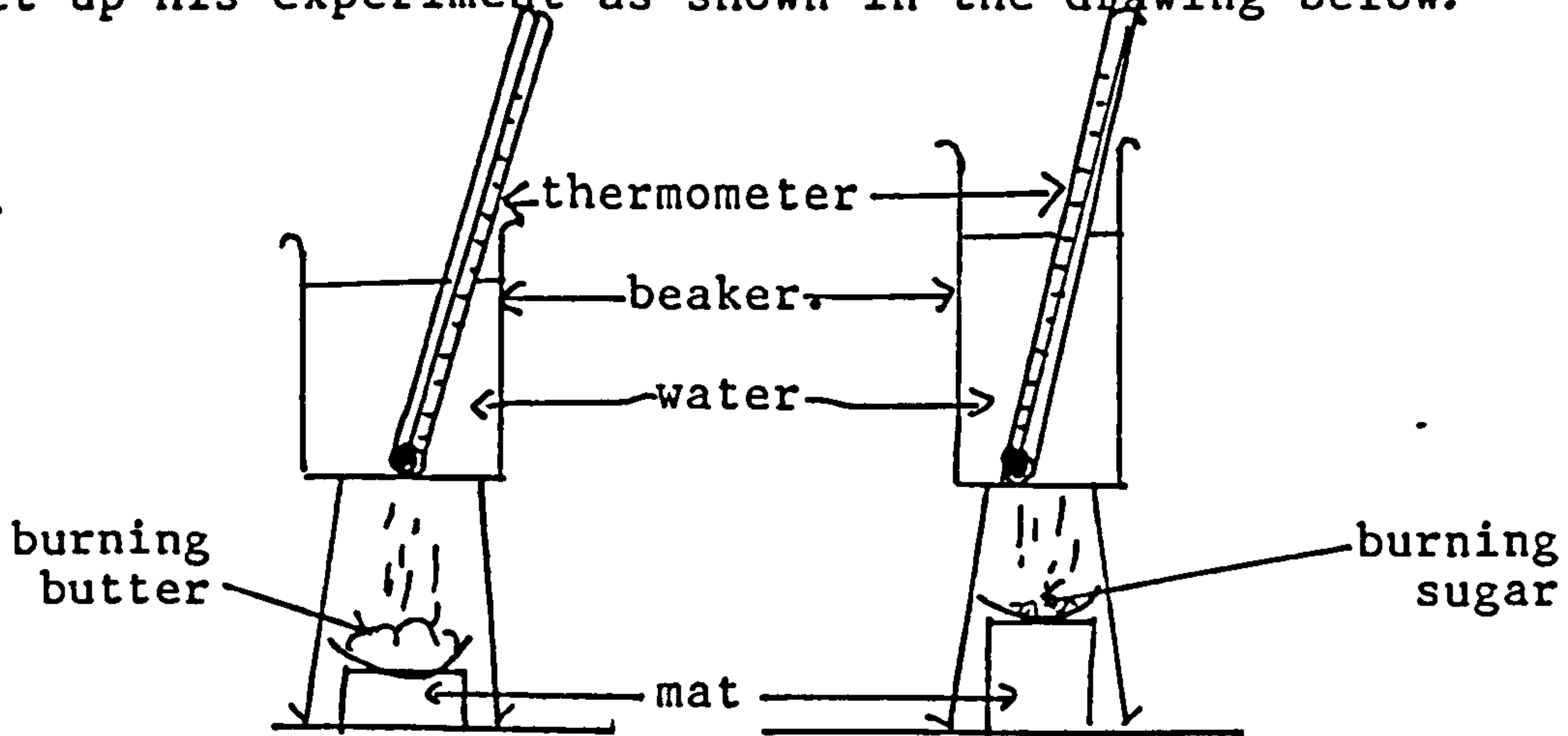
Name _____

School _____

An Experiment about energy in food.

John was told by his teacher that you could measure the amount of energy in food by burning the food and using the heat given out to warm water. You could use a thermometer both to stir the water and measure the temperature of the water.

He set up his experiment as shown in the drawing below.



Neither John's teacher nor his friends thought that the experiment was very fair.

Please say three things that you can see in the drawing that seem unfair.

1. Skill 27 uncontrolled variable

2.

3.

How would you correct these three mistakes?

Skill 28 controlling the uncontrolled variable

When John had made the experiment as fair as he possibly could he found that the water above the burning butter always got hotter than the water above the burning sugar. This was in fact the expected answer.

Can you think of three different possible reasons for this water ending up hotter?

Reason1. Skill 30 and Skill 29.

Reason2

Reason3

Could you make up a plan to test one of your reasons?

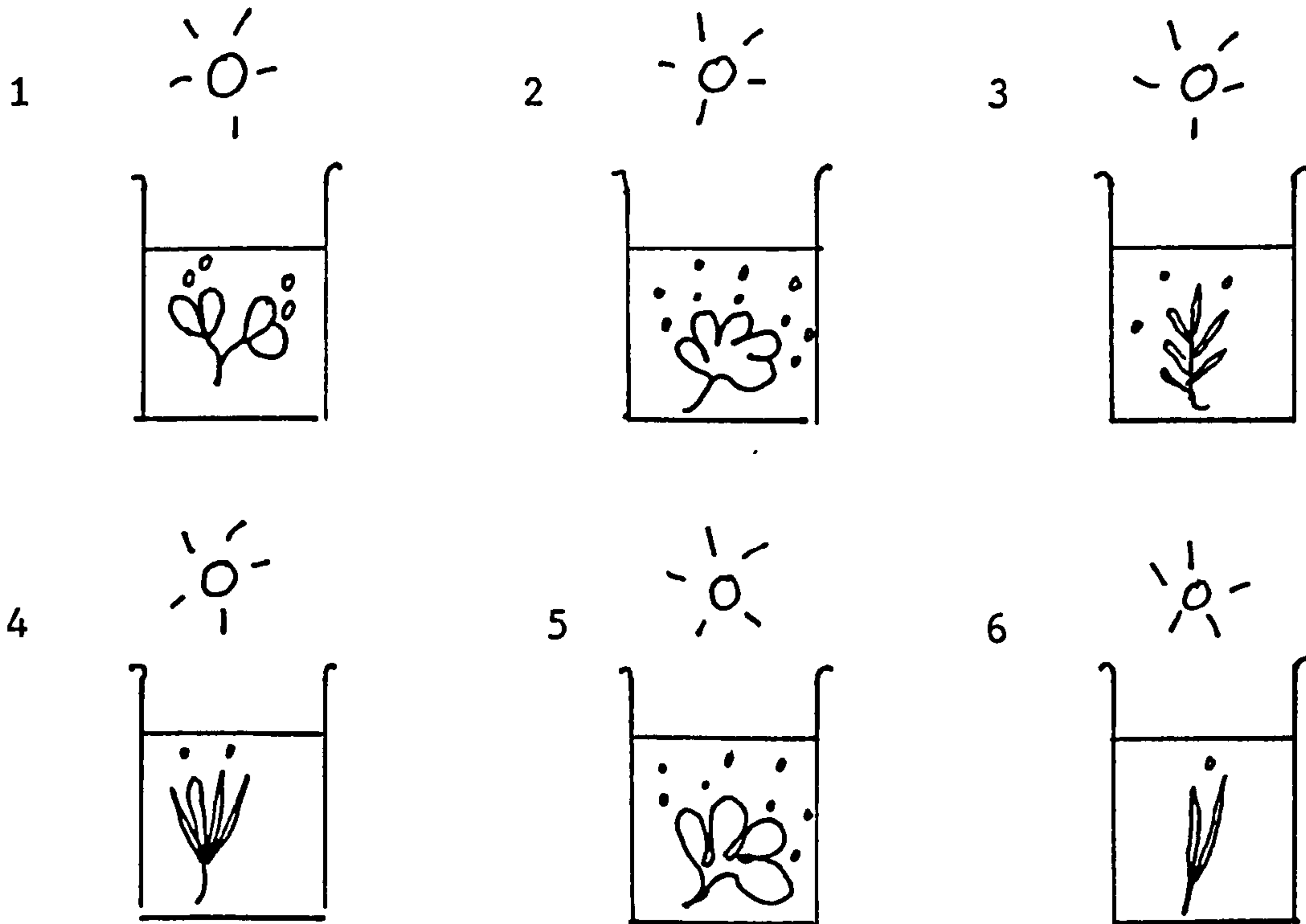
Plan.

Skill 32.

An Experiment with Water Plants.

Mary was working with water plants and noticed that they gave out bubbles when the sun shone on them. Mary's teacher asked her to find out as much as she could about bubbling by different water plants.

This is Mary's experiment set up in the classroom.



Which is the best bubbler? Skill 25

Which is the worst bubbler? Skill 25

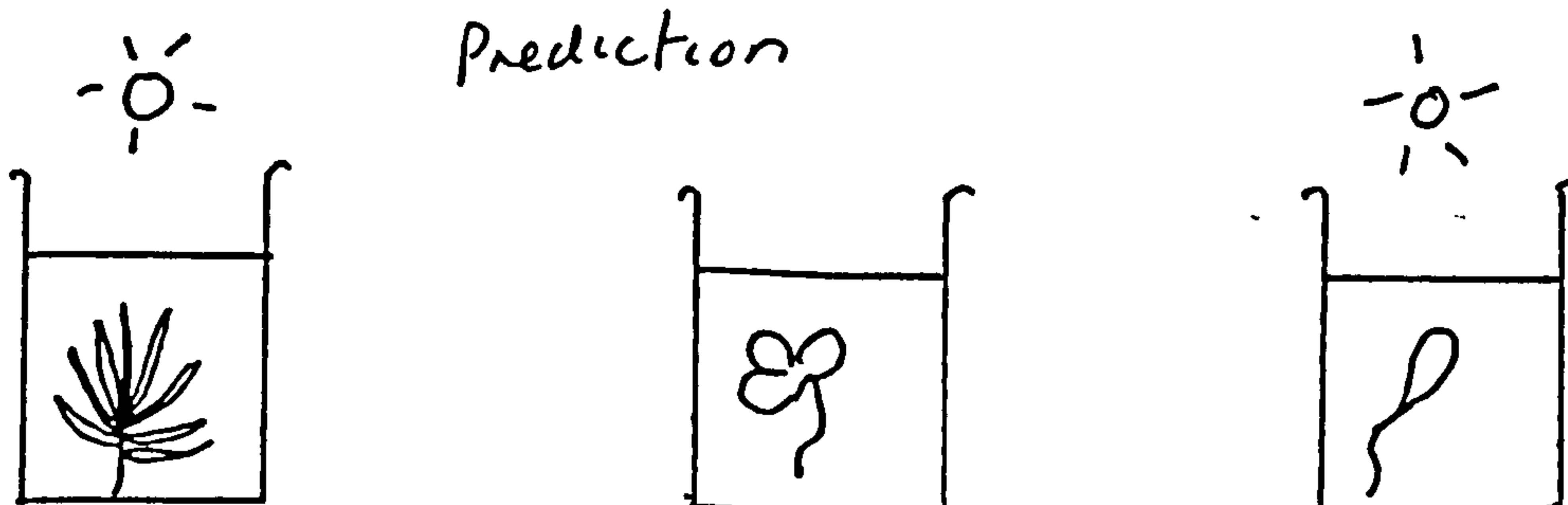
Is there anything special about good bubblers when you look at them as compared to bad bubblers? Skill 25 Skill 26

Arrange the bubblers in order best bubbler's number first, worst bubbler's number last. Skill 25

Can you see a special pattern relating the leaves to the number of bubbles? Please write what it is.

Which bubbler seems wrong Skill 23

How many bubbles would you expect in the next three containers? Please say how you have worked out your 3 answers.

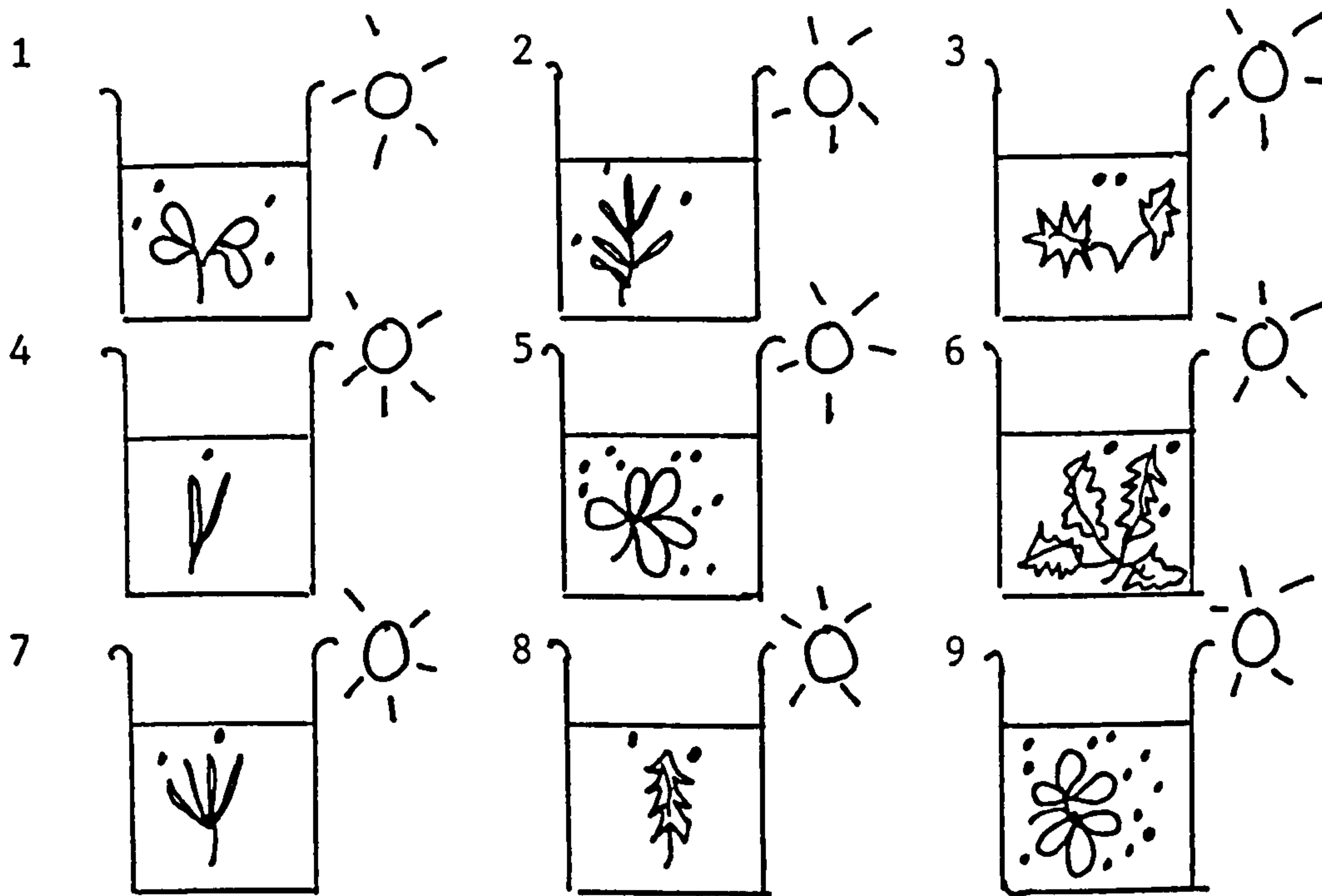


An Experiment with Water Plants 2

Mary was working with water plants, she noticed that they gave out bubbles when the sun shone on them and suspected that the bubbles were oxygen and that the plants were photosynthesising. Mary's teacher asked her to compare the rate of photosynthesis in different types of water plants.

In order to photosynthesise the plants needed carbon dioxide and this was provided in solution in the water.

This is Mary's experiment set up in the classroom.



Which is the best photosynthesiser? Skill 25

Which is the worst photosynthesiser? Skill 25

Arrange the plants in order working from the best to the worst photosynthesiser.

Skill 25

Can you see a special pattern in these results? Please state what it is.

Skill 25 and Skill 26.

Which plant appears to be photosynthesising at the 'wrong' rate? Please state how you would have expected it to produce bubbles. Skill 23 and skill 26.

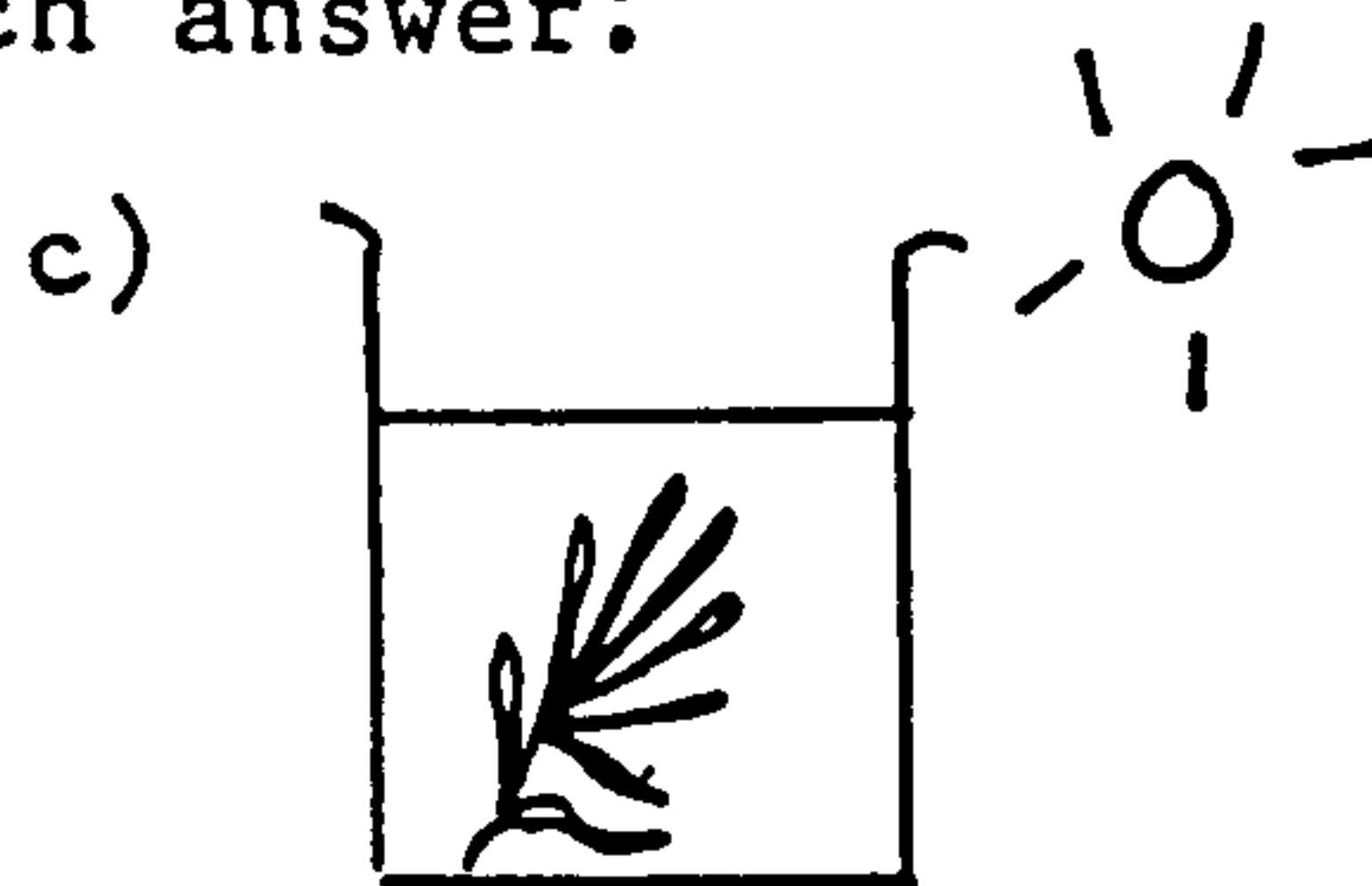
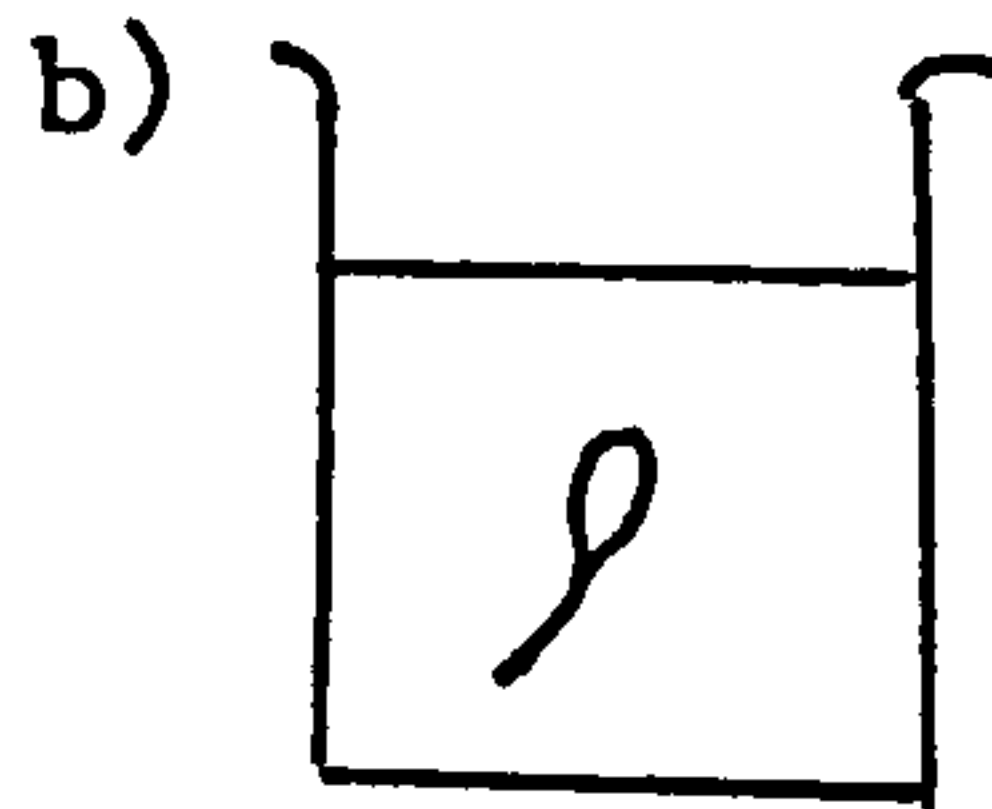
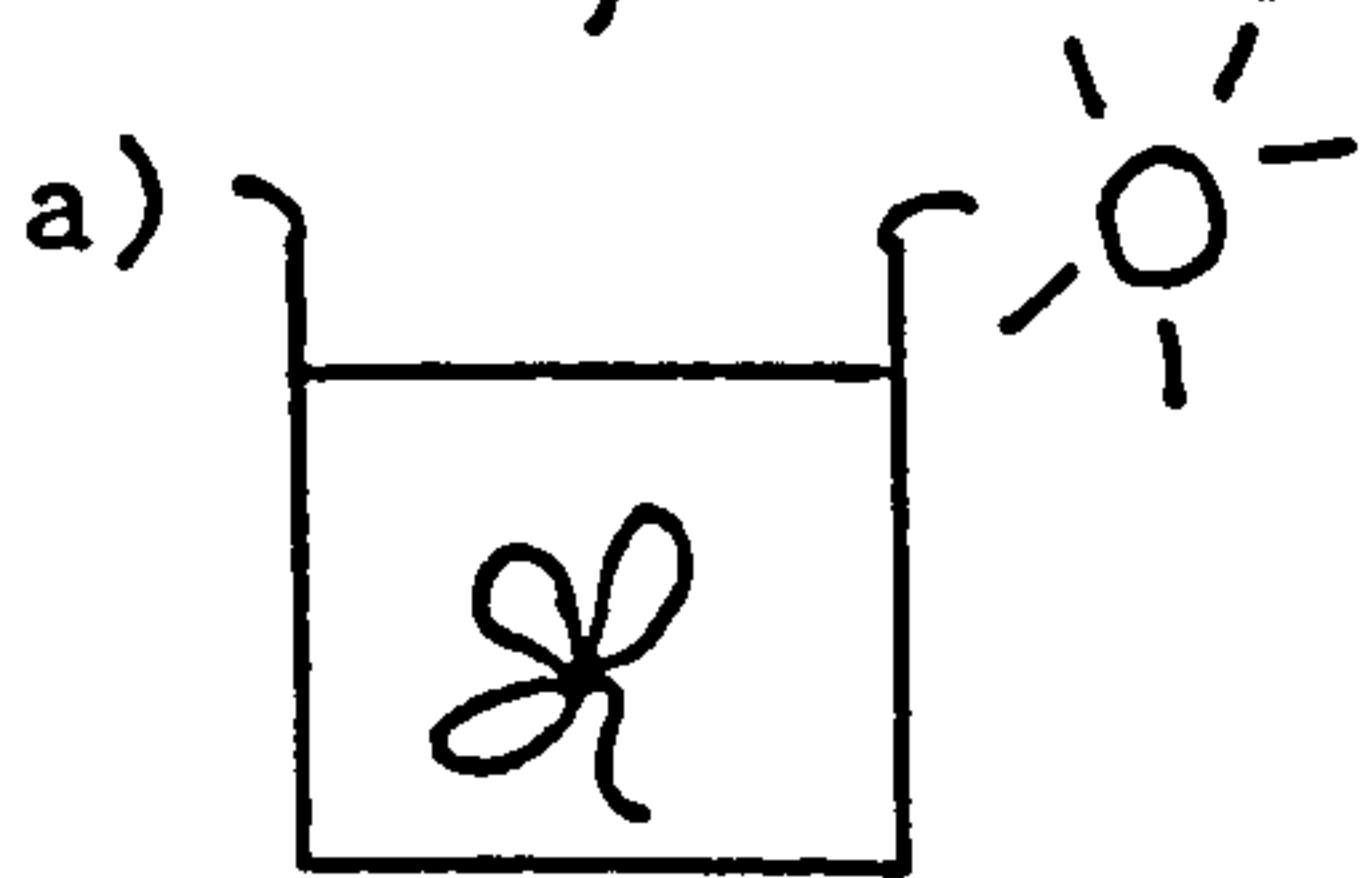
Please give THREE DIFFERENT possible explanations for this unexpected result.

1, Skills 29 and 30

2,

3,

How many bubbles of gas would you expect in the next three beakers, please give a reason for each answer?



a) Prediction.

b)

c)

'A' Level Trial Exam Paper
Incorporating the Biology Skills

Option C CELLS THEIR PRODUCTS AND INTERACTIONS.

ANSWER QUESTION ONE AND ONE OTHER QUESTION.

COMPULSORY QUESTION:

Only brief or tabulated answers are required for section (a)

(a) Define each item and state where it occurs.

- (i) N acetylglucoseamine.
- (ii) Flagellin.
- (iii) Single stranded RNA.
- (iv) A capsomere.
- (v) Penicillinase.
- (vi) An absorption site.

6 marks

(b) In order to test the relative efficiencies of two antibiotics a little of each antibiotic was mixed with bacteria taken from a throat swab and allowed to grow on a nutrient agar plate.

State two major faults in this technique. *Skill 27 and Skill 28*

How would you eliminate each fault?

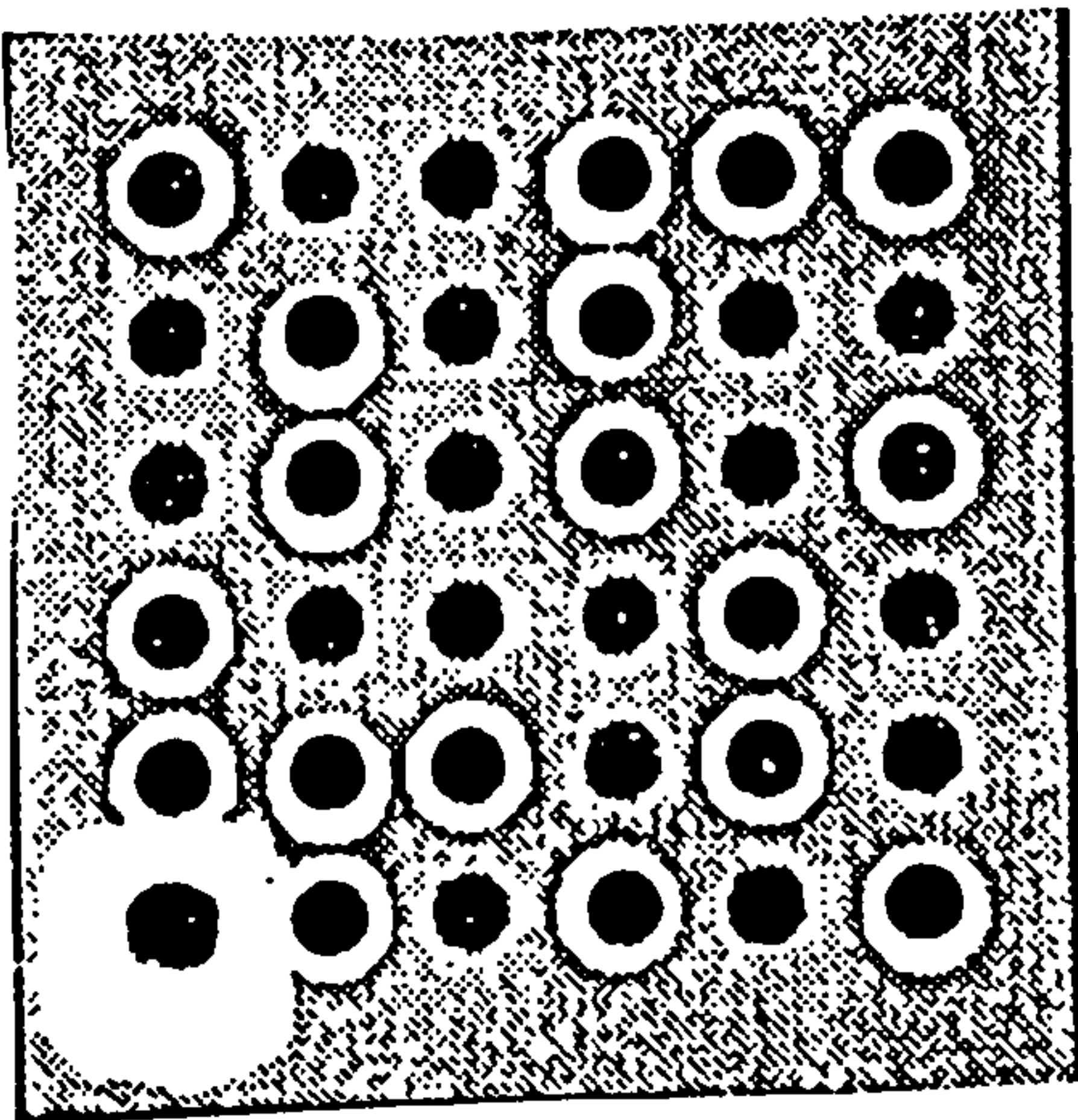
4 marks

(c) The diagram below shows an assay plate used to test chemotherapeutic agents. Samples of an agent were placed in small wells punched in the agar and a sterile nutrient agar seeded with a test bacterium.

Following incubation the plate had the appearance as shown below.

Grey areas indicated bacterial growth.

Black areas show the presence of chemotherapeutic agent.



(A) Explain the significance of the clear zone around some of the wells. *Skill 25*

(B) Give THREE DIFFERENT explanations for the variation in size of the typical cleared as opposed to infected areas.

Skill 30 and Skill 29

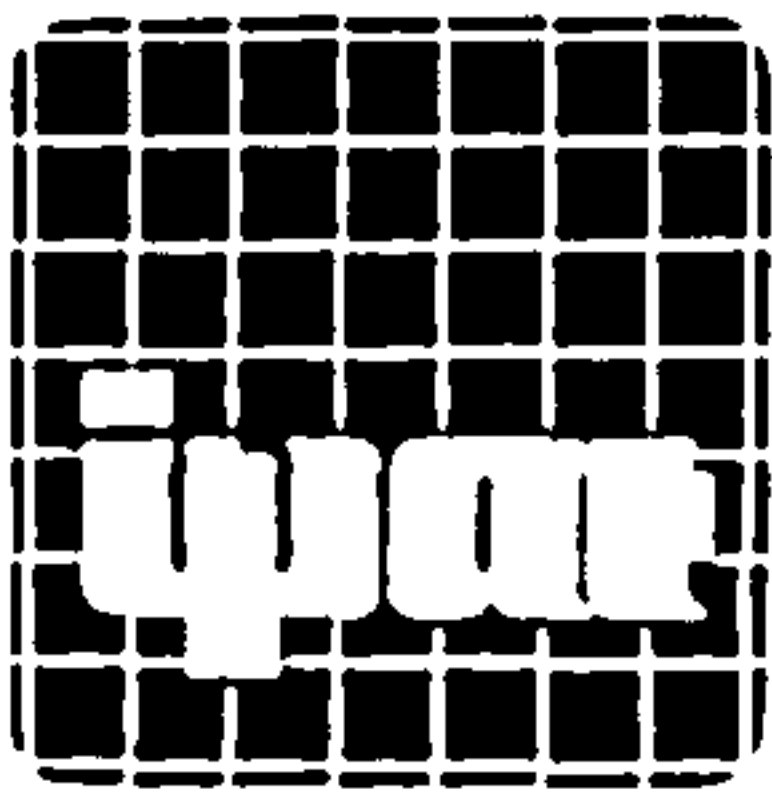
(C) Suggest two definite conclusions you can draw about the growth of bacteria on this assay plate. Skill 26

(D) One result is obviously ATYPICAL what do you consider to be wrong with this result? Skill 23

(E) Devise a simple procedure to test your suggestion.

4 marks.

Skill 32.



T 11

Test of "g": *CULTURE FAIR*

Scale 2, Form A

Prepared by R. B. Cattell and A. K. S. Cattell

Name _____ Sex _____
 First Last (Write M or F)

Name of School (or Address) _____

Today's Date _____ Grade (or Class) _____

Date of Birth _____ Age _____
 Month Day Year Years Months

Test	Score	Remarks
1		
2		
3		
4		
		Total Score

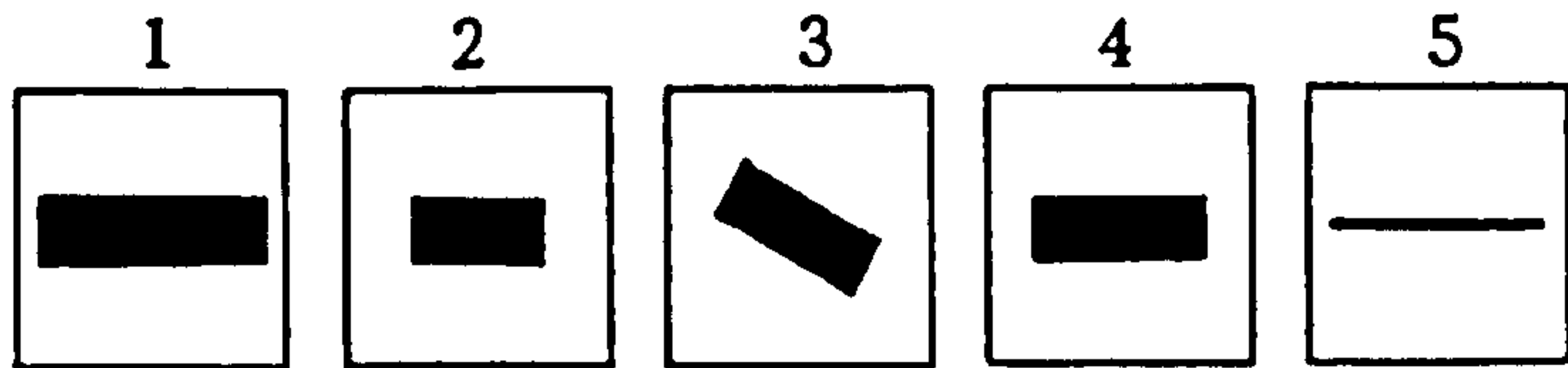
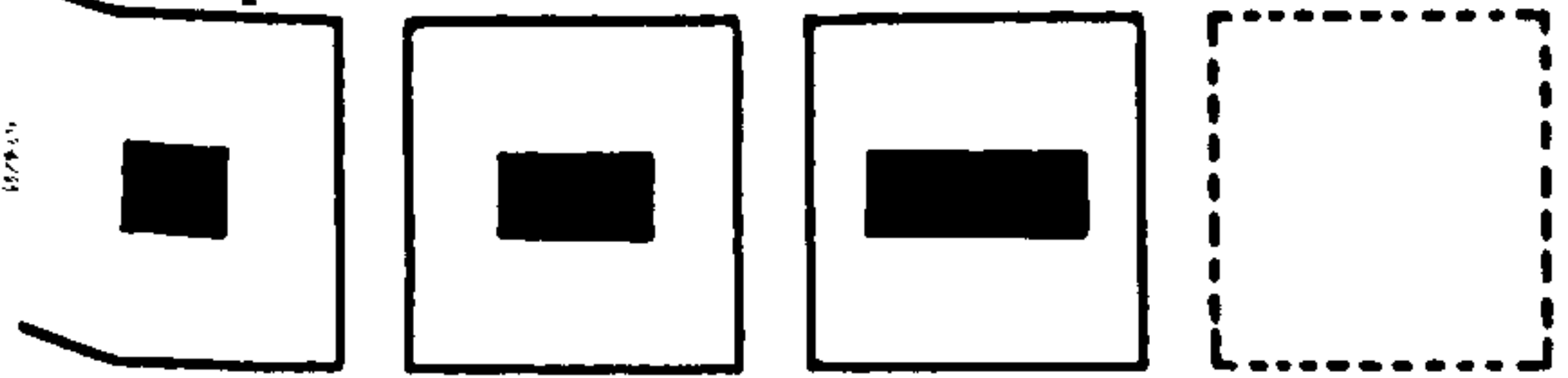
M. _____

Q. _____

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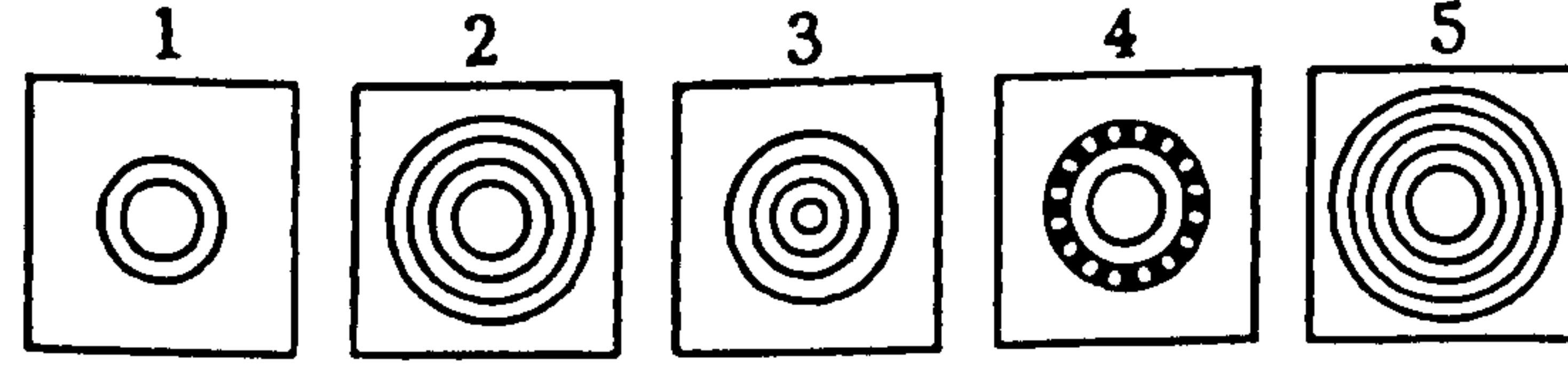
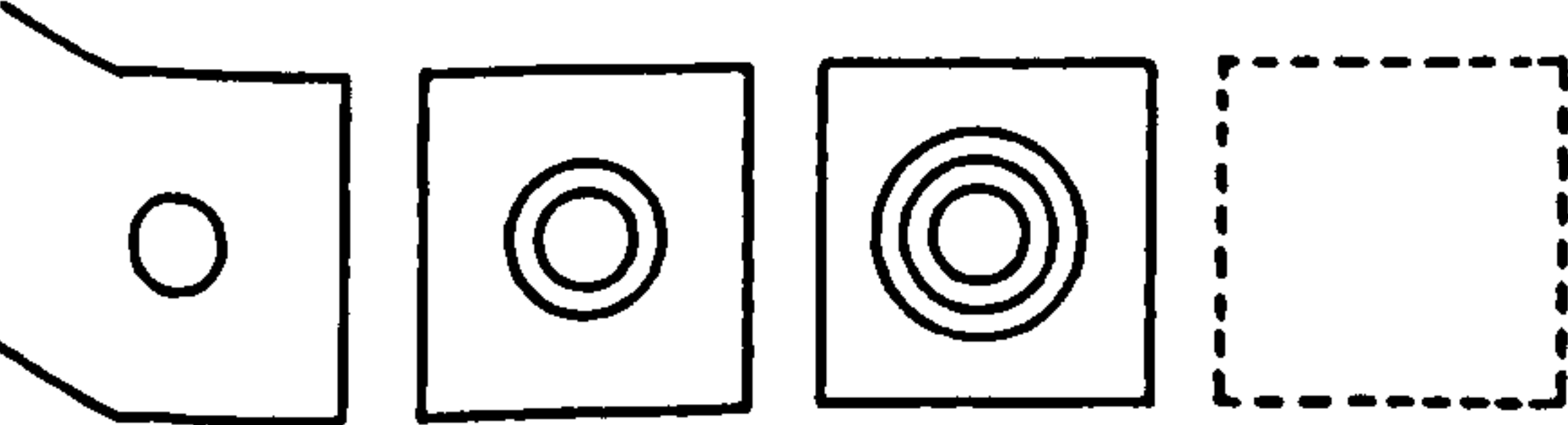
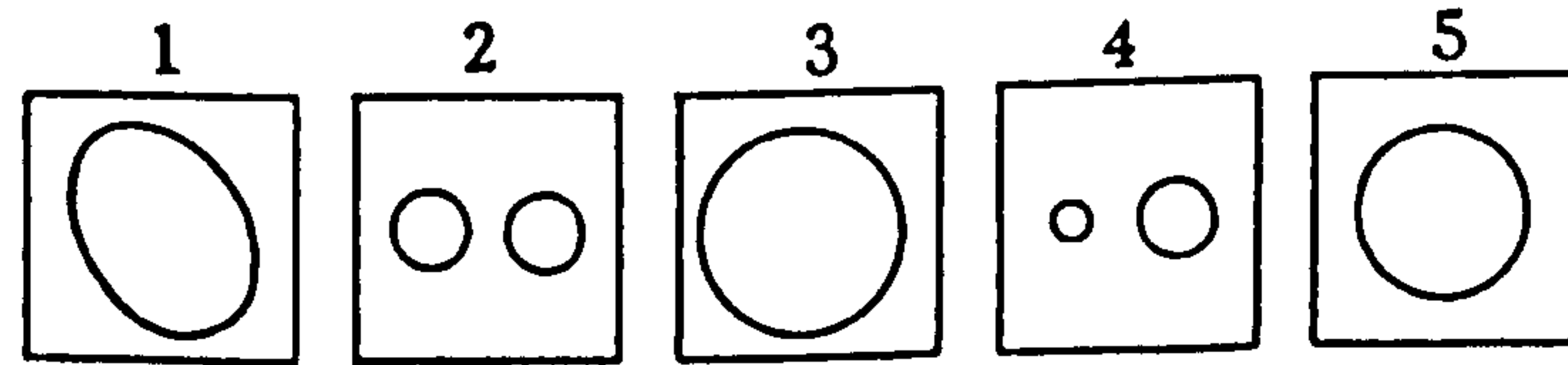
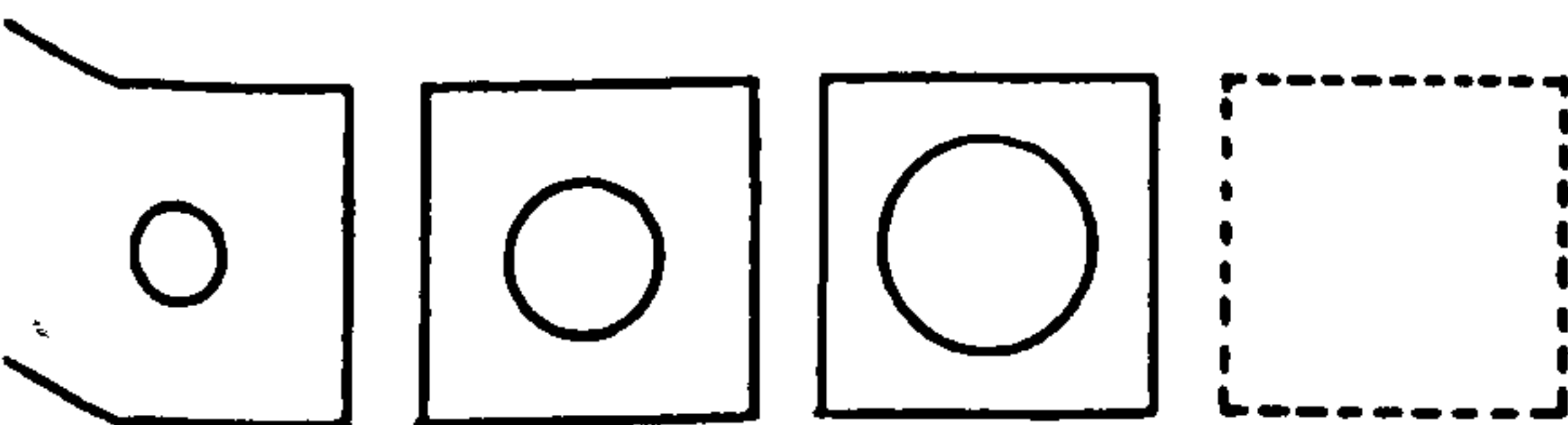
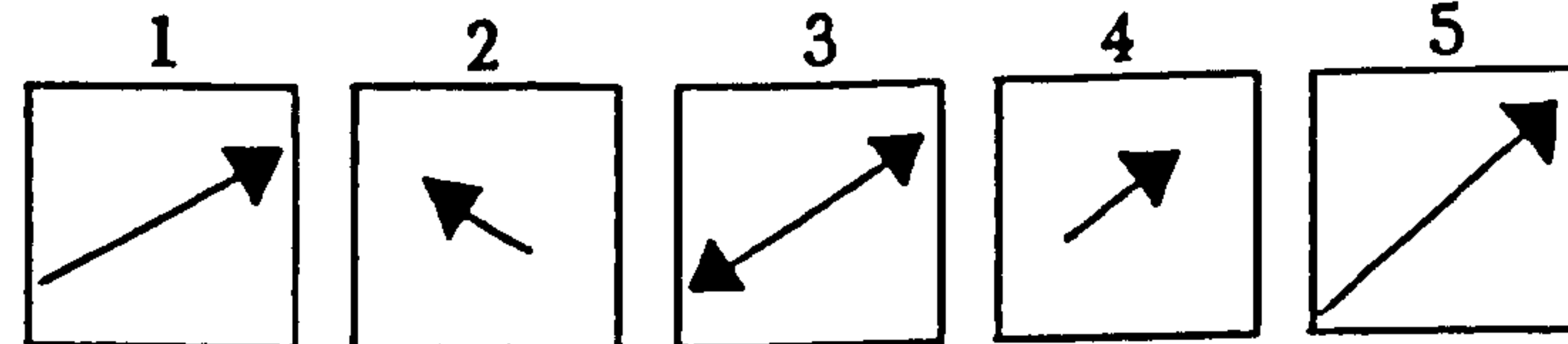
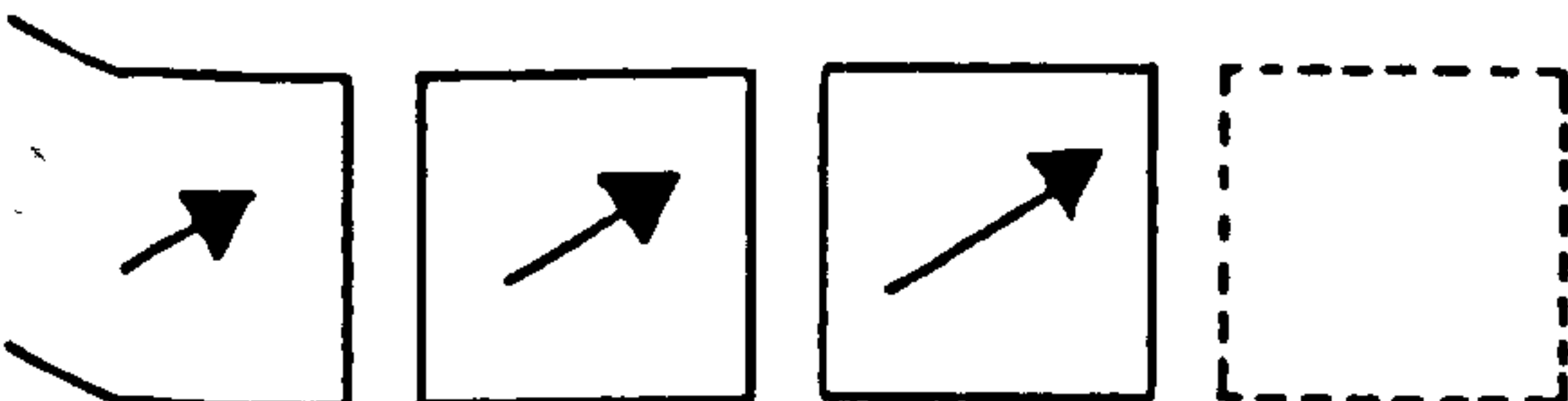
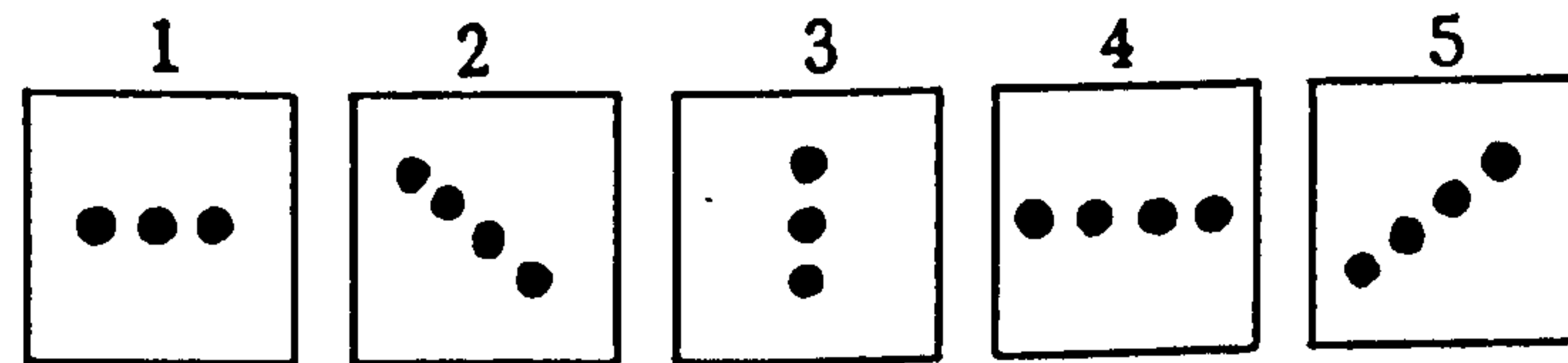
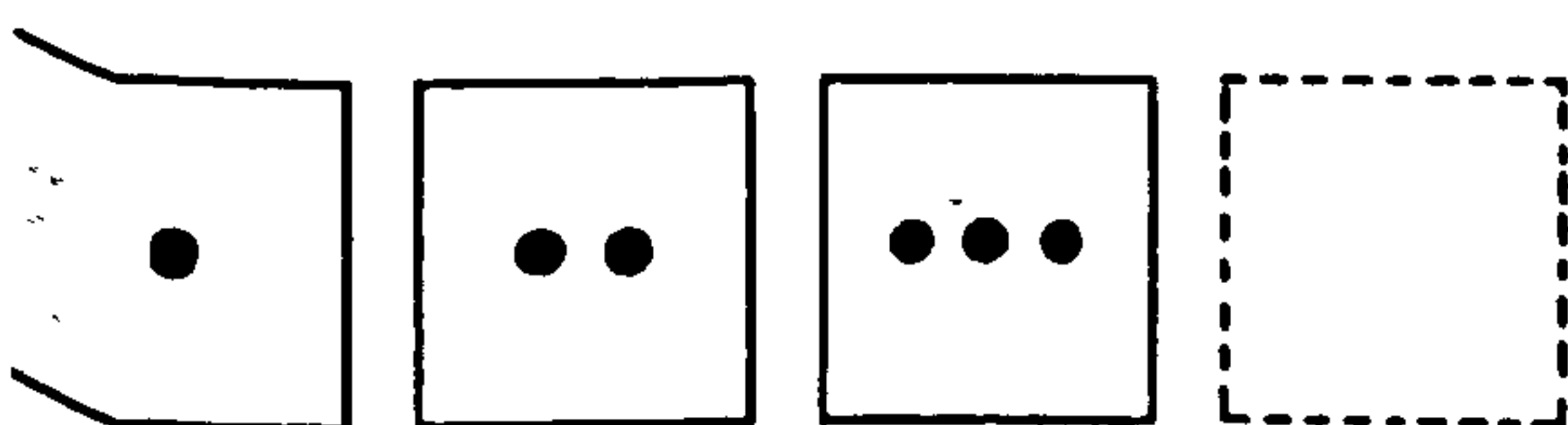
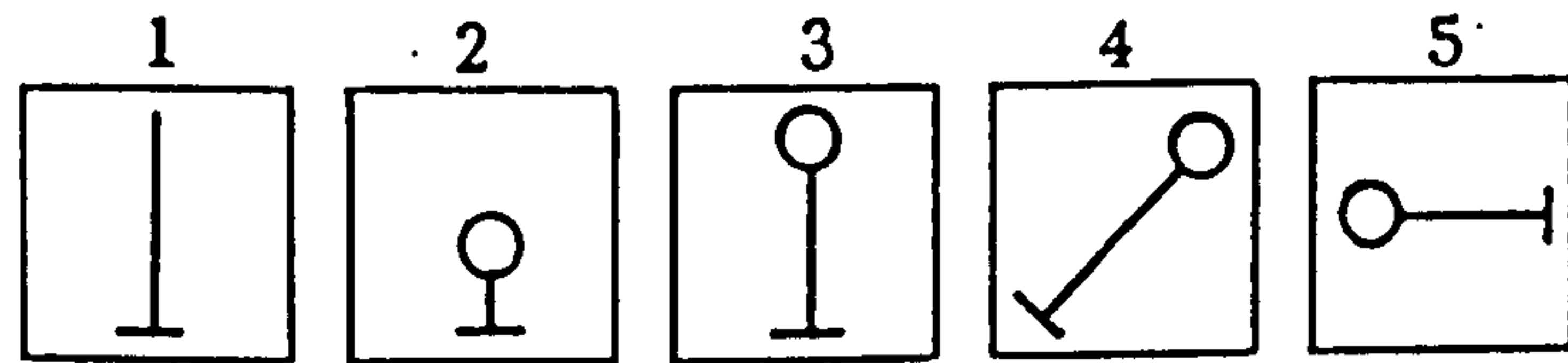
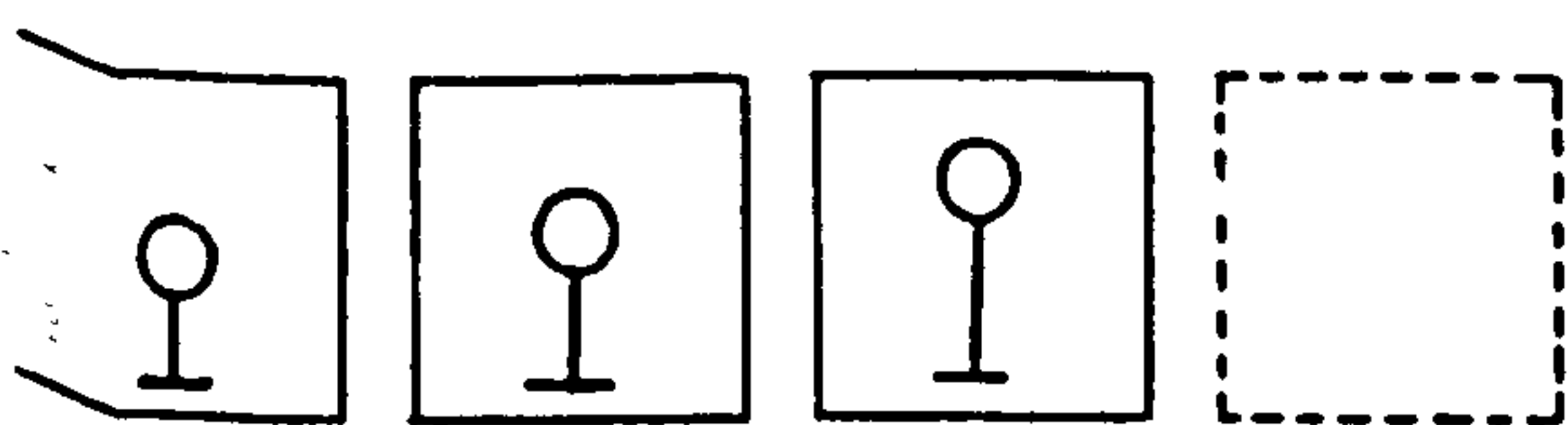
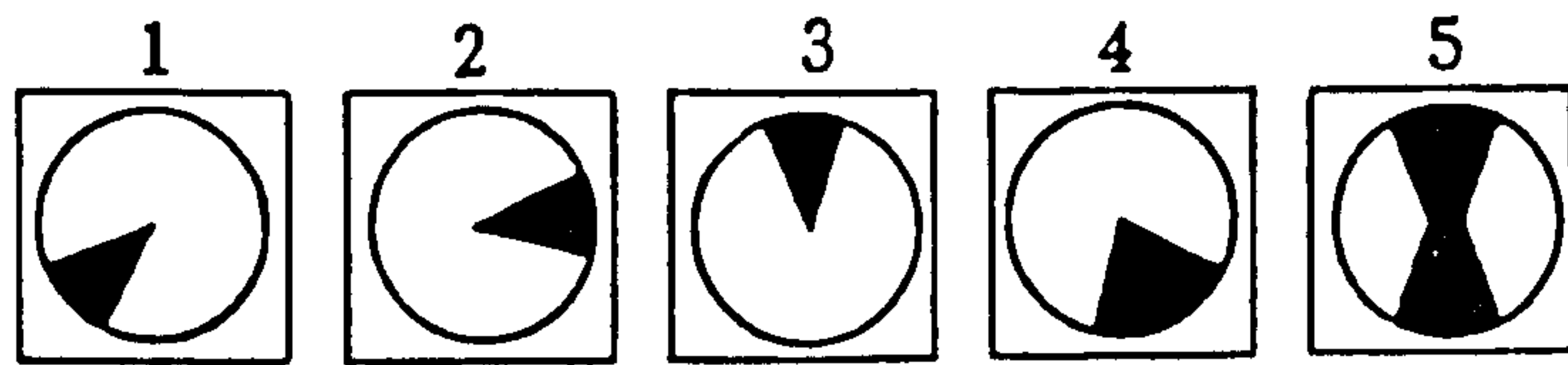
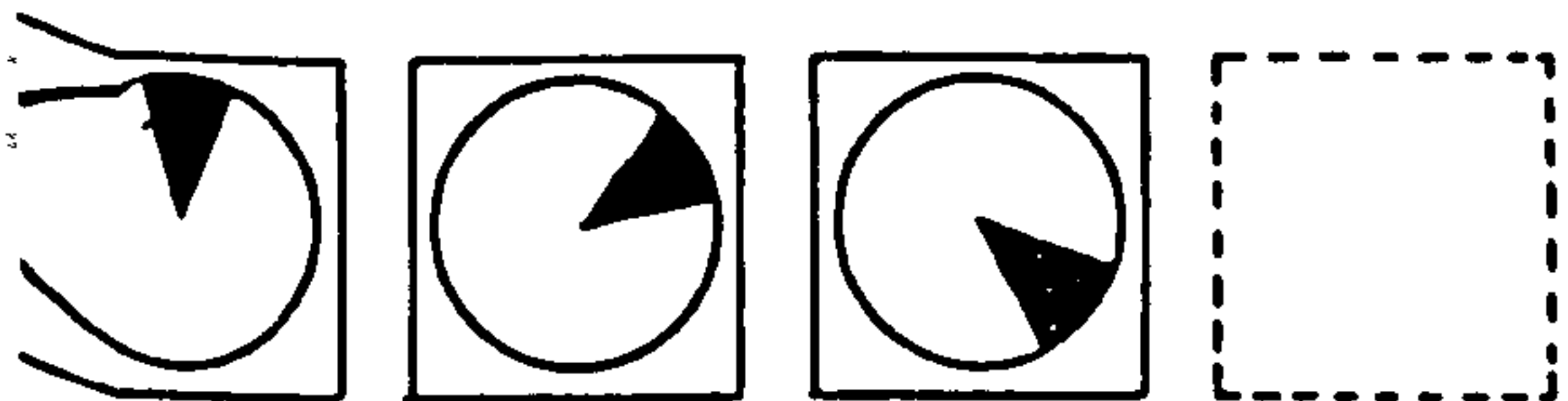
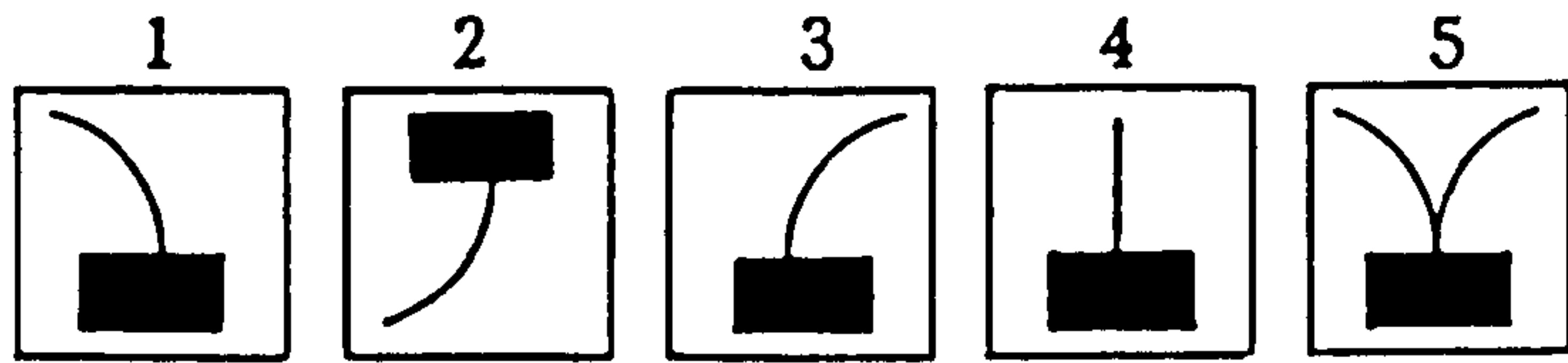
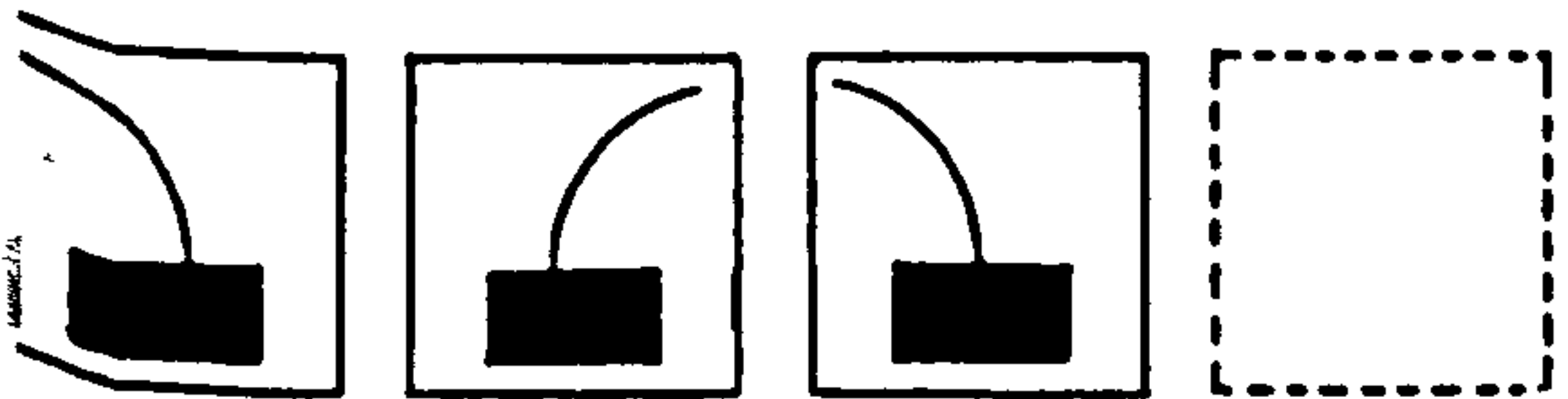
TEST 1

Examples



Answers

1

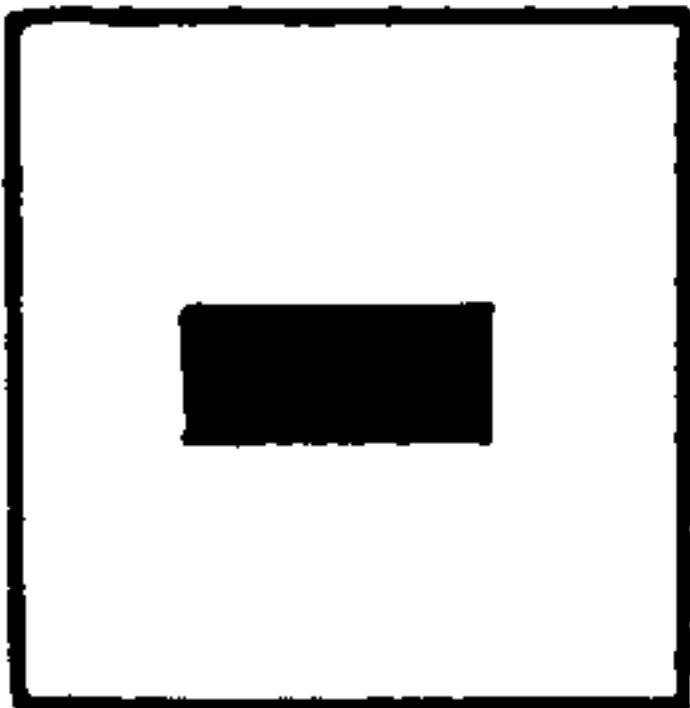
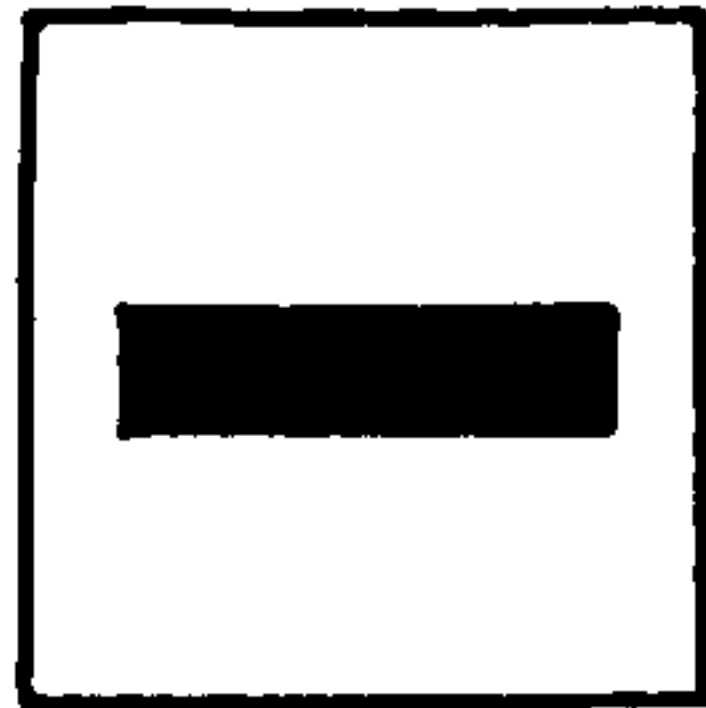
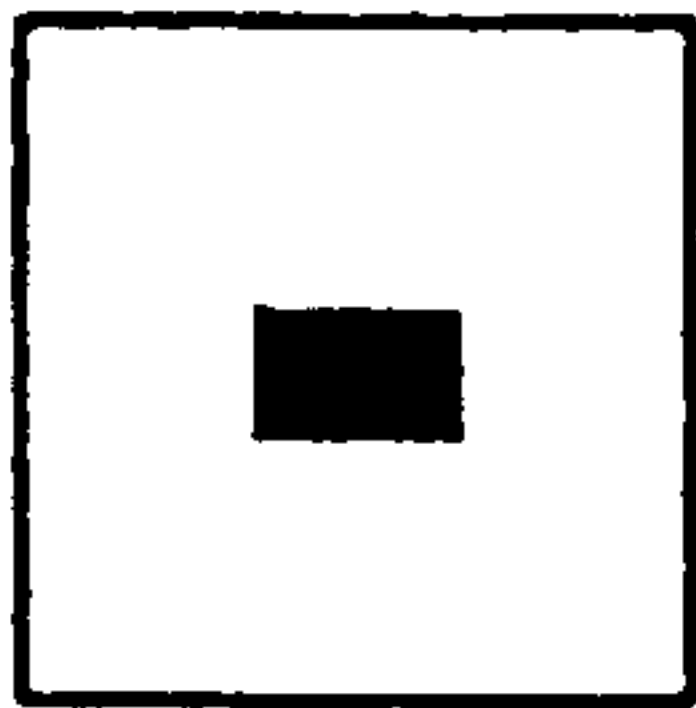
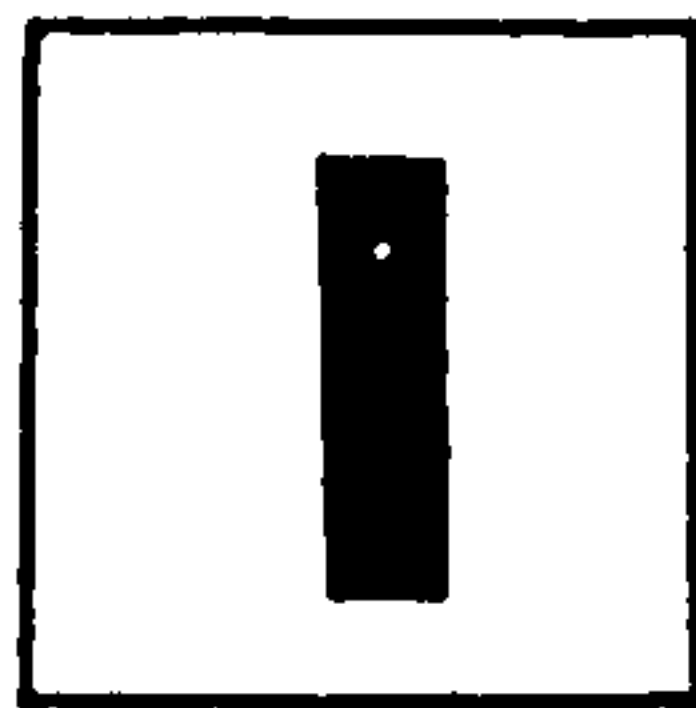
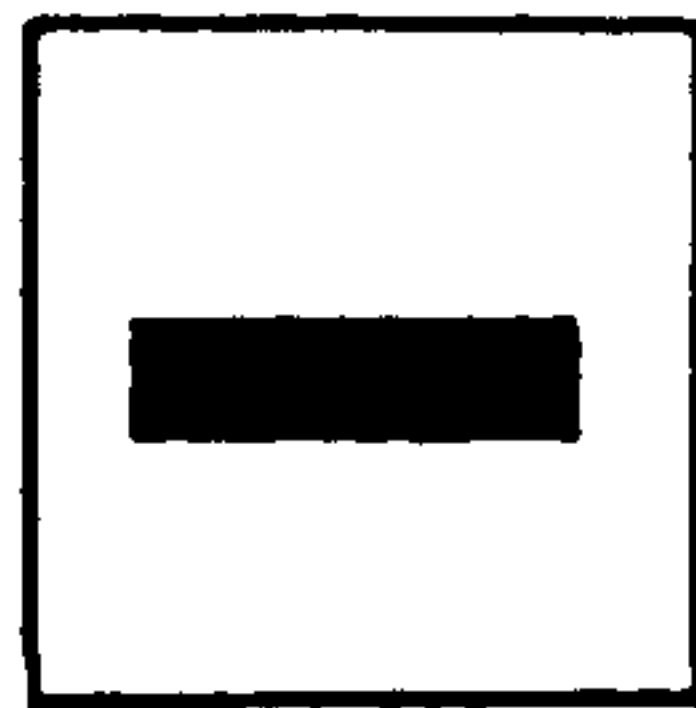
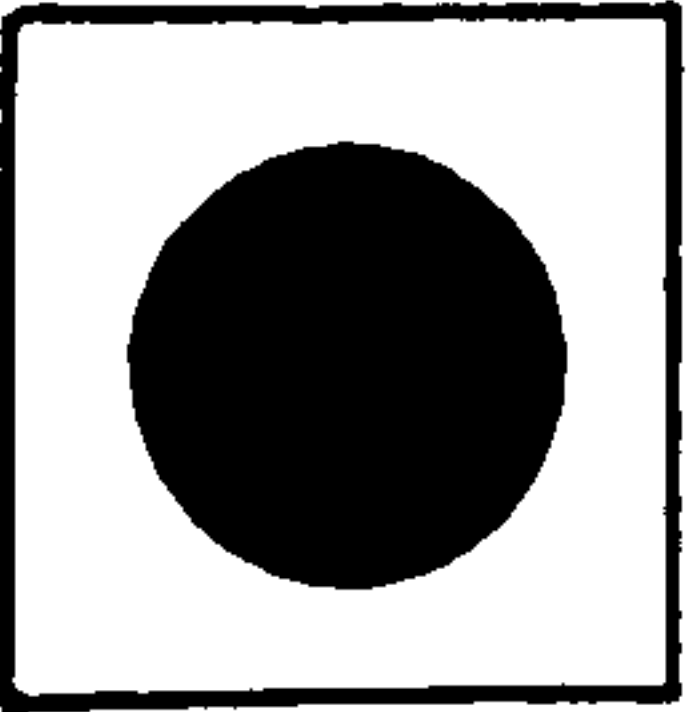
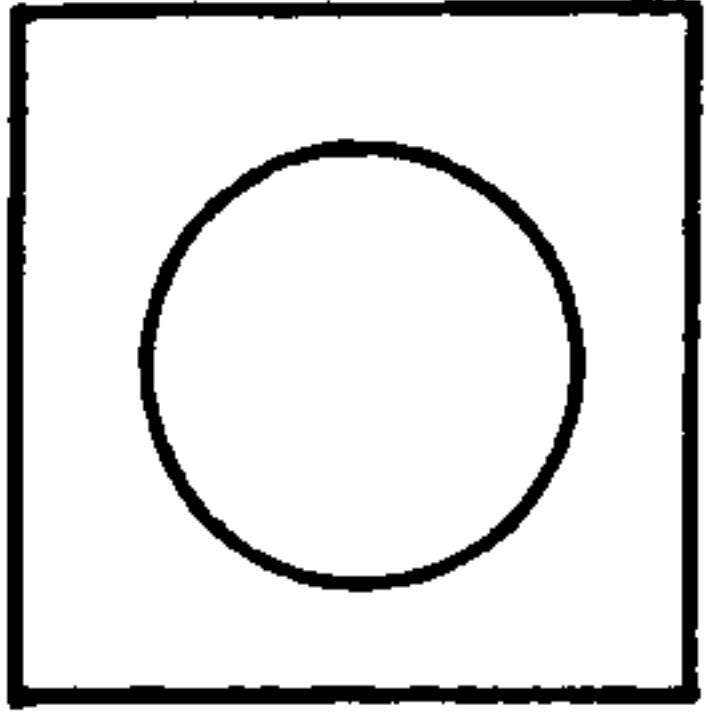
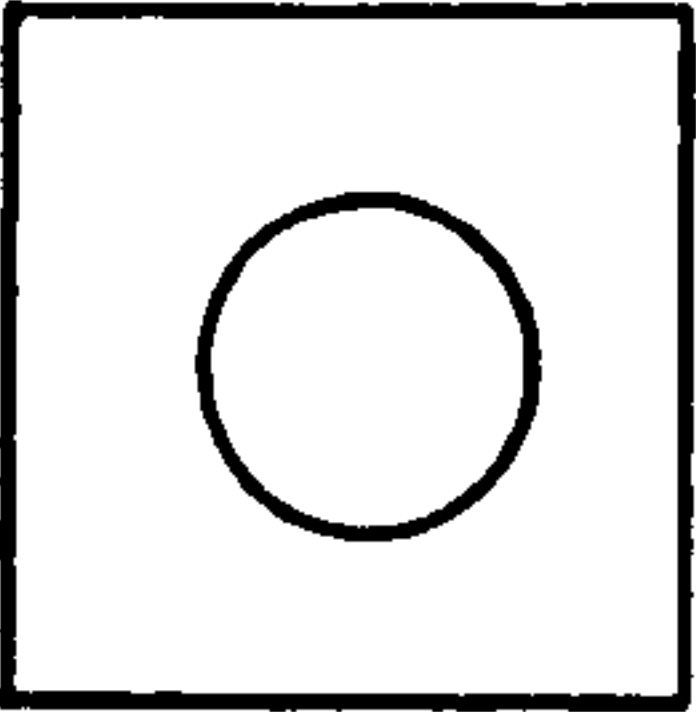
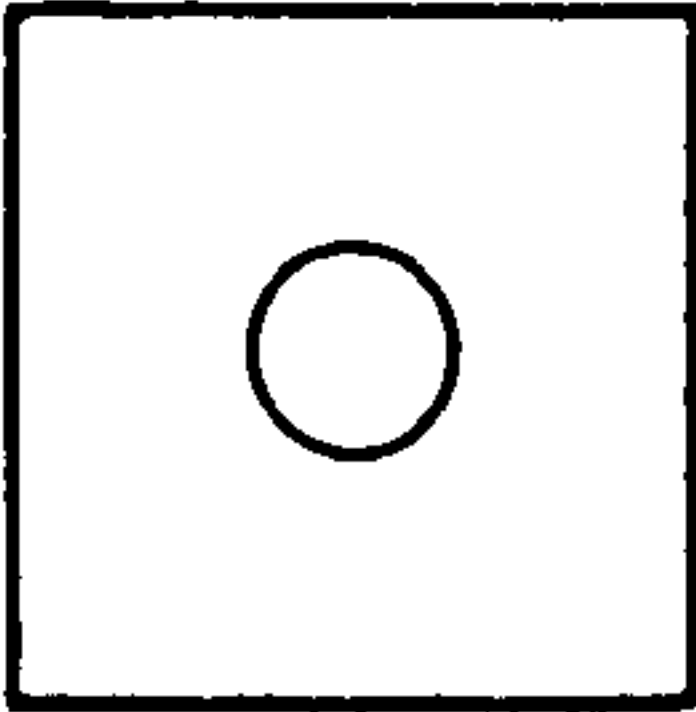
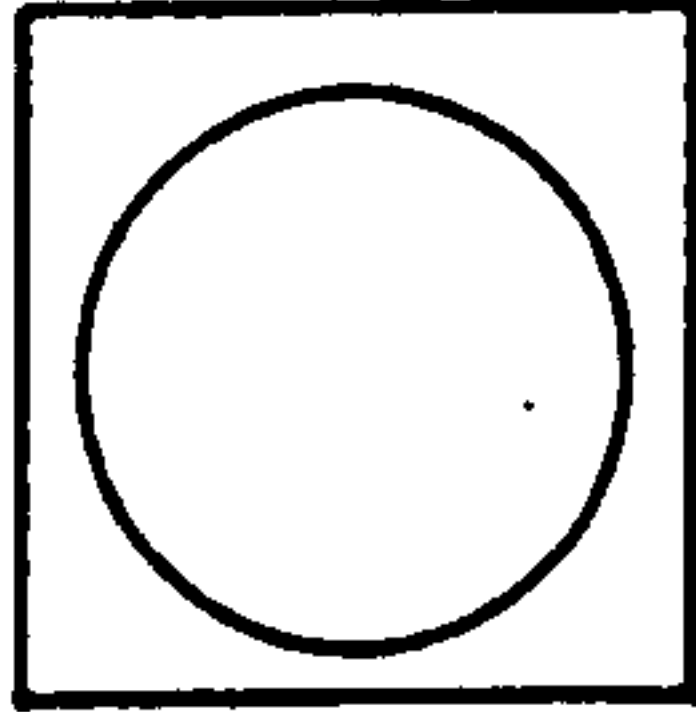


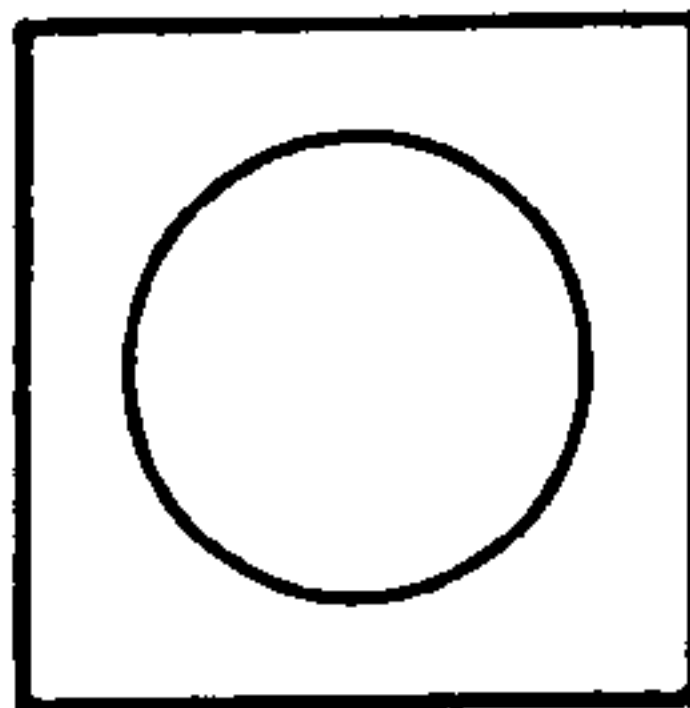
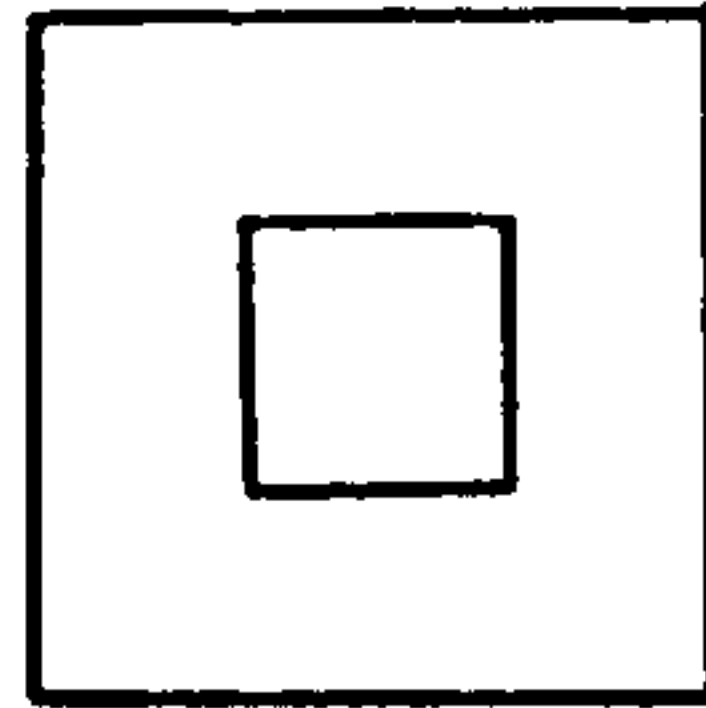
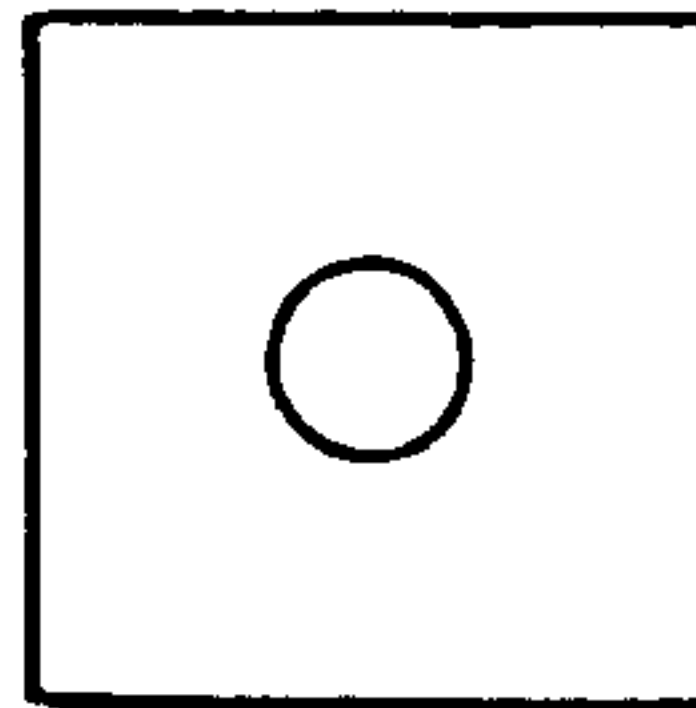
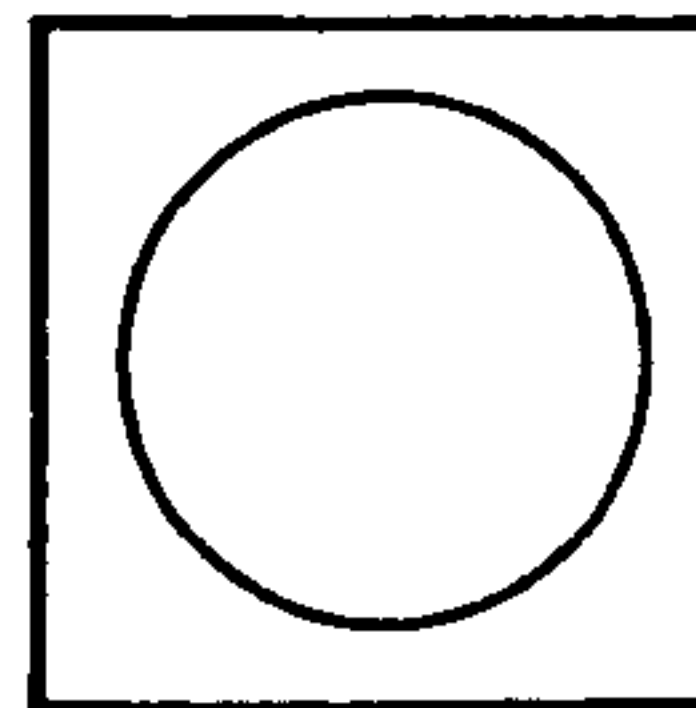
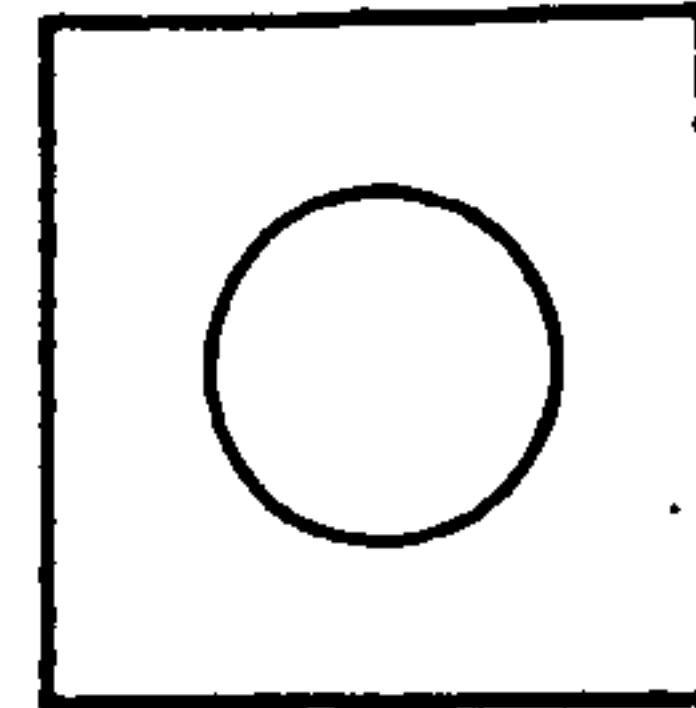
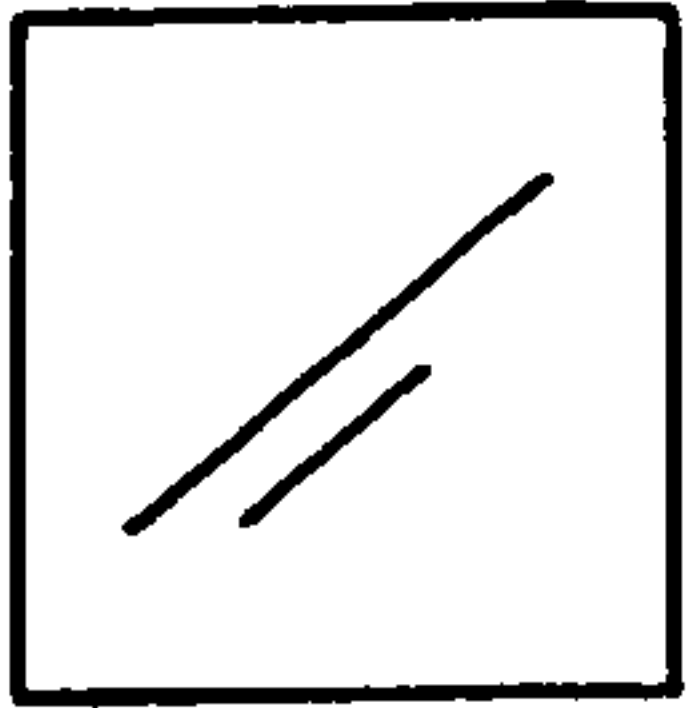
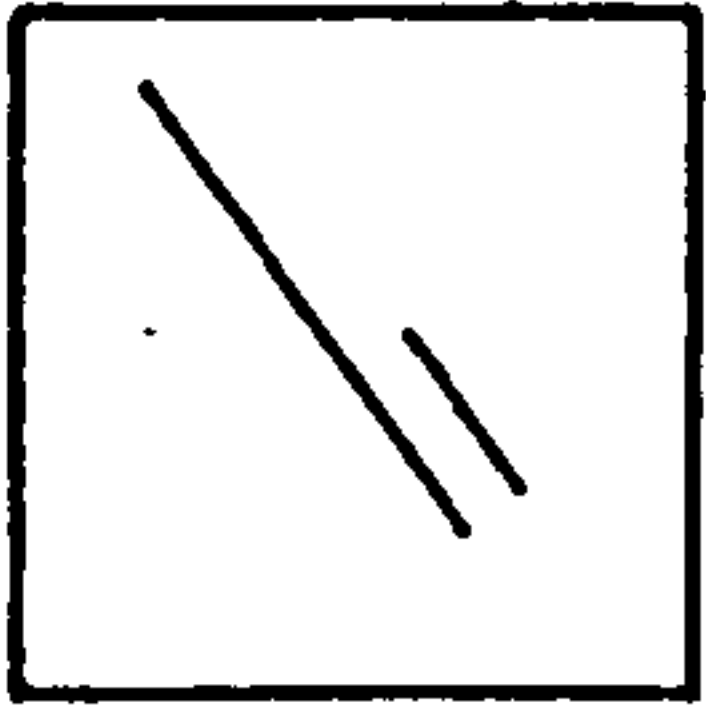
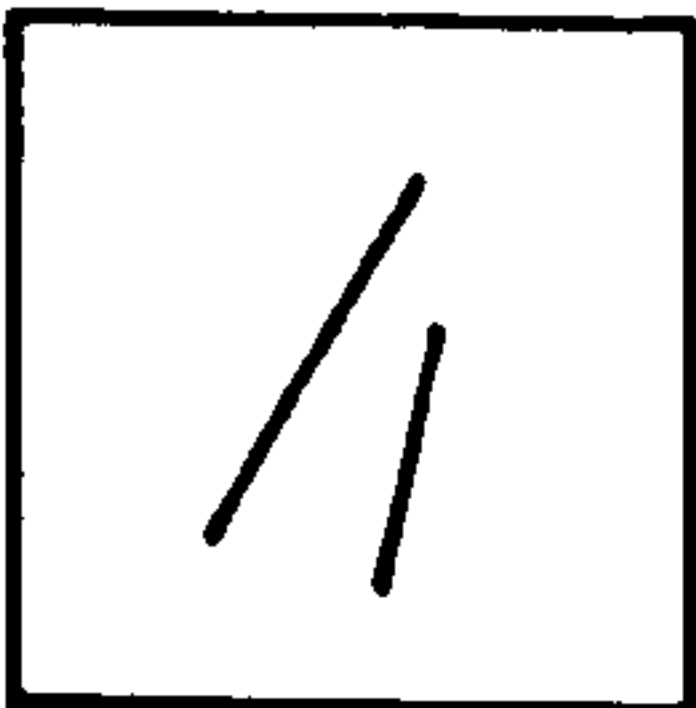
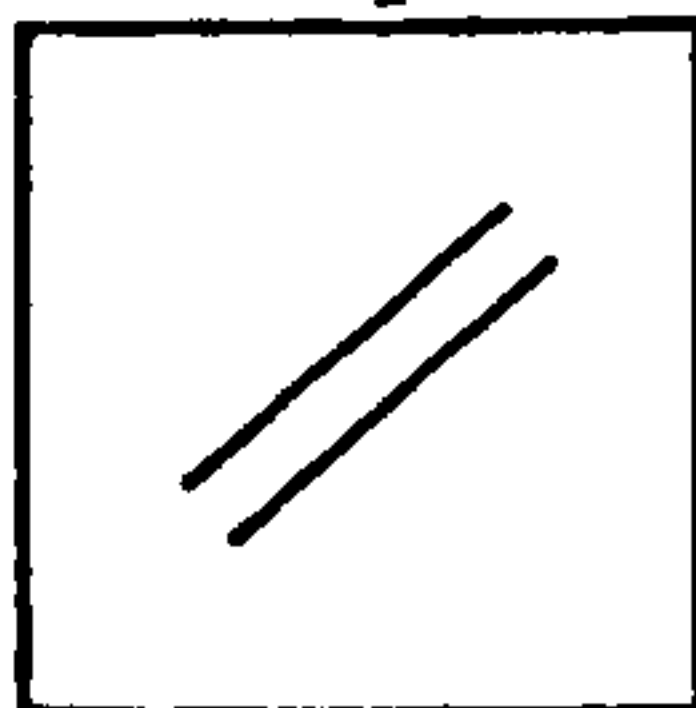
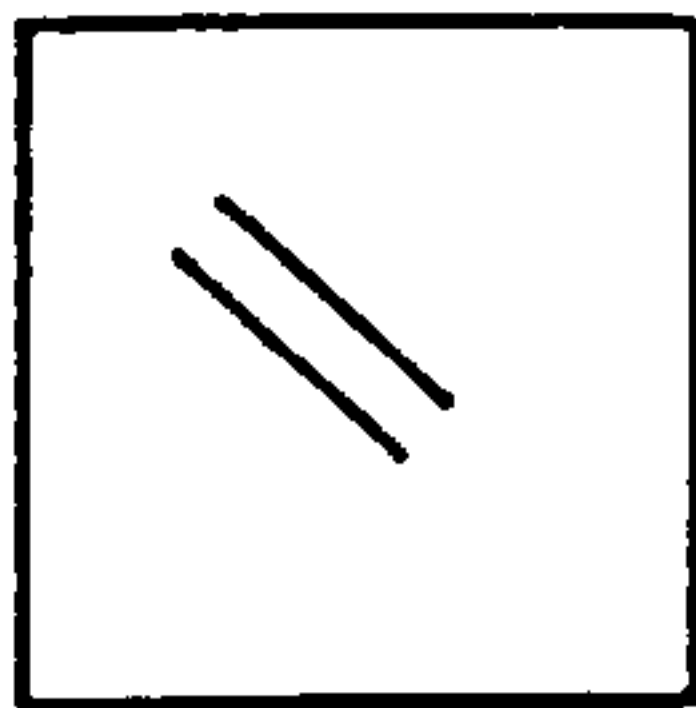
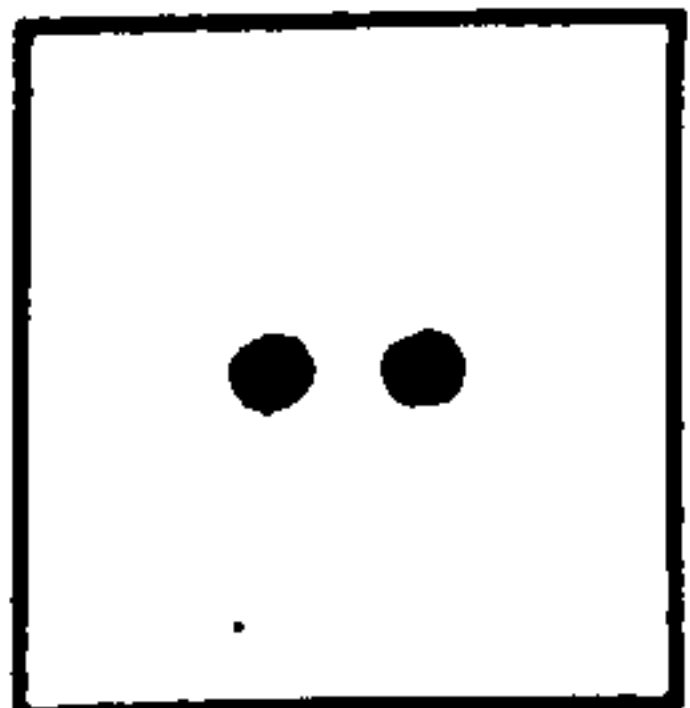
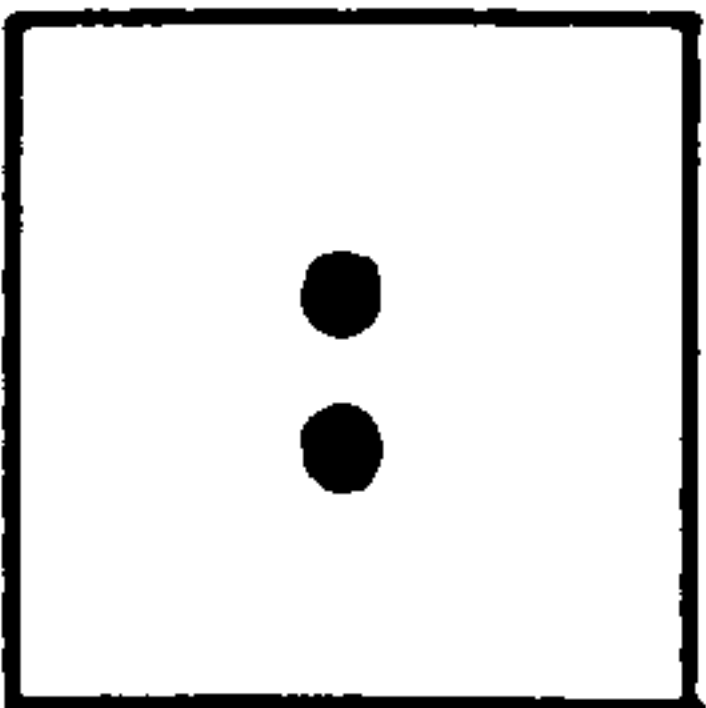
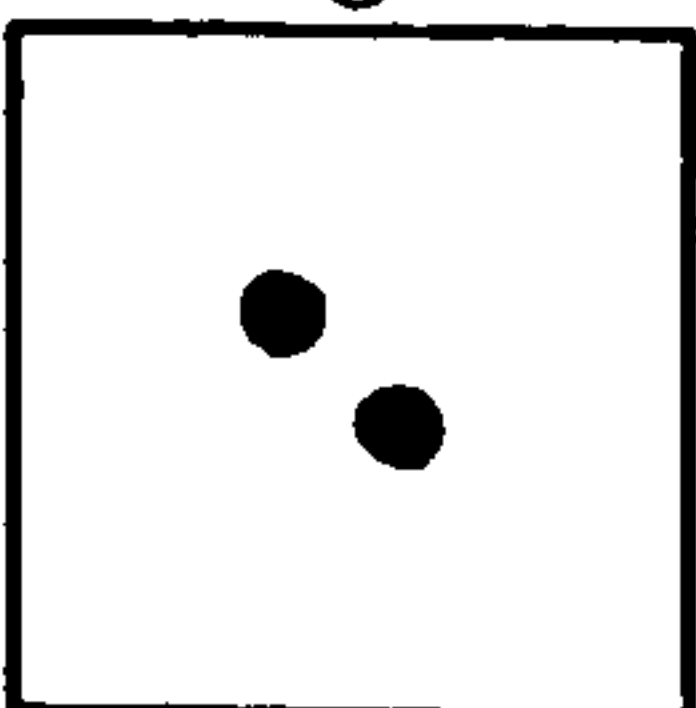
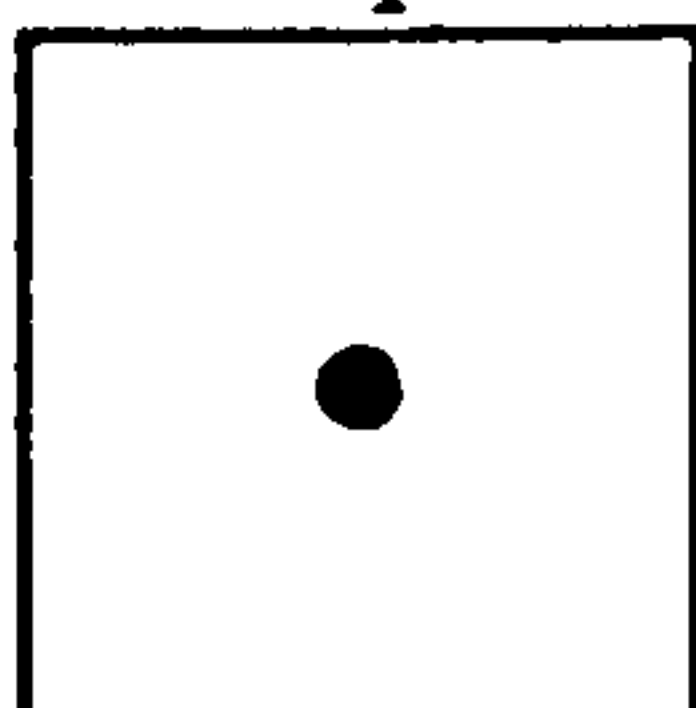
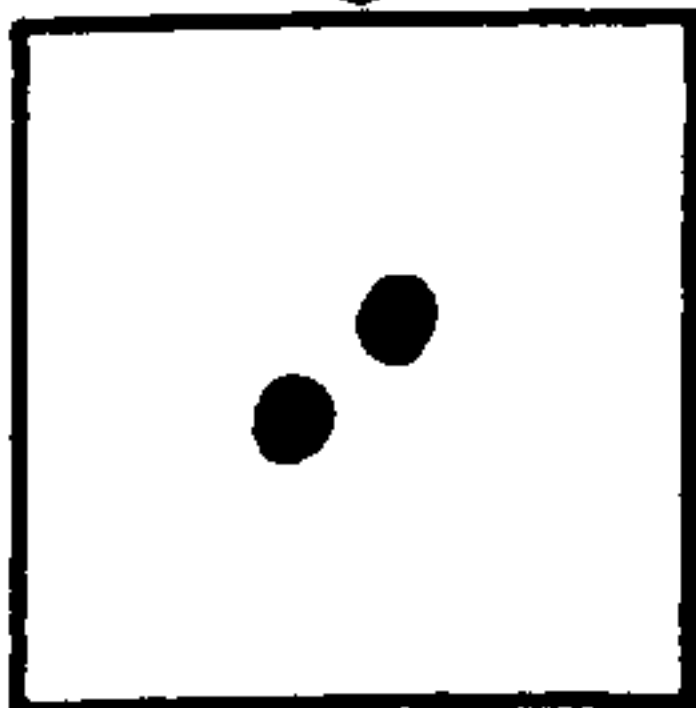
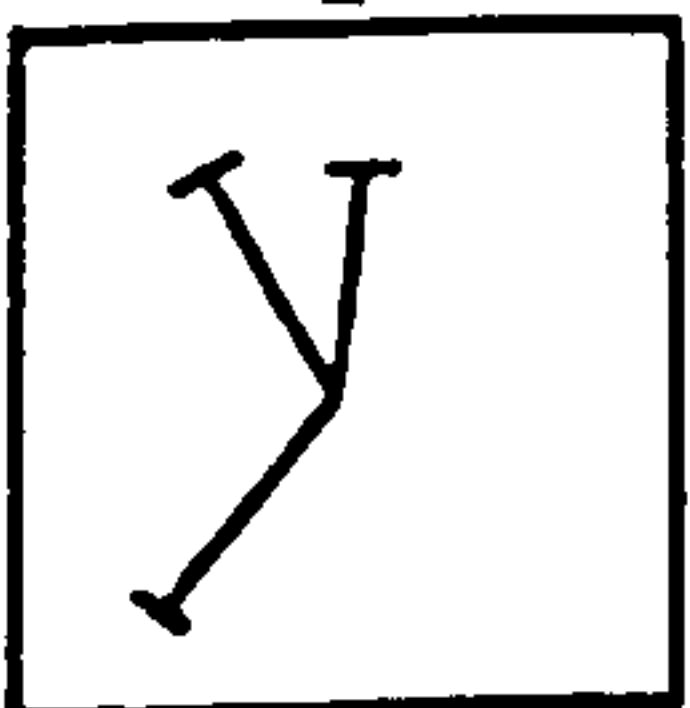
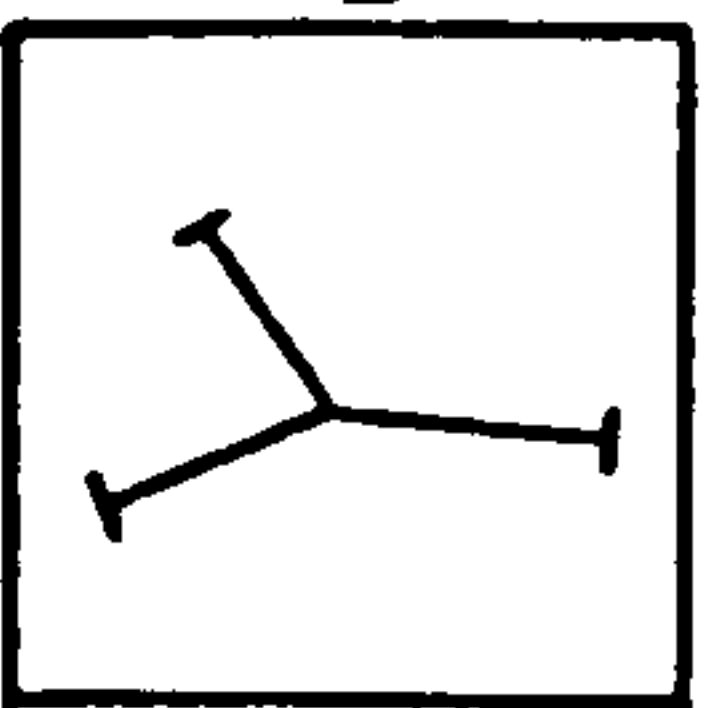
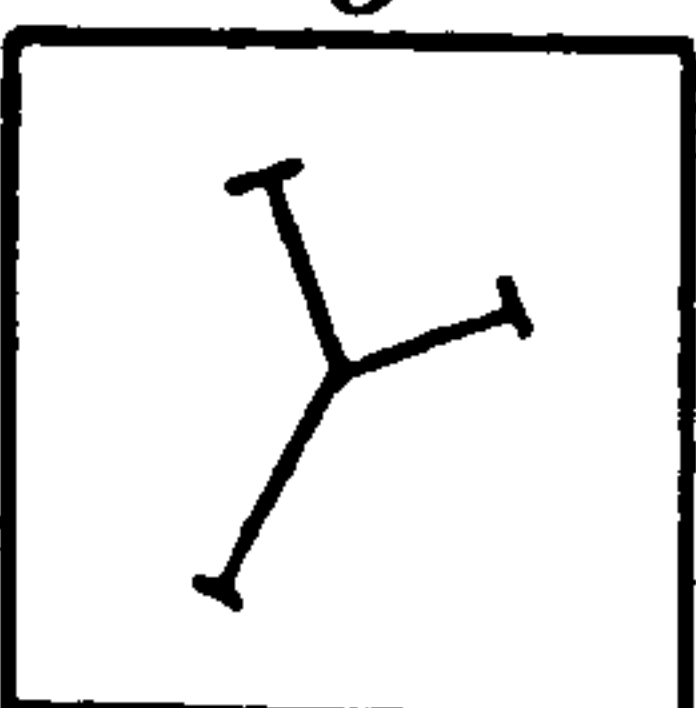
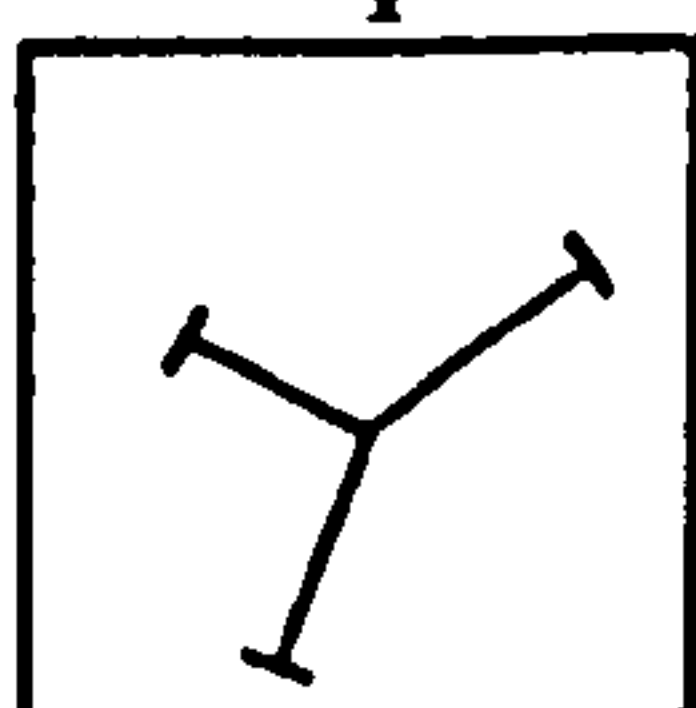
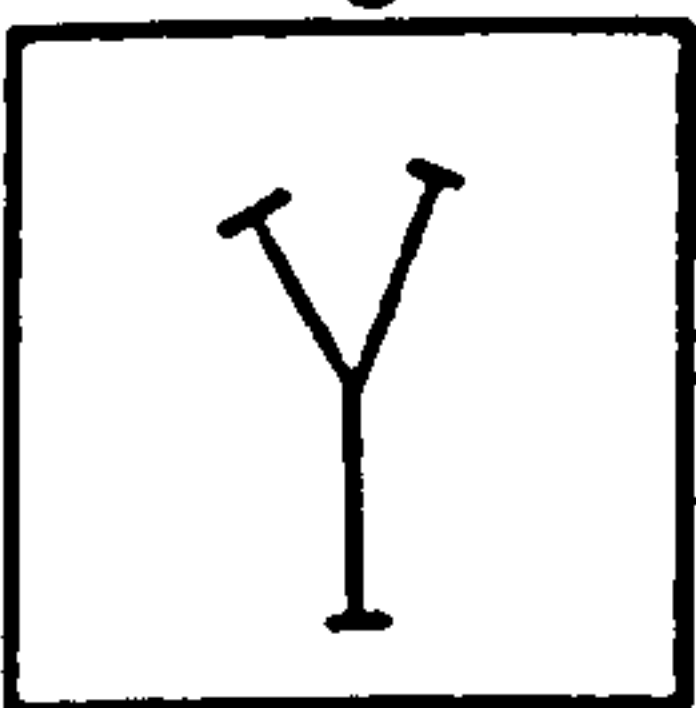
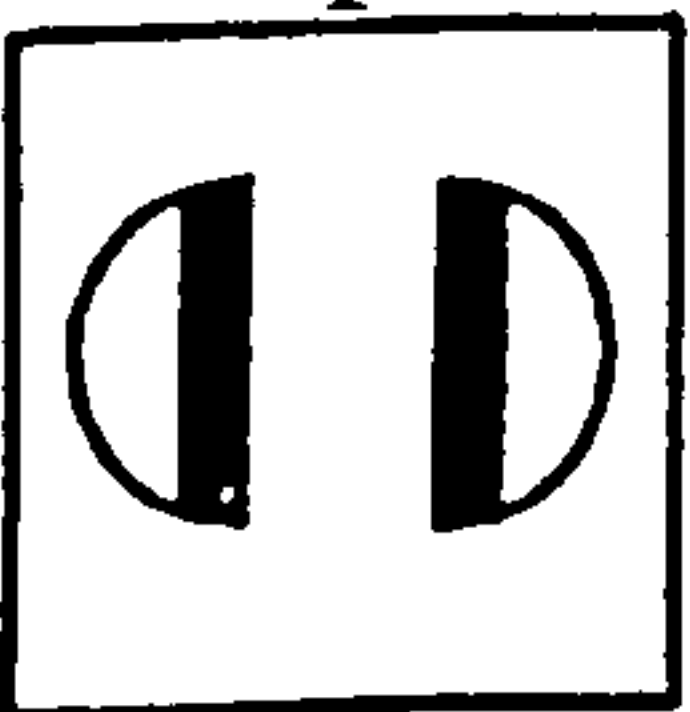
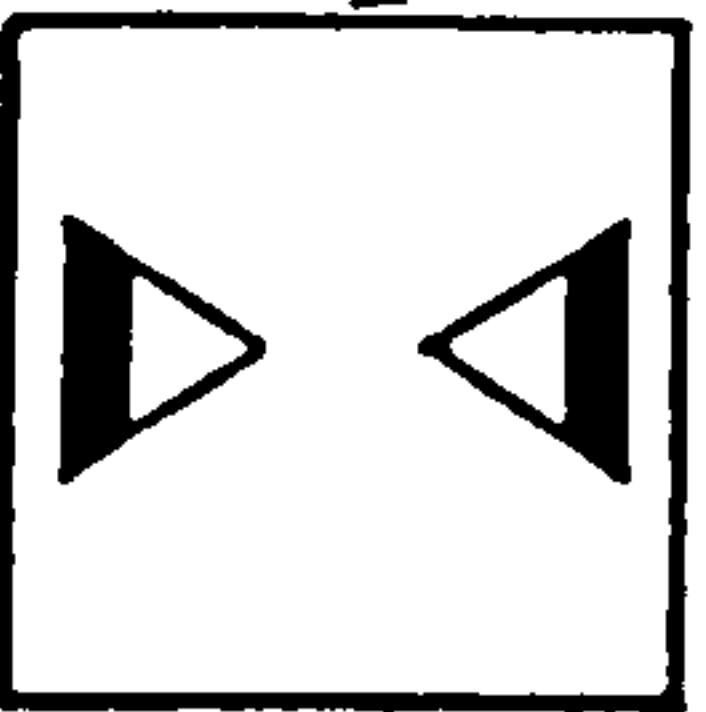
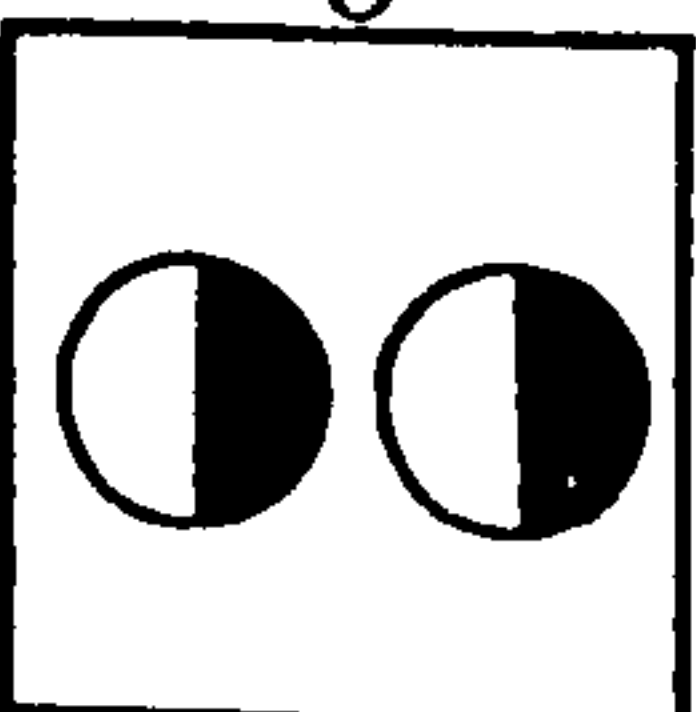
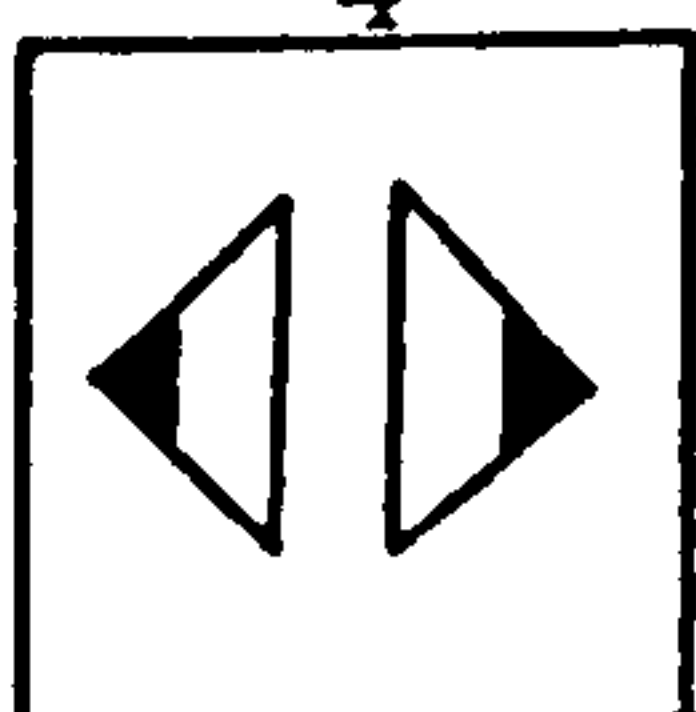
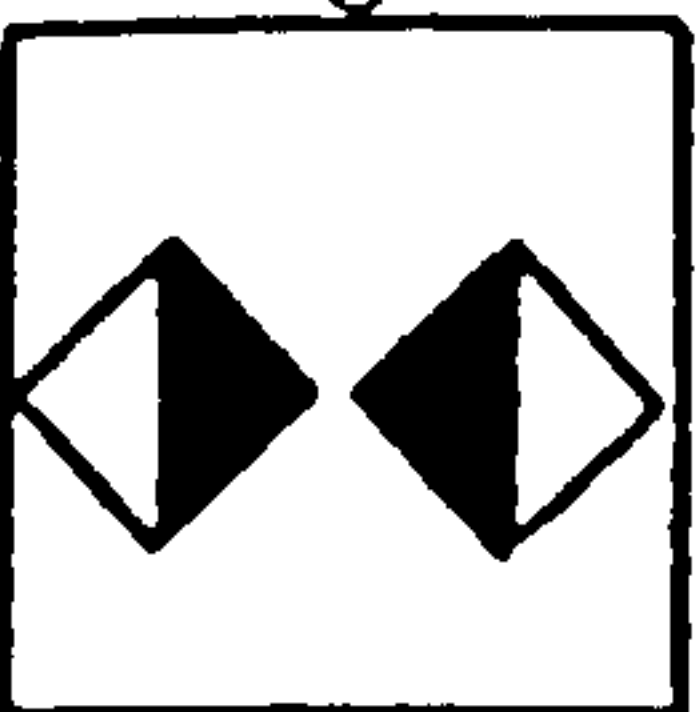
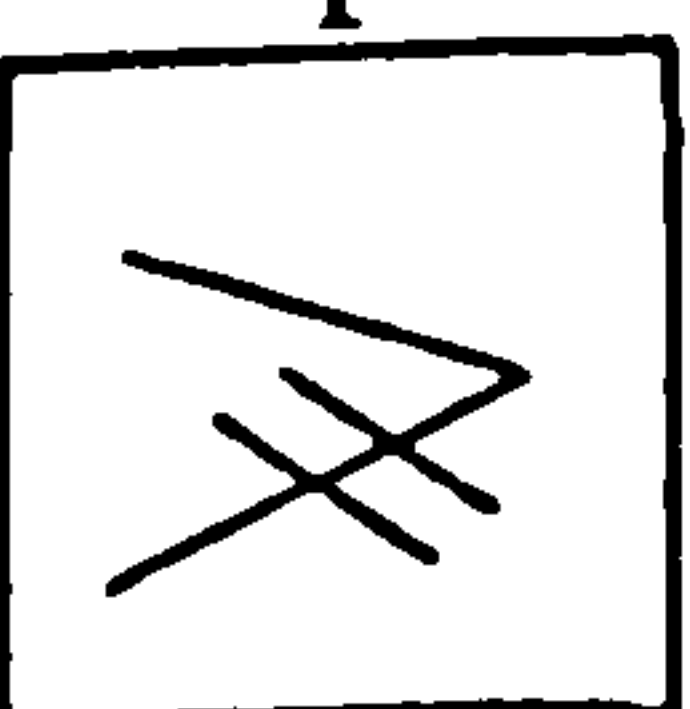
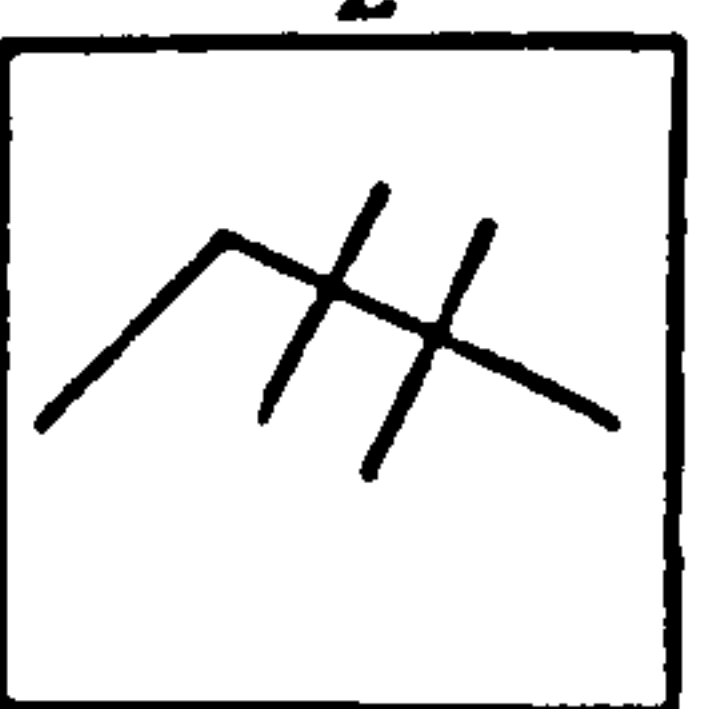
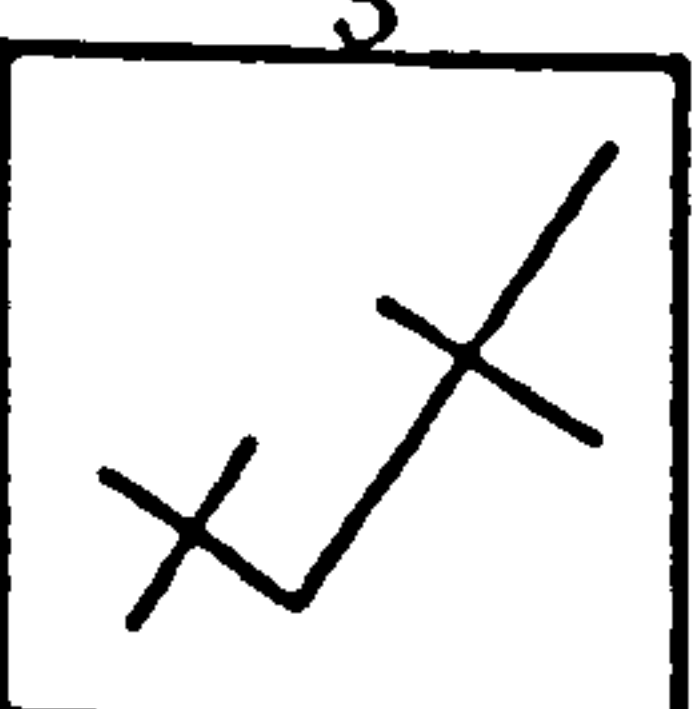
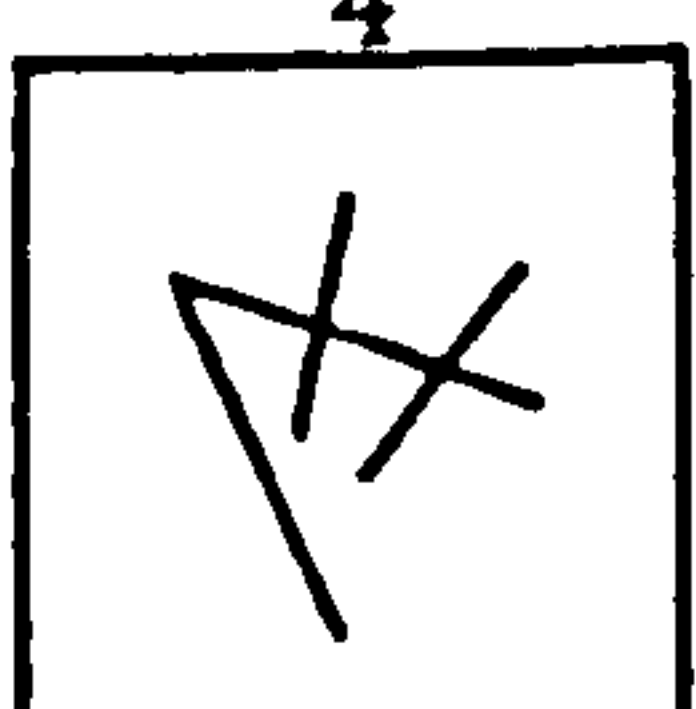
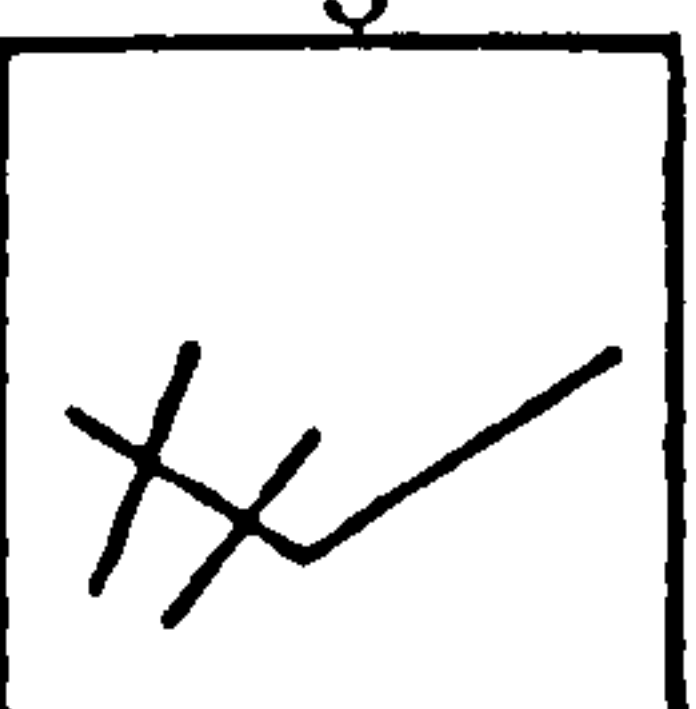
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				1 	2 	3 	4 	5 	<input type="checkbox"/>
				1 	2 	3 	4 	5 	<input type="checkbox"/>
				1 	2 	3 	4 	5 	<input type="checkbox"/>
				1 	2 	3 	4 	5 	<input type="checkbox"/>
				1 	2 	3 	4 	5 	<input type="checkbox"/>
				1 	2 	3 	4 	5 	<input type="checkbox"/>

End of Test 1

TEST 2

Examples

	1	2	3	4	5	Answers
						<input type="checkbox"/> 4
						<input type="checkbox"/>

1.						<input type="checkbox"/>
2.						<input type="checkbox"/>
3.						<input type="checkbox"/>
4.						<input type="checkbox"/>
5.						<input type="checkbox"/>
6.						<input type="checkbox"/>

					Answers
1 	2 	3 	4 	5 	<input type="checkbox"/>
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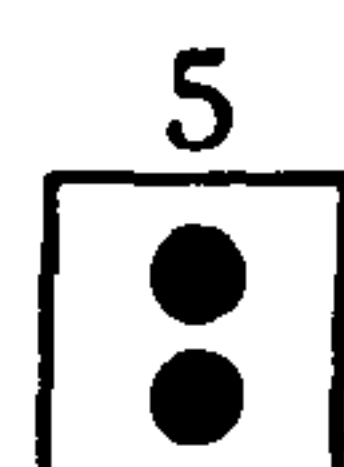
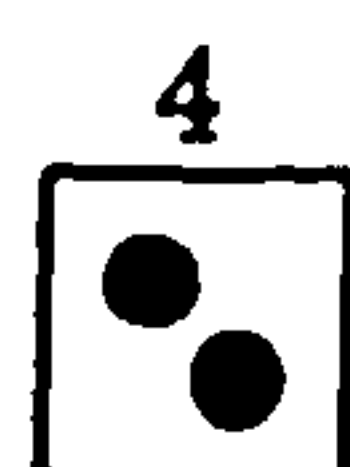
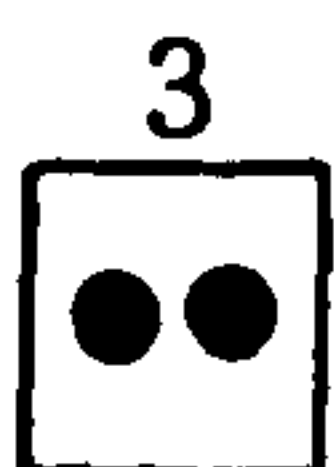
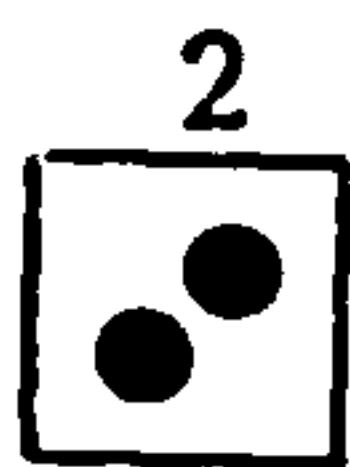
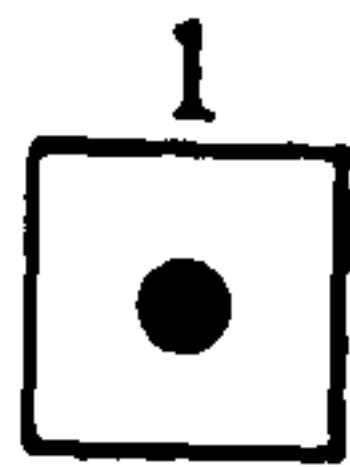
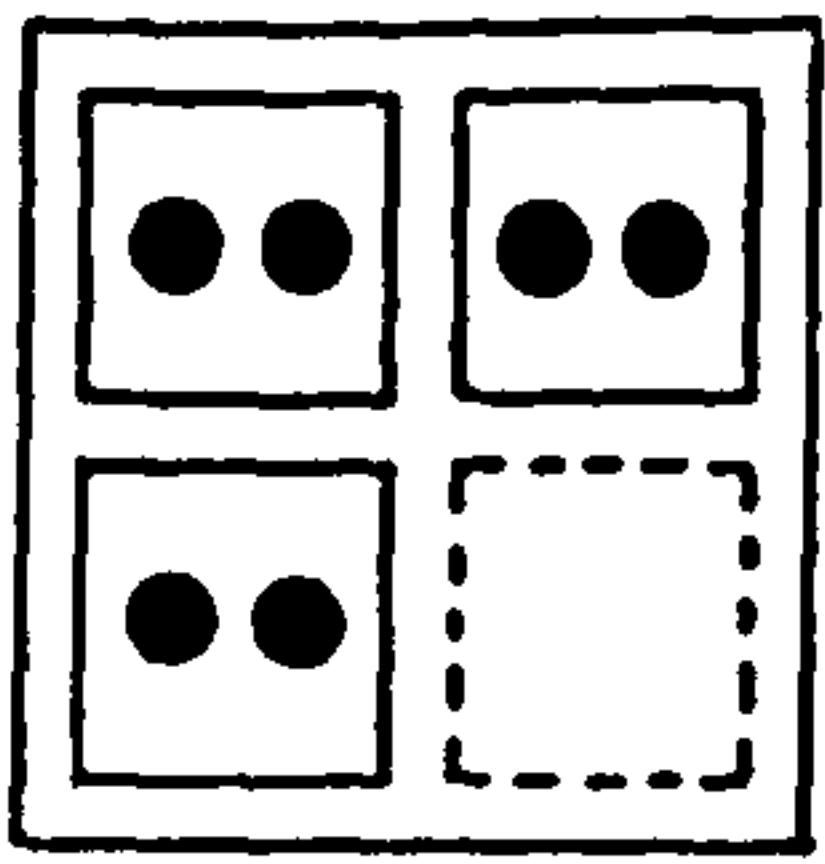
End of Test 2

4.

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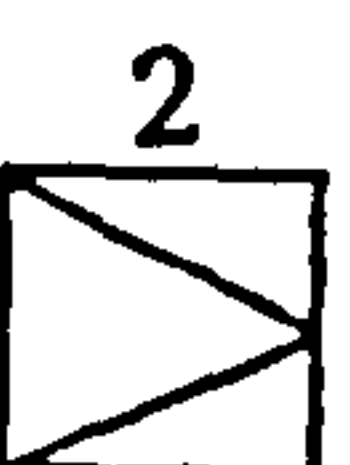
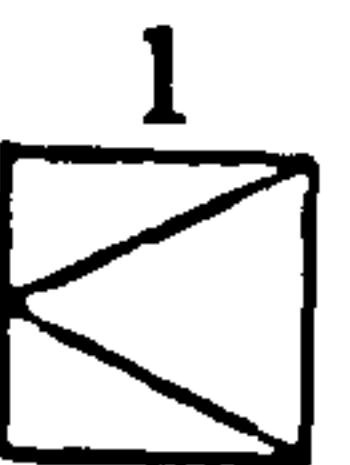
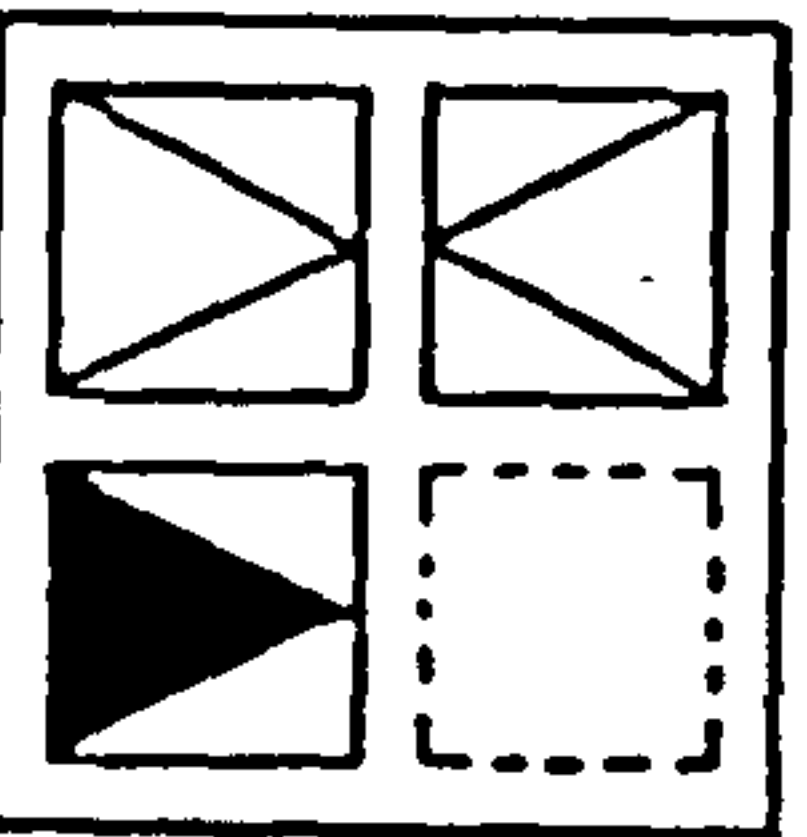
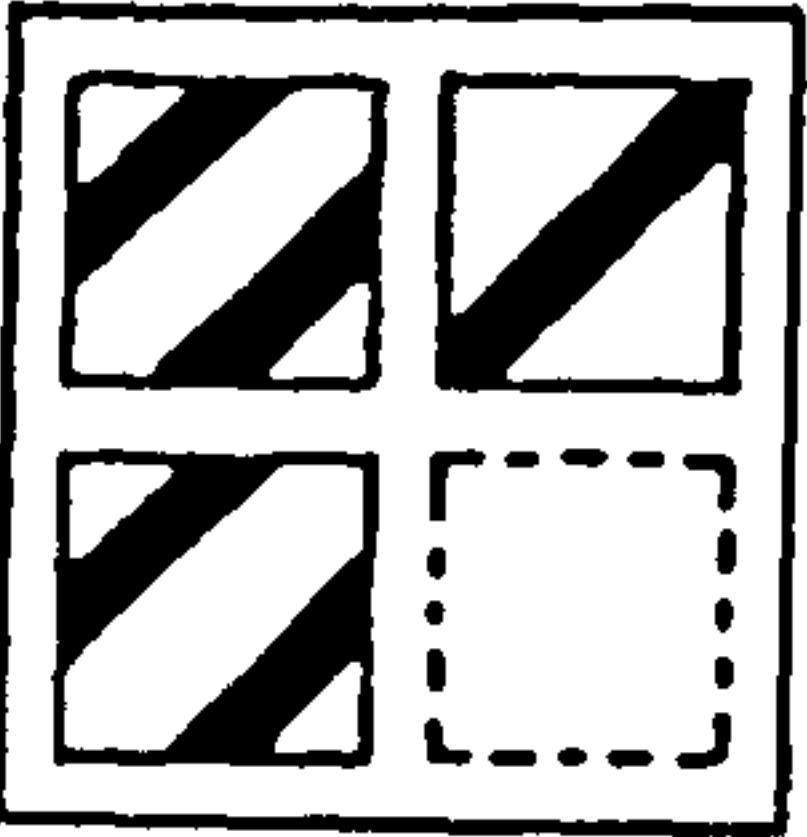
TEST 3

Examples

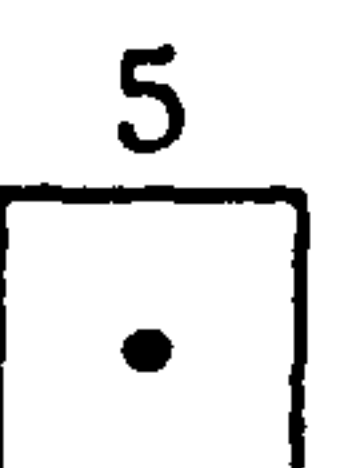
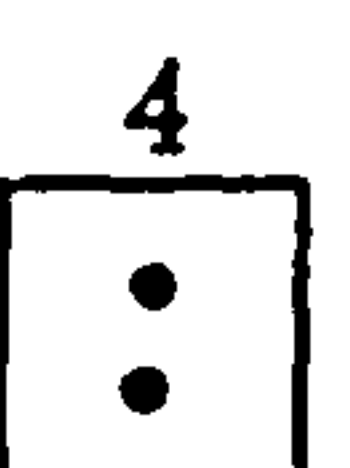
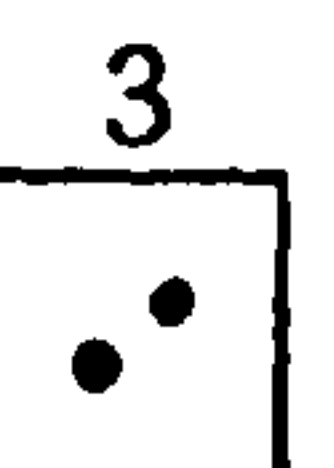
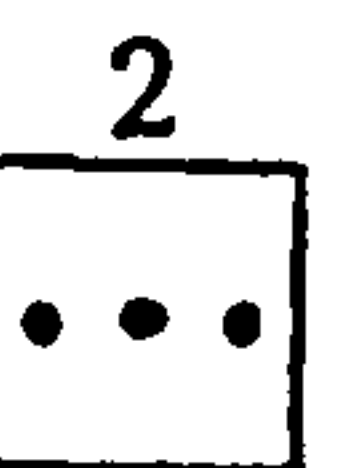
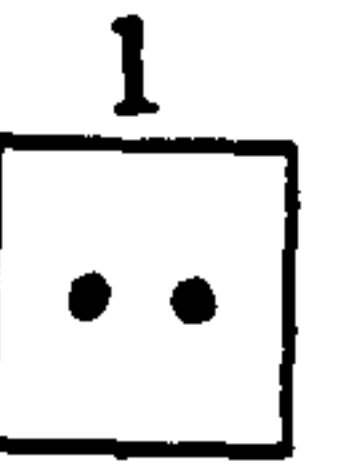
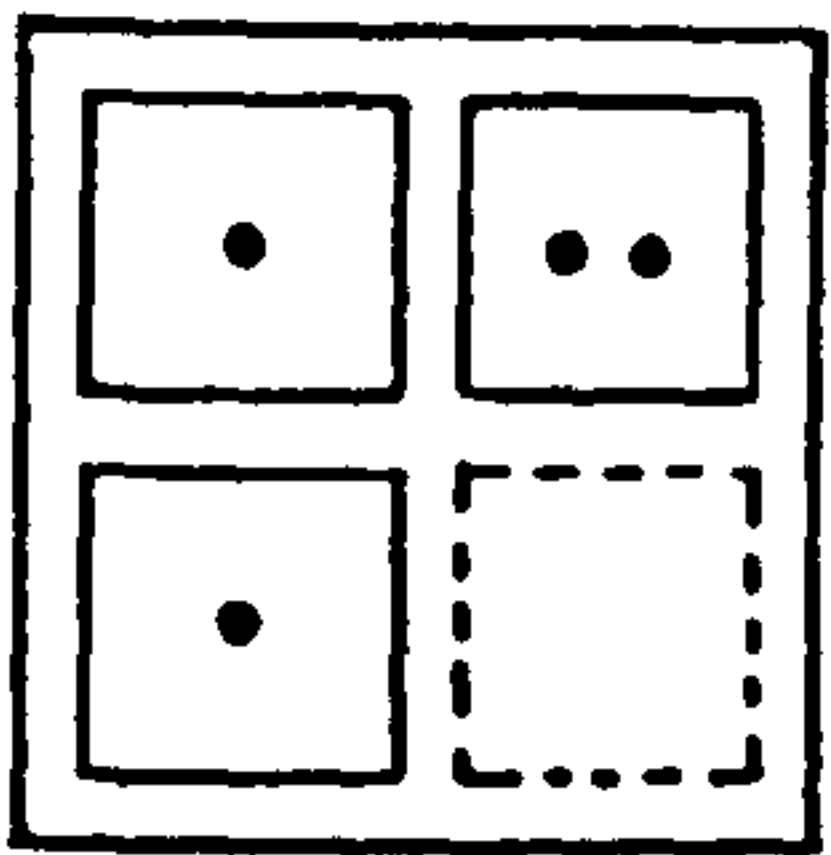


Answers

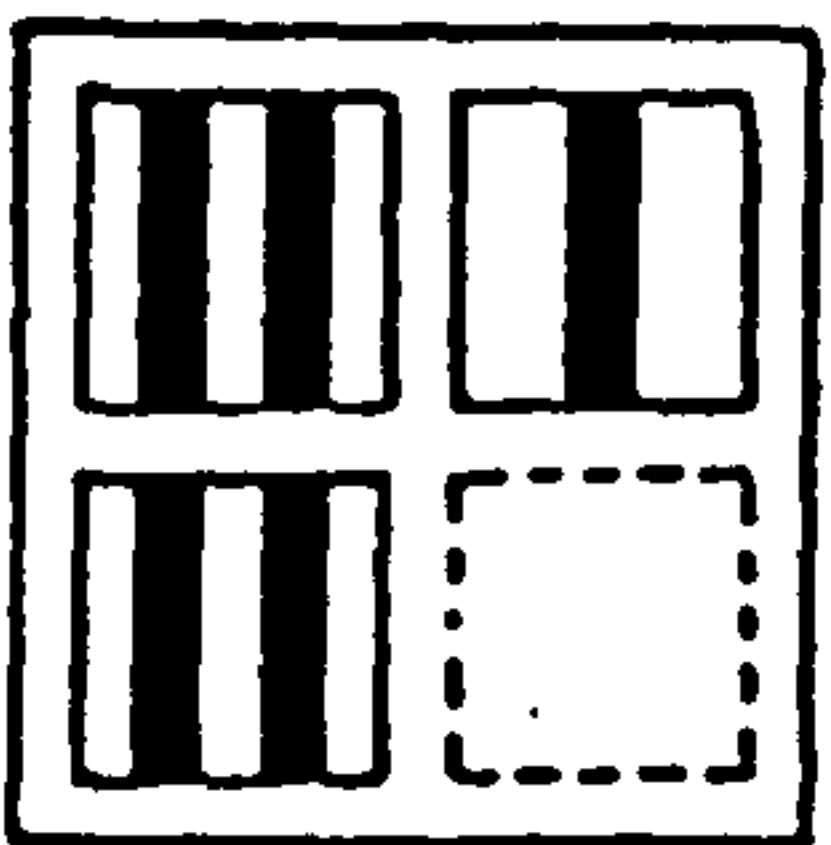
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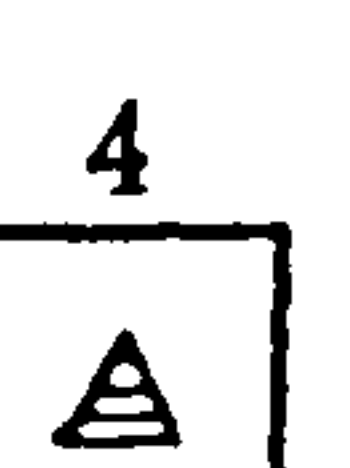
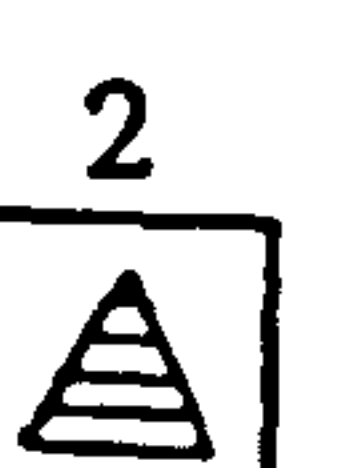
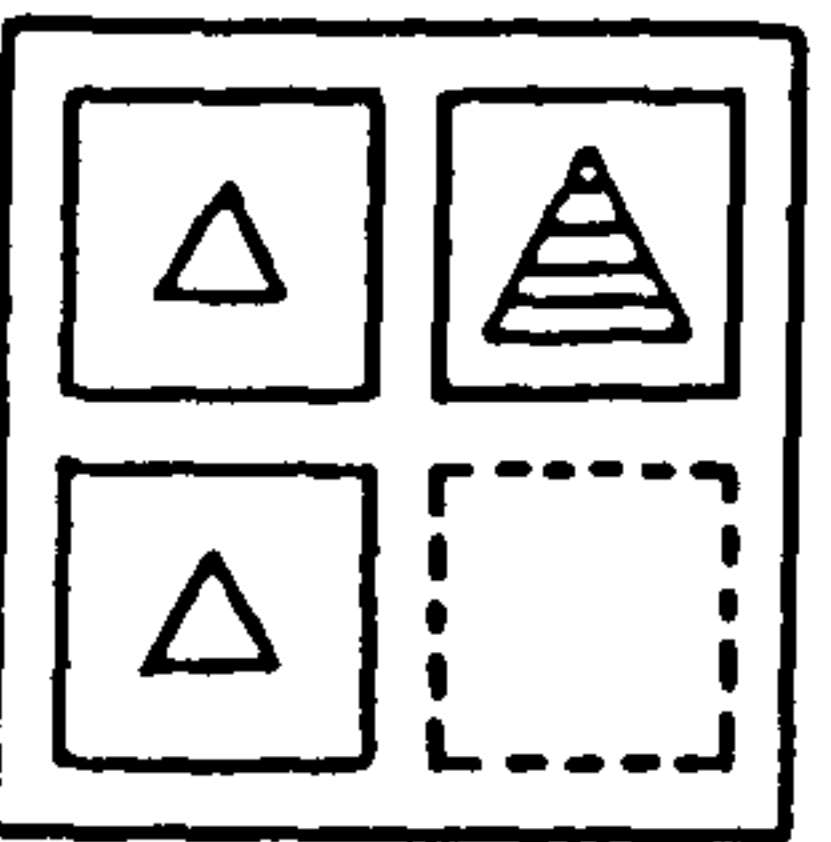
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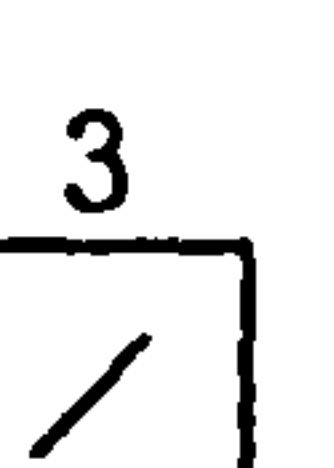
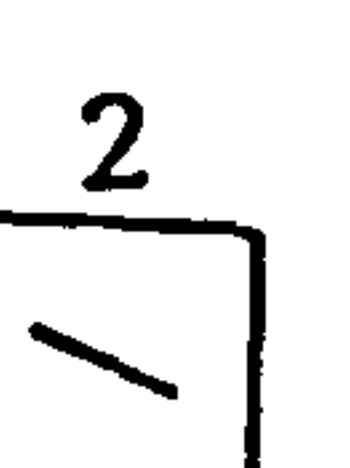
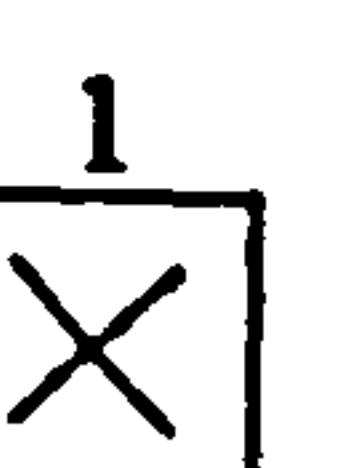
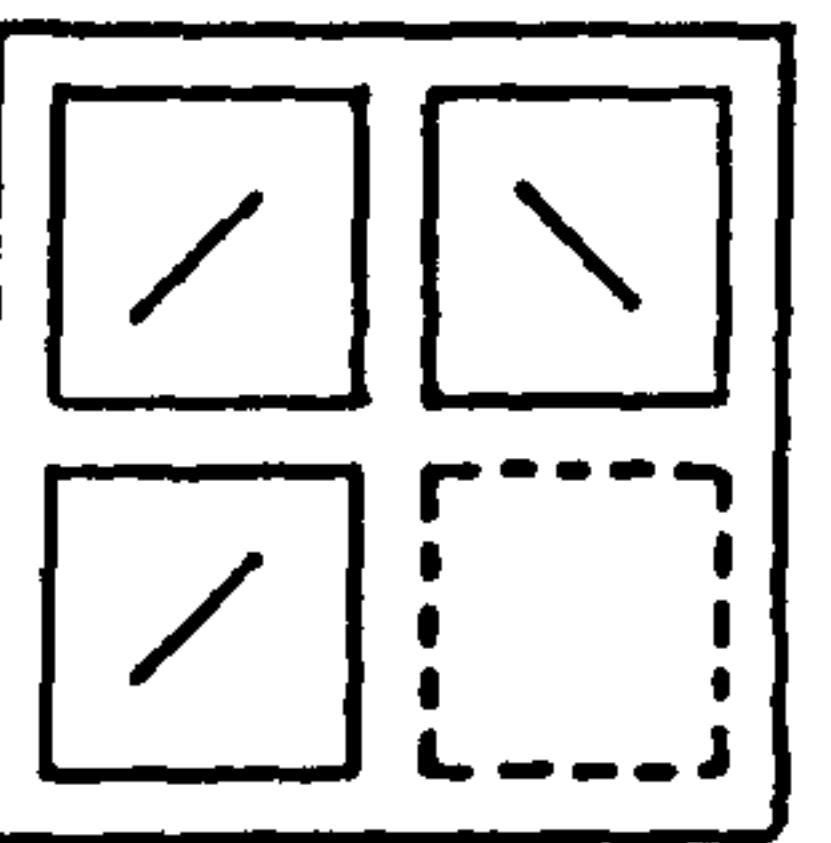
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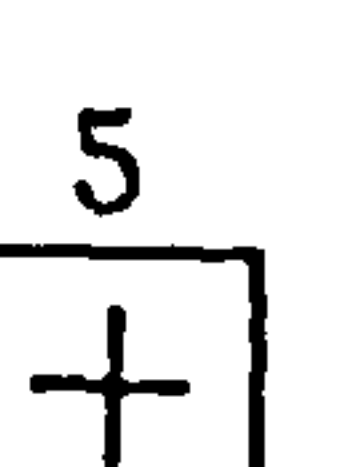
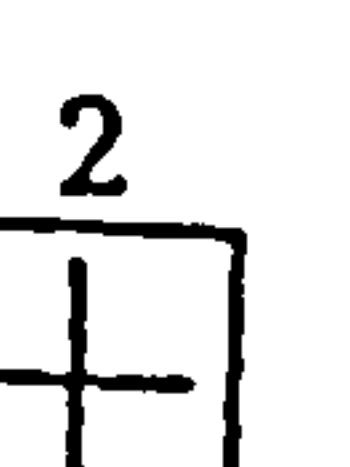
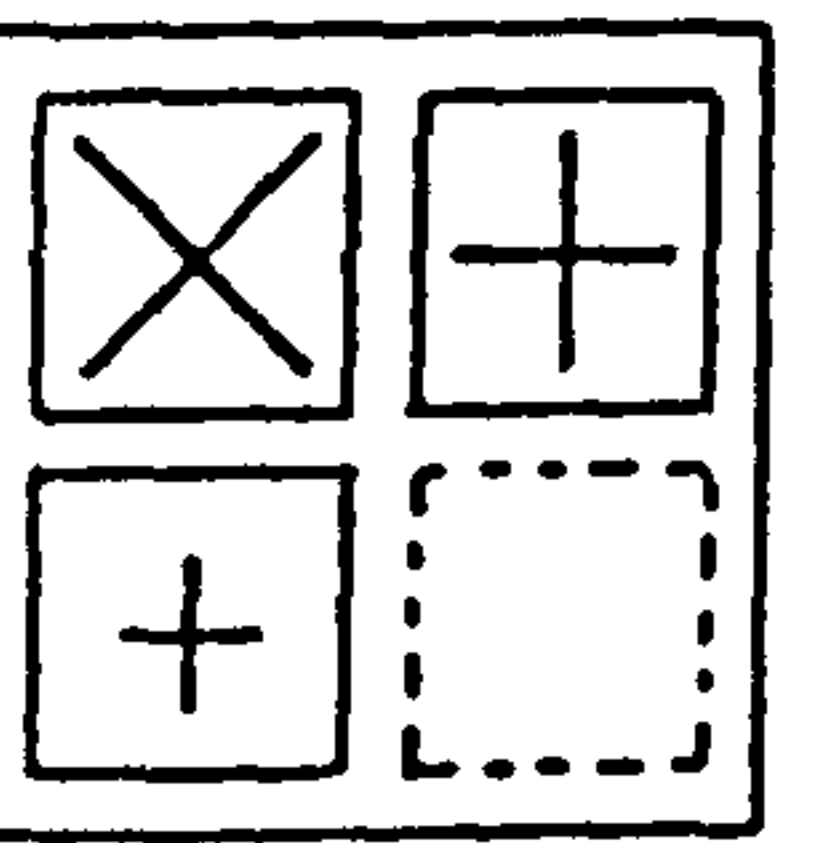
3.



4.

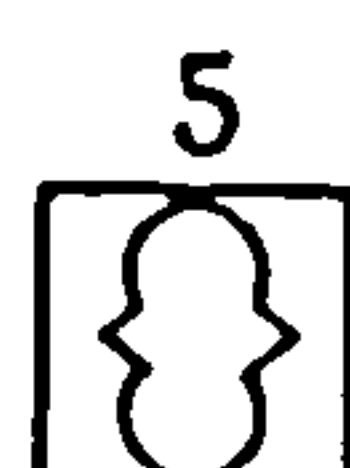
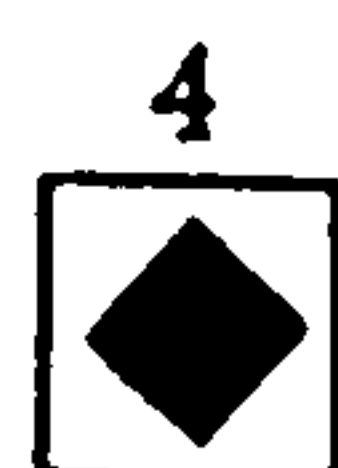
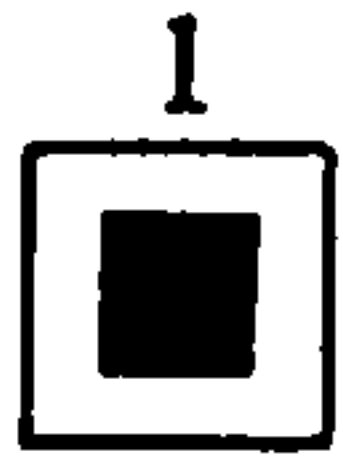
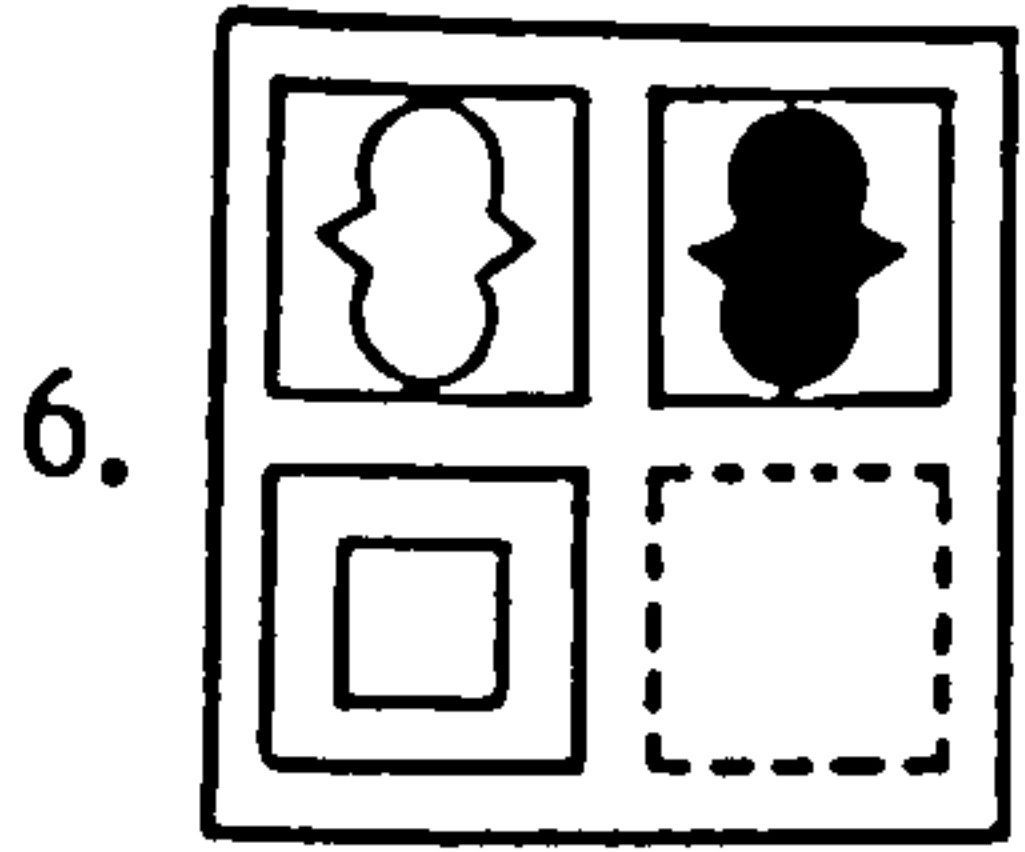


5.

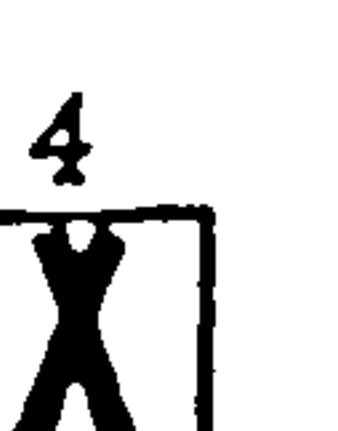
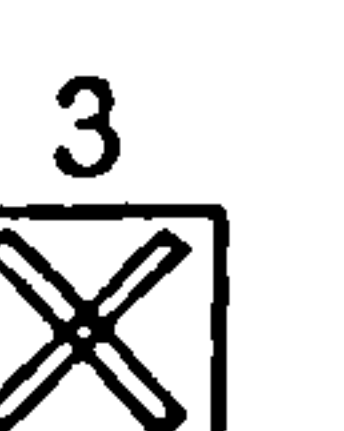
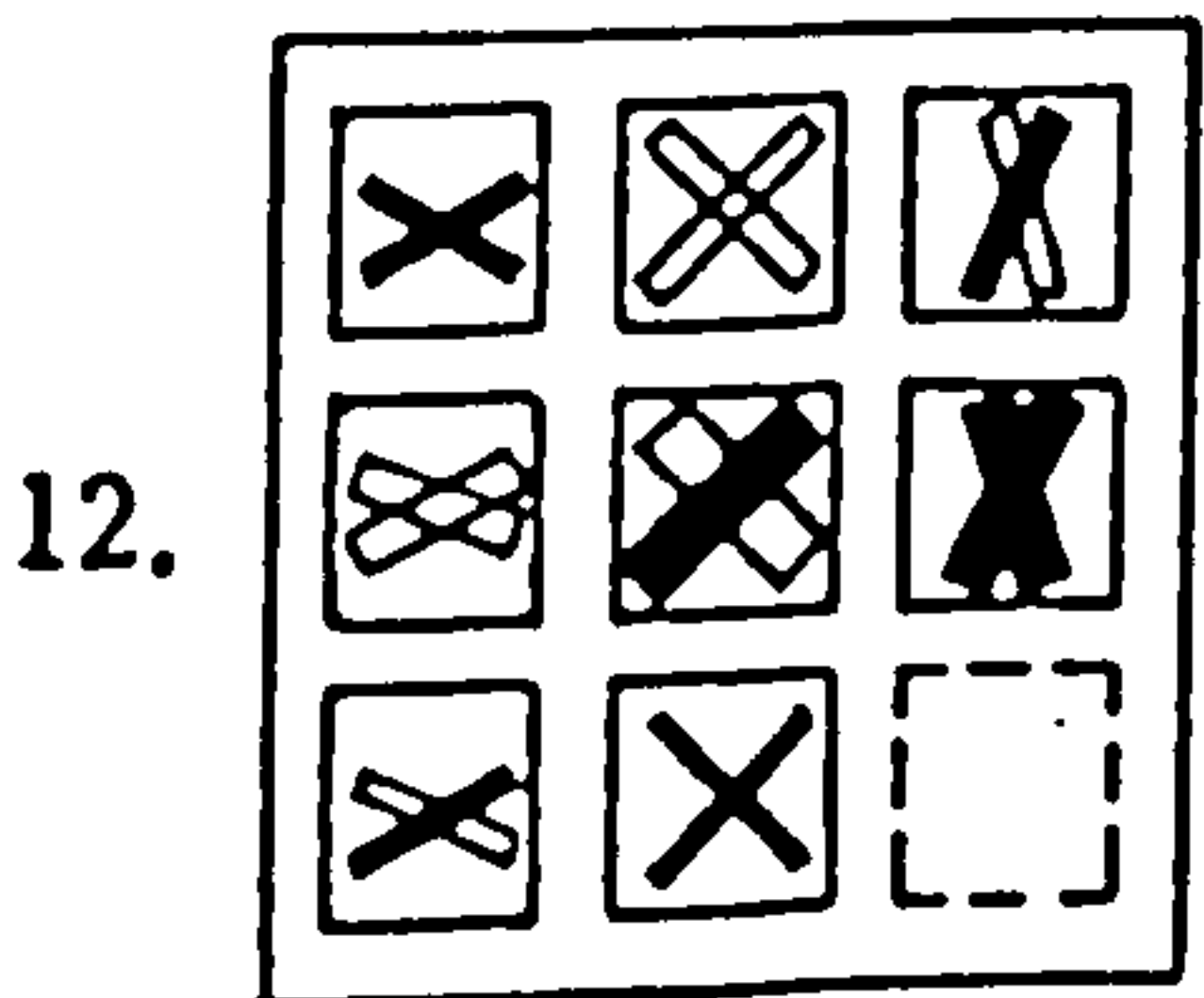
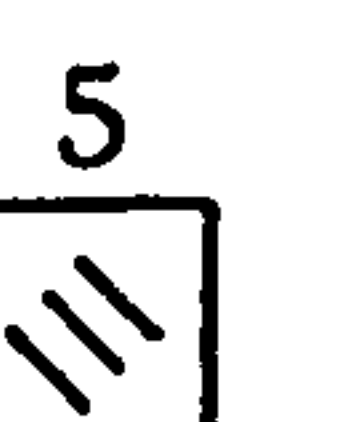
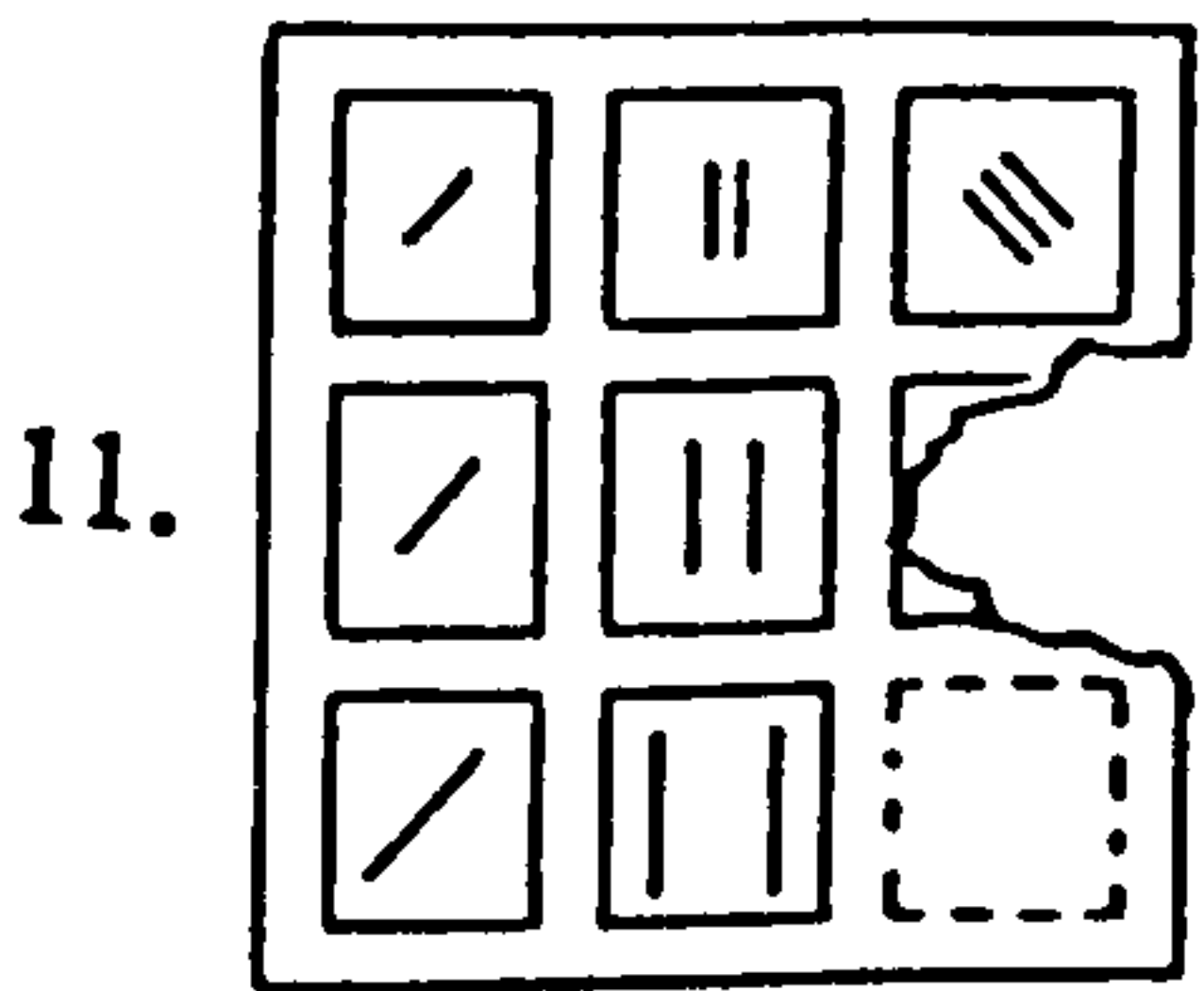
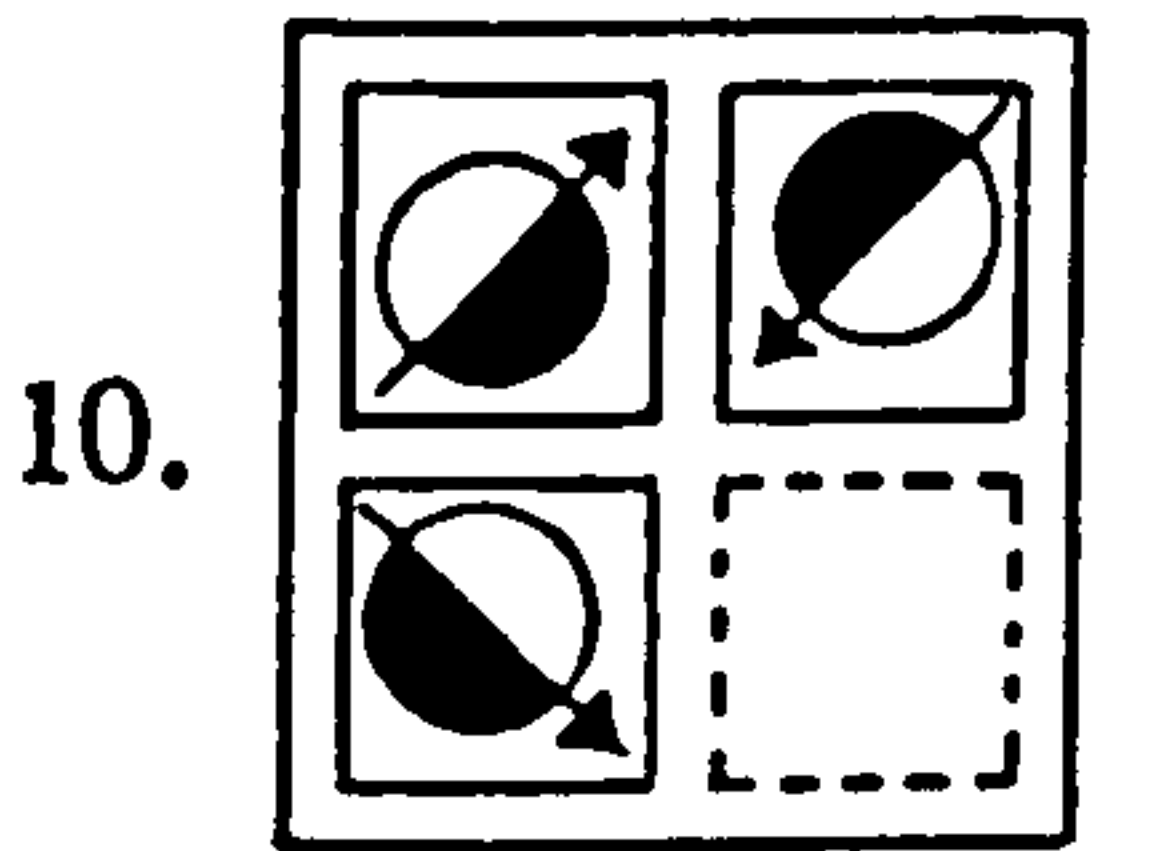
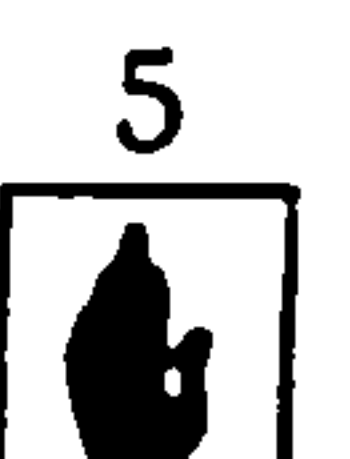
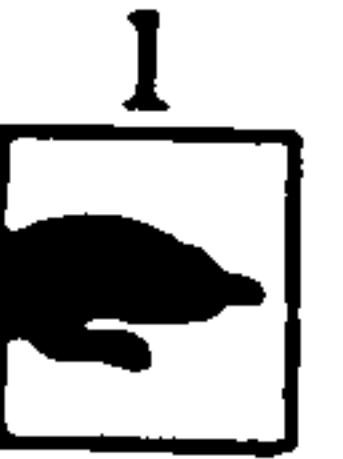
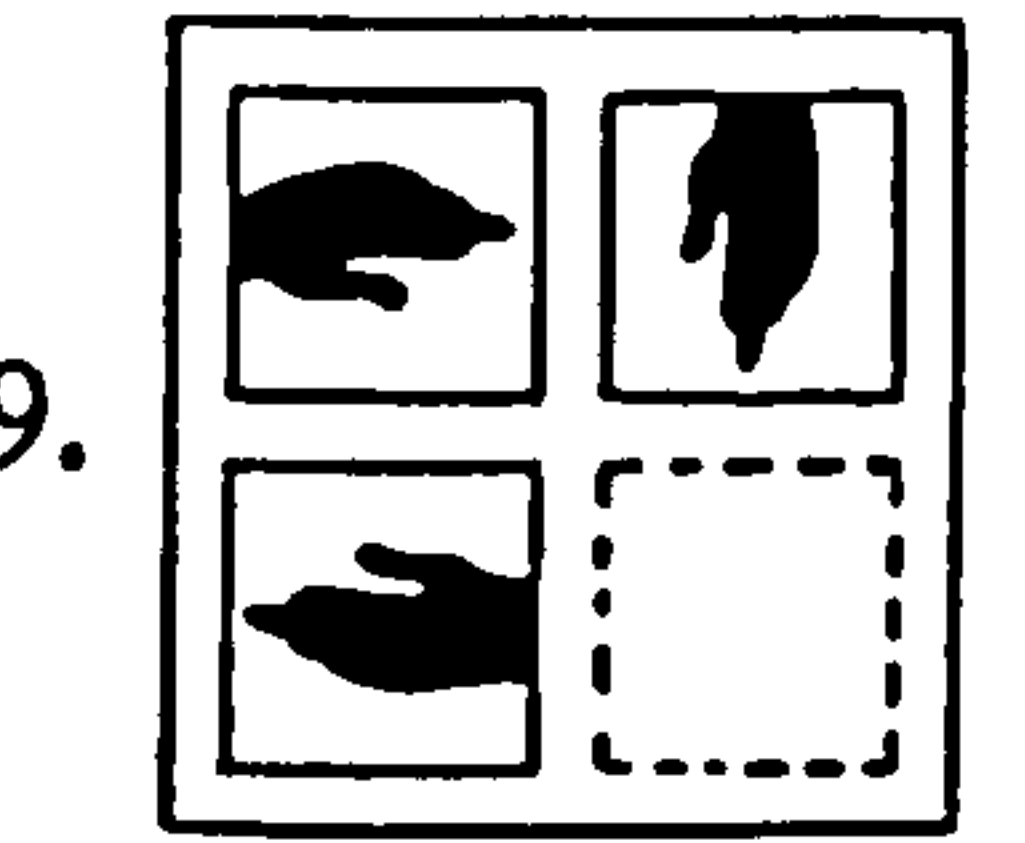
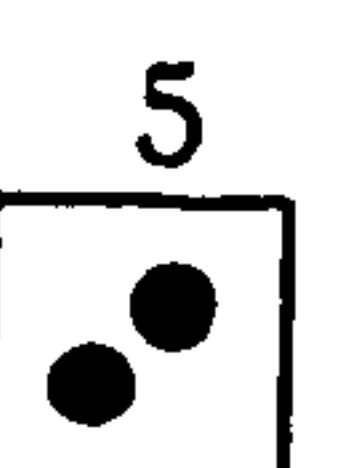
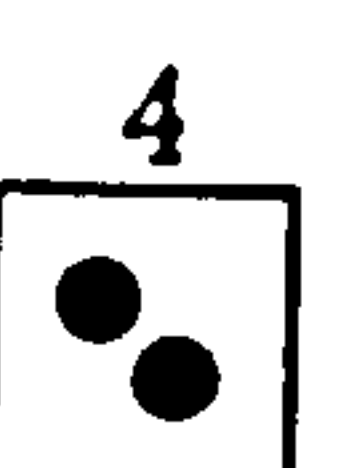
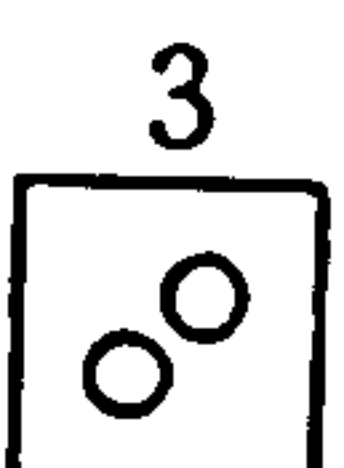
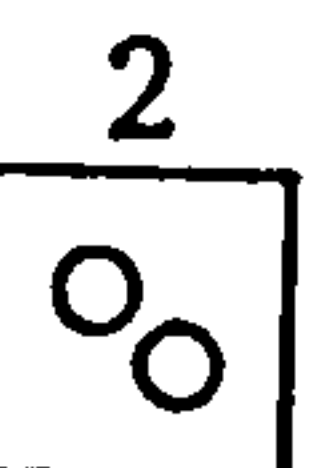
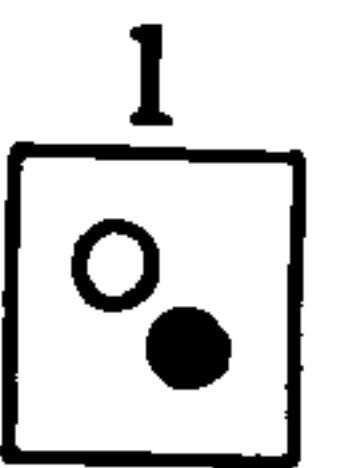
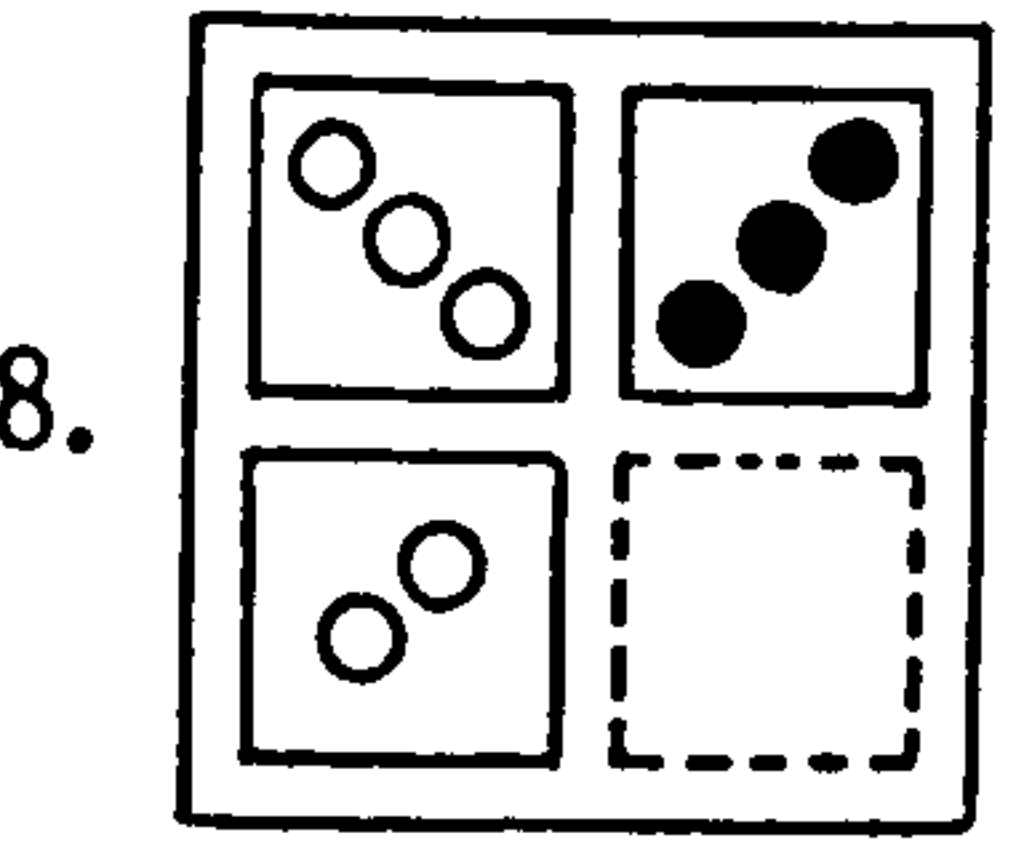
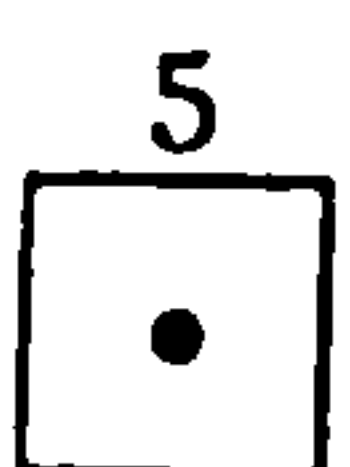
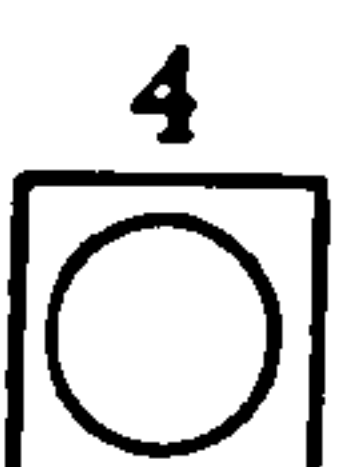
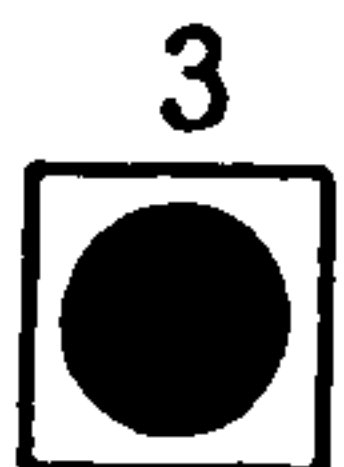
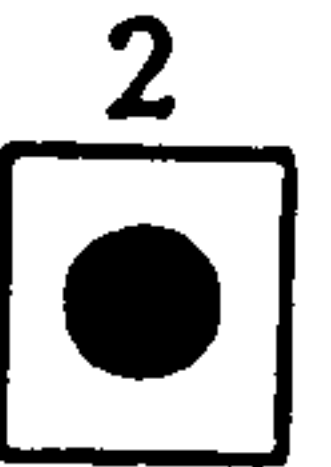
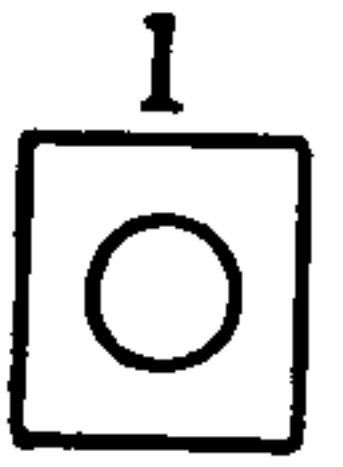
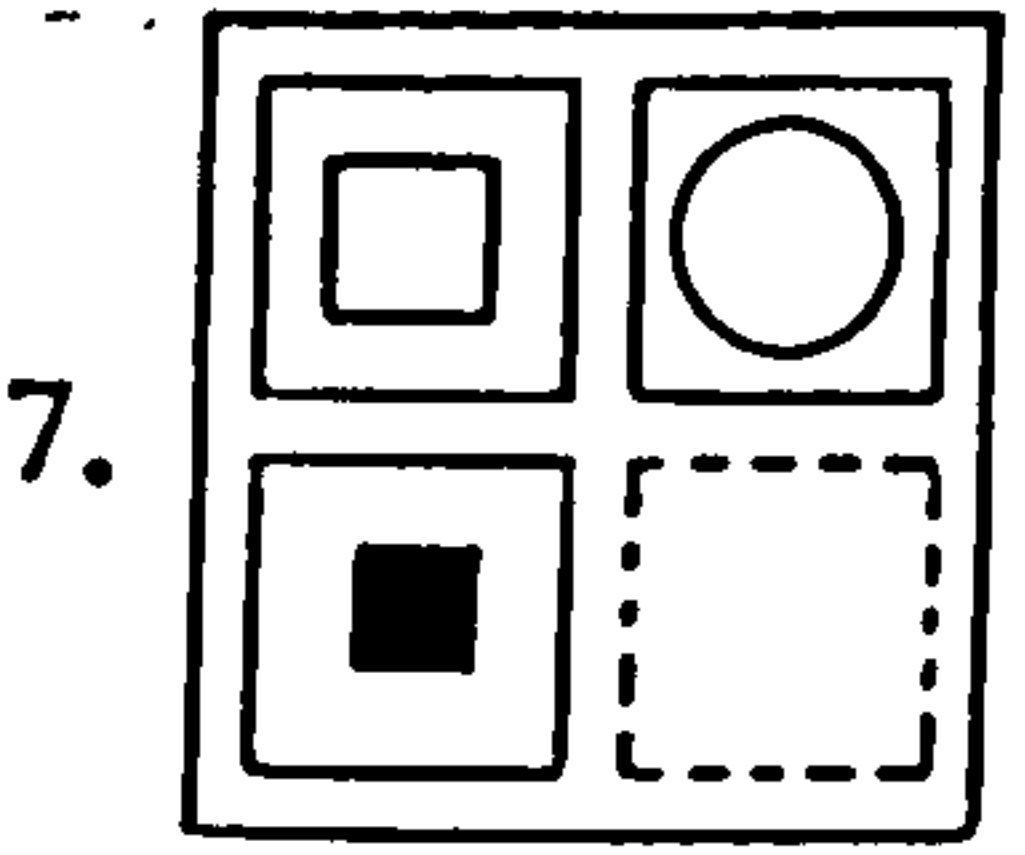
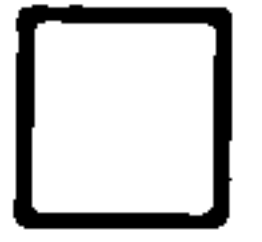


5.

Go on to the next page.



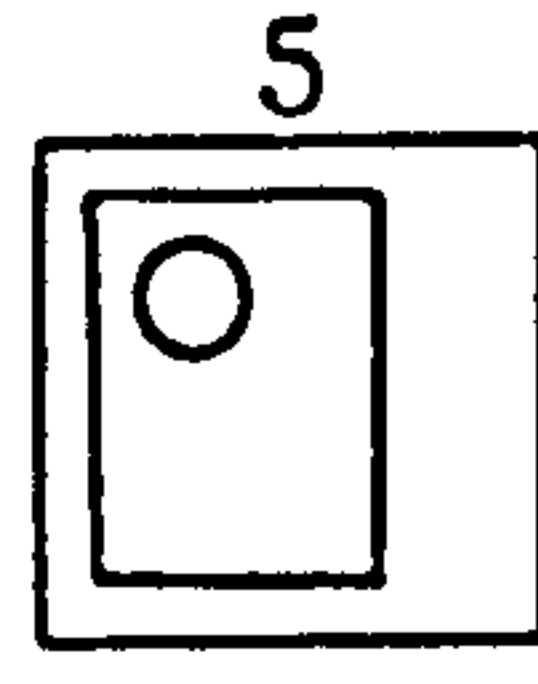
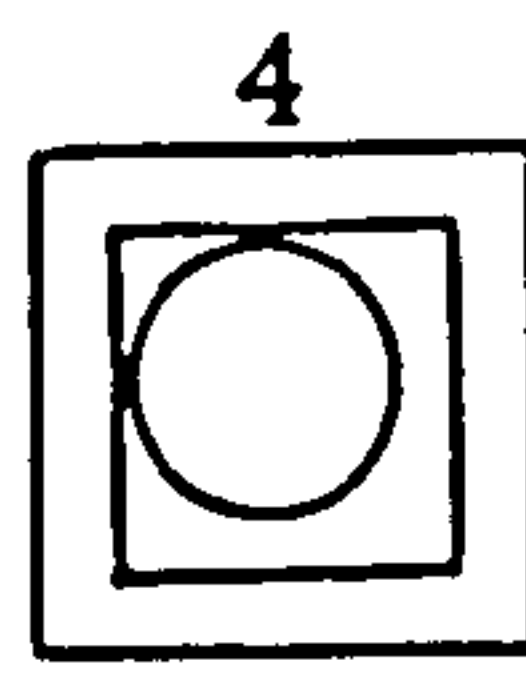
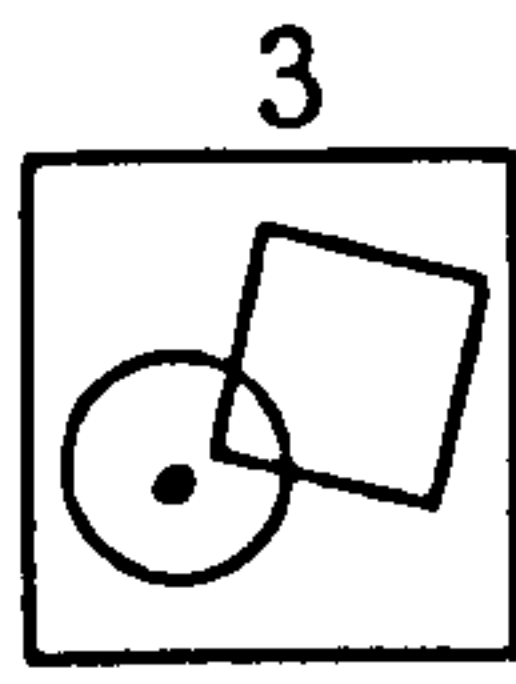
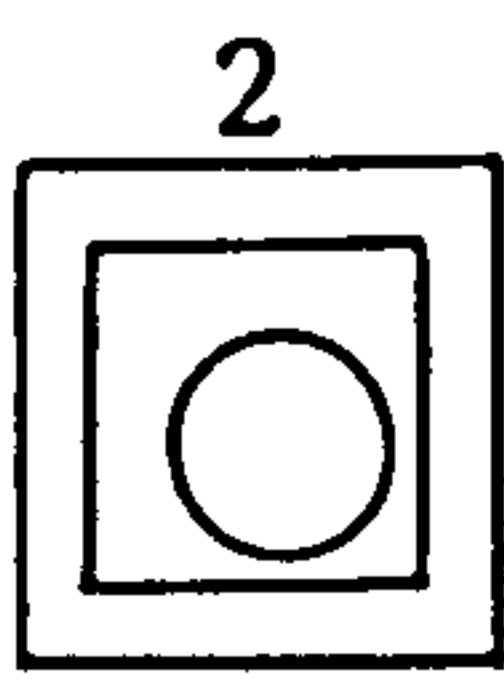
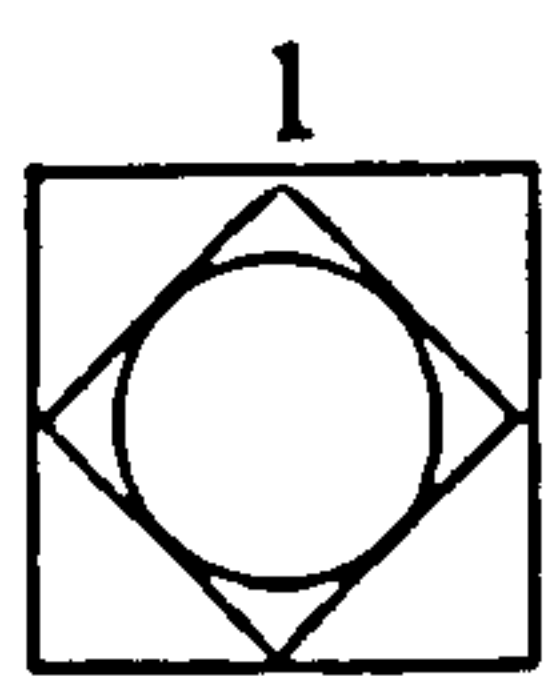
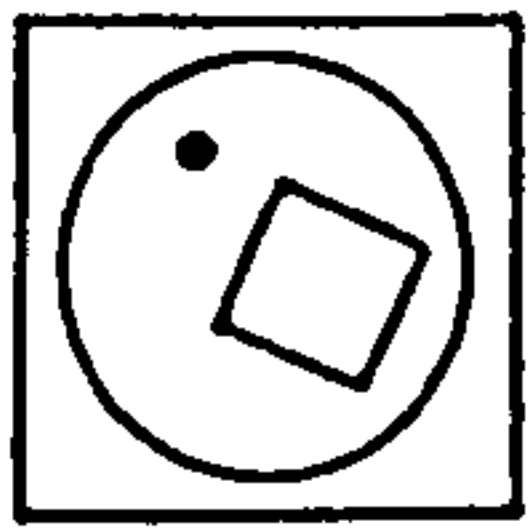
Answers



End of Test 3

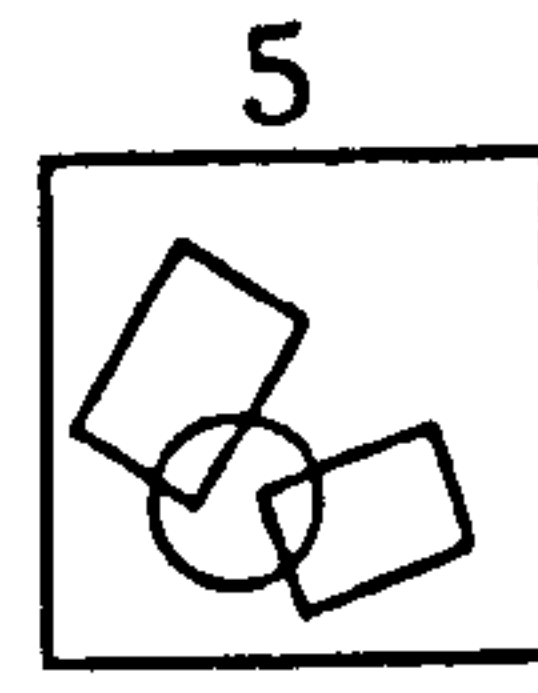
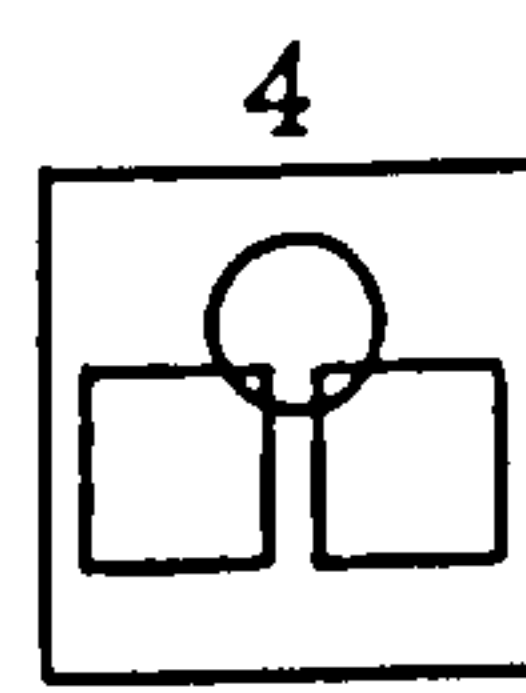
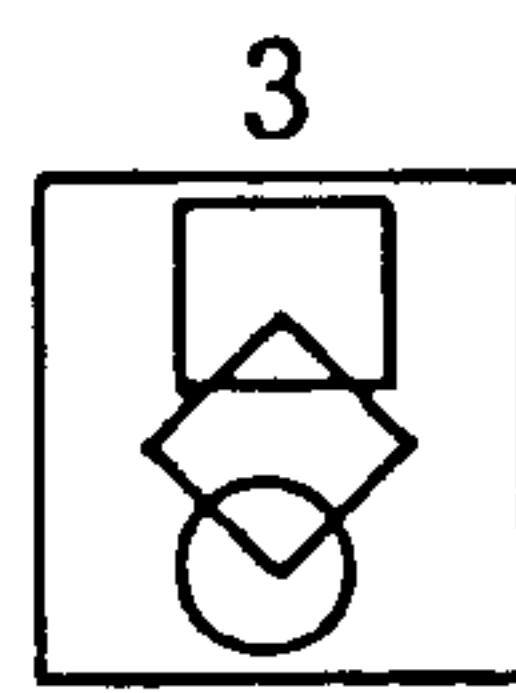
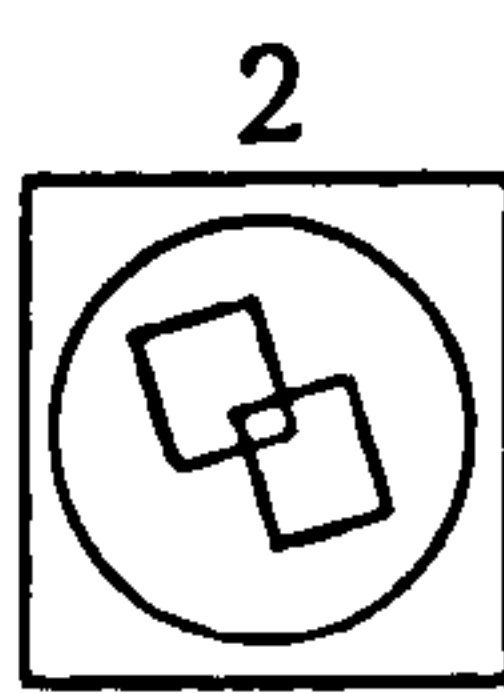
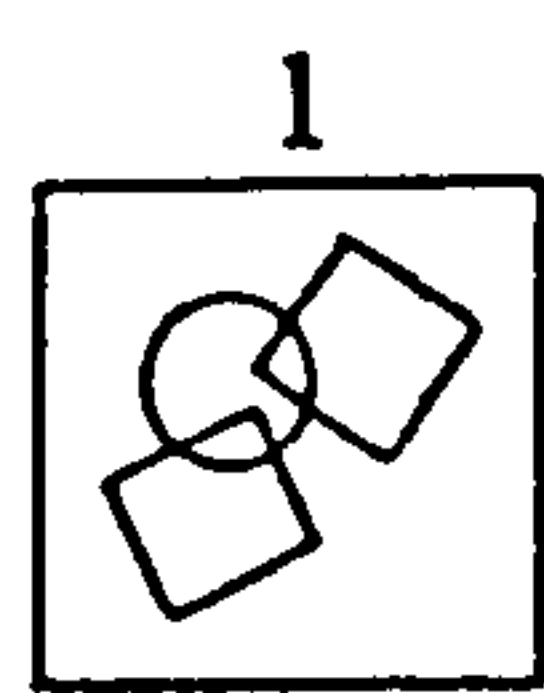
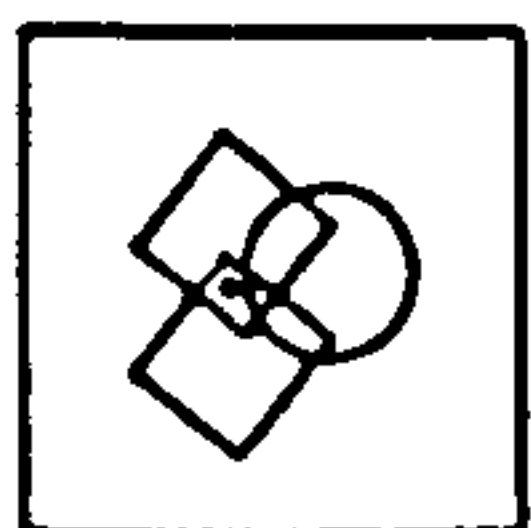
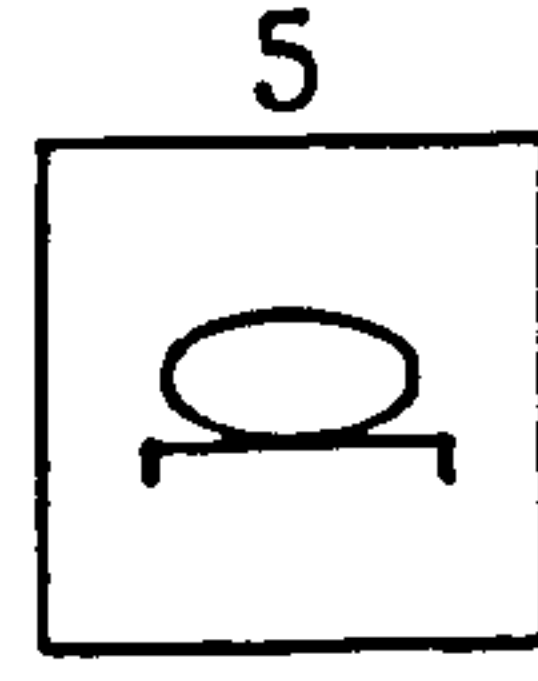
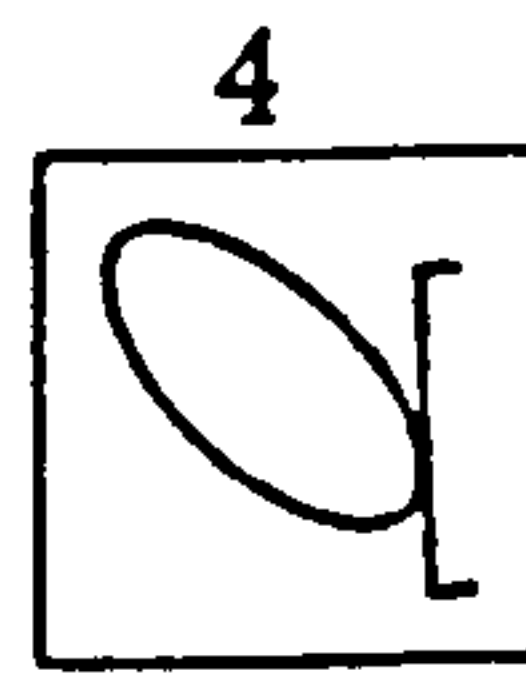
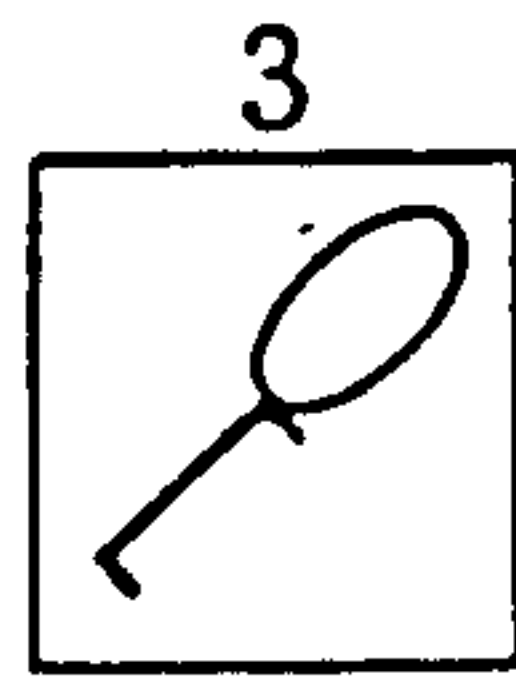
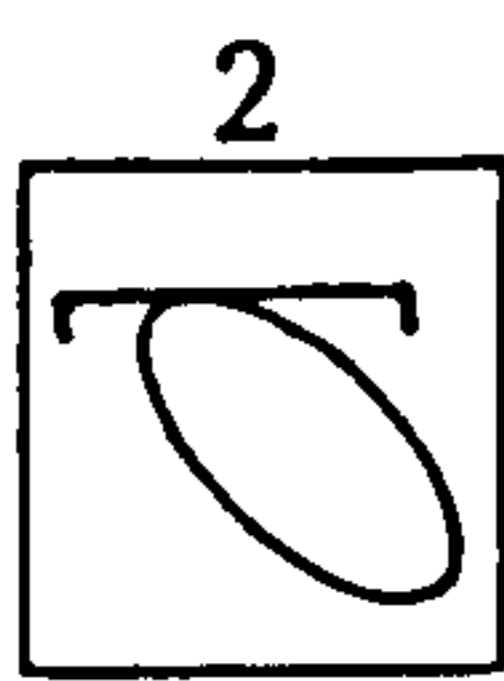
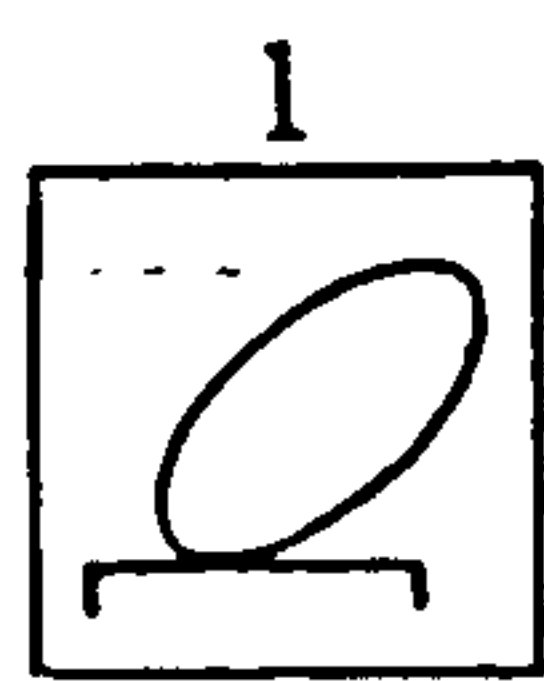
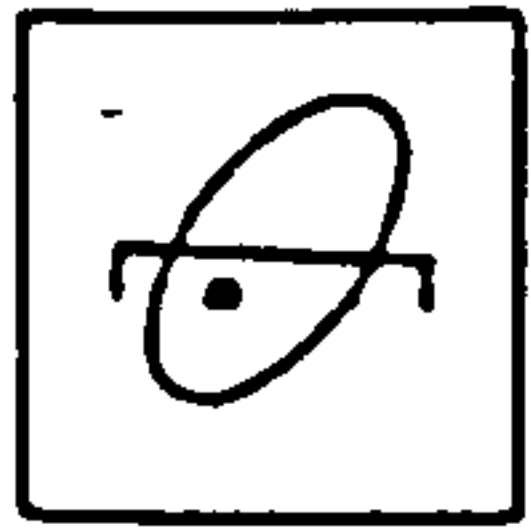
TEST 4

Examples

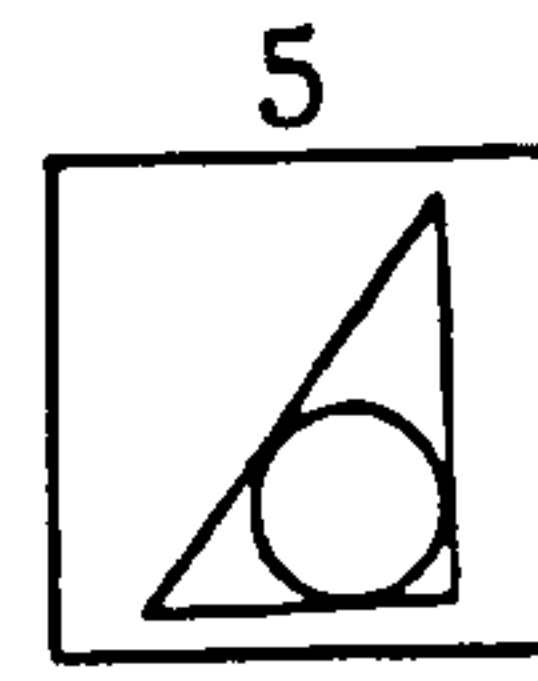
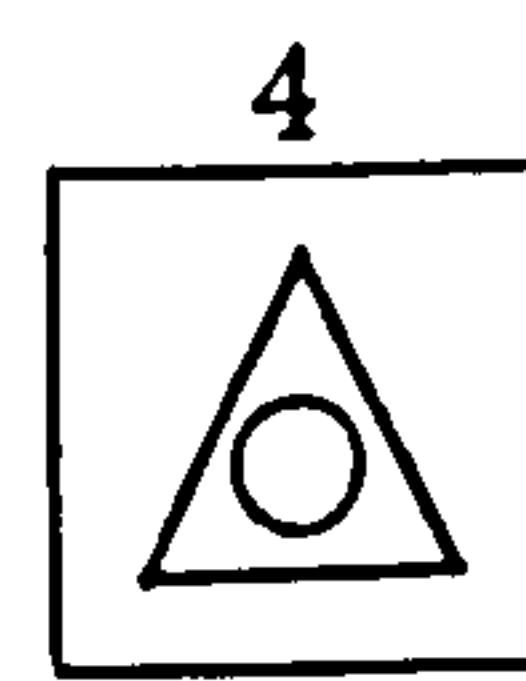
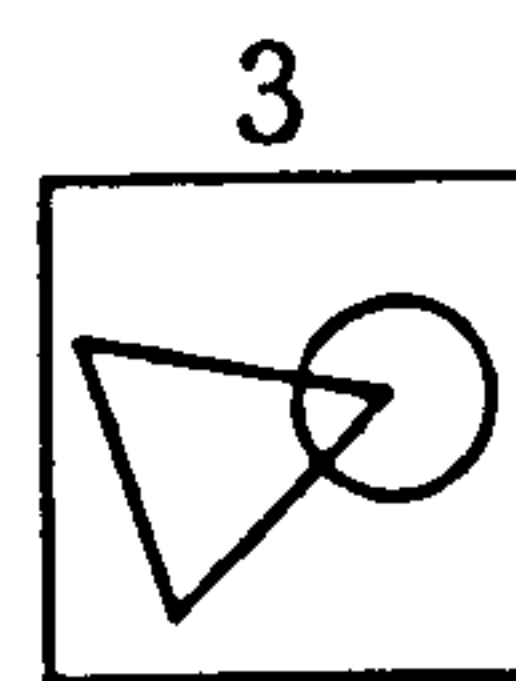
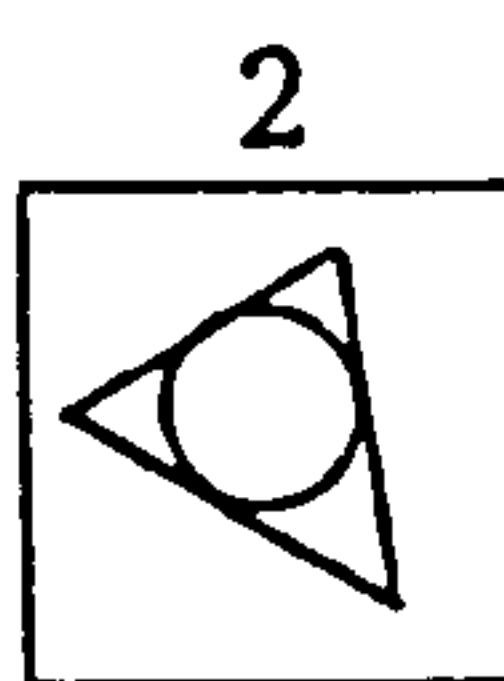
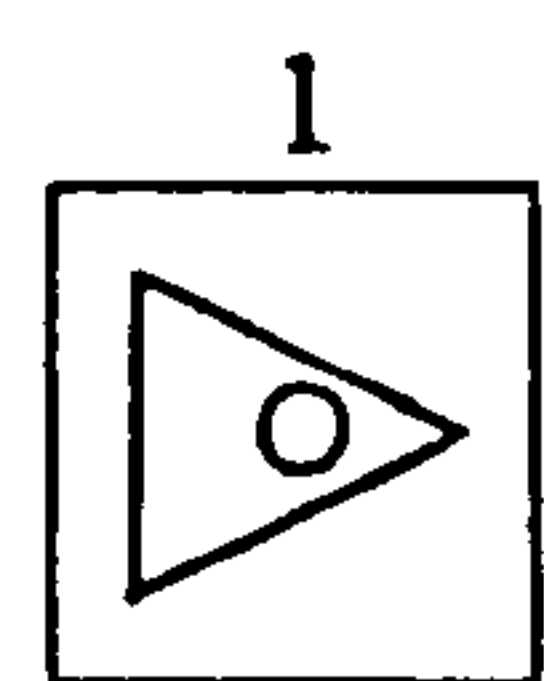
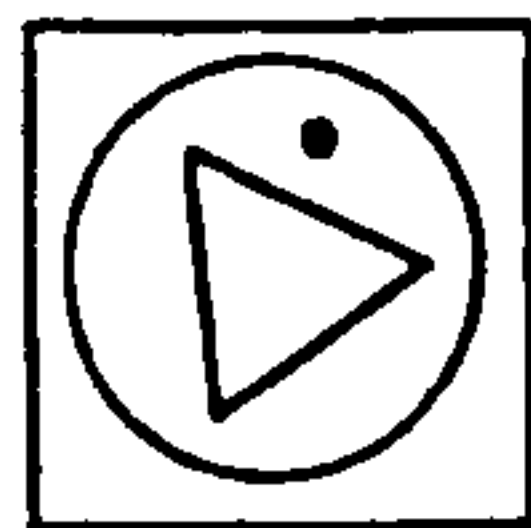


Answers

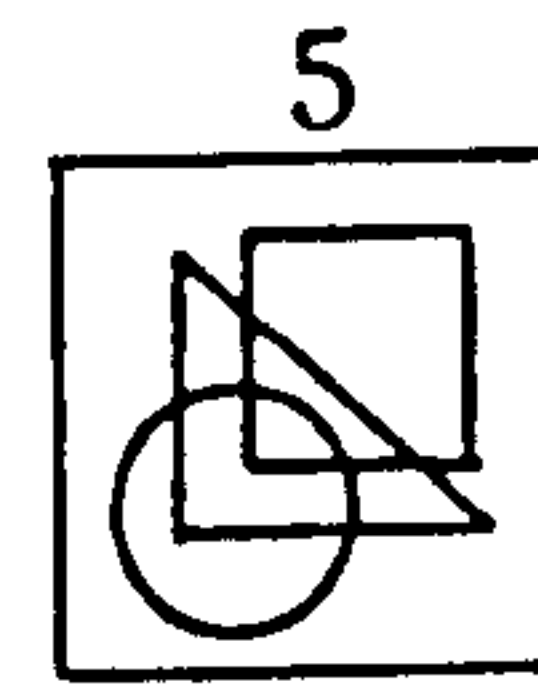
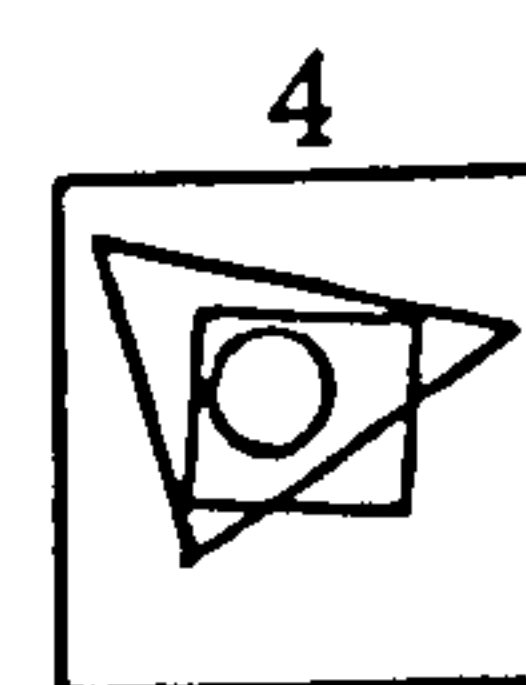
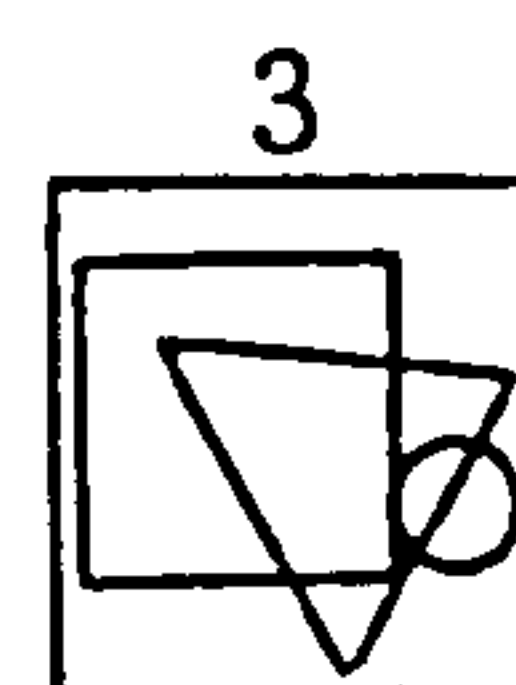
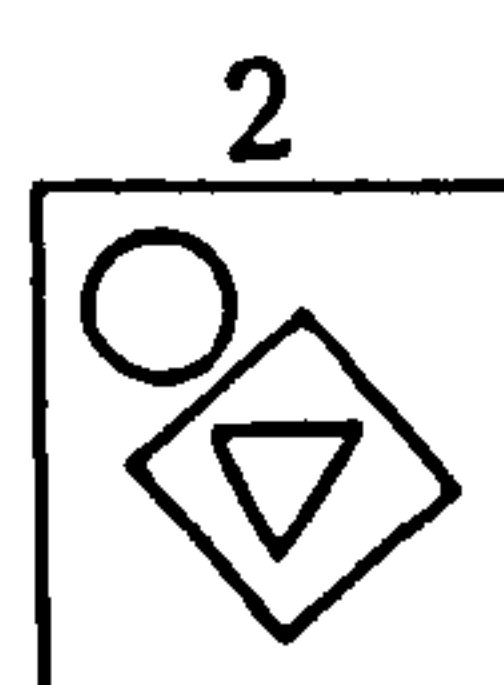
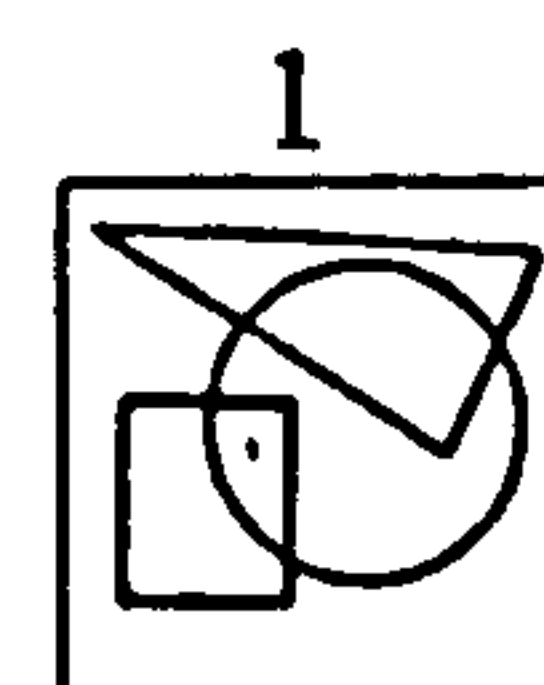
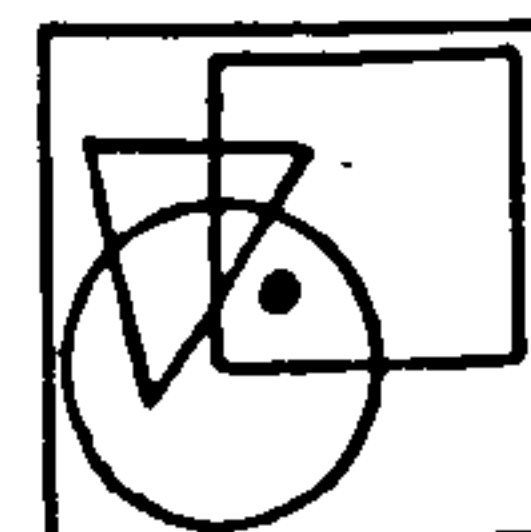
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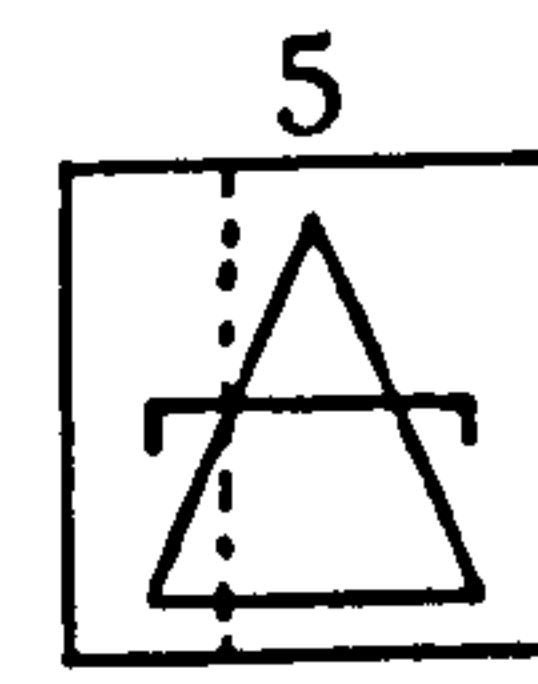
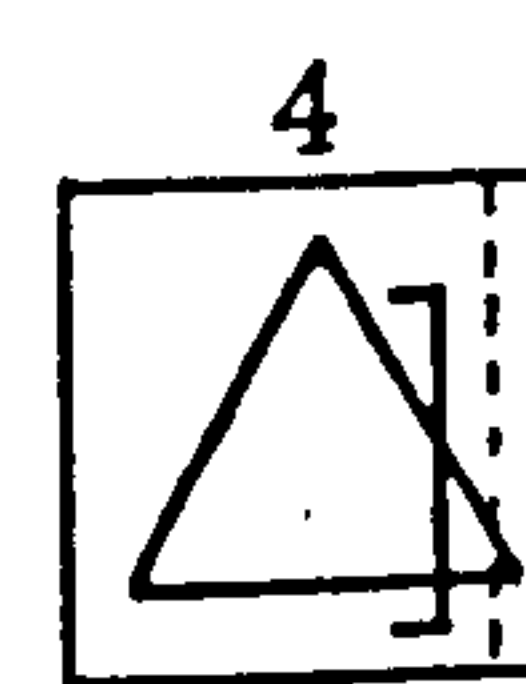
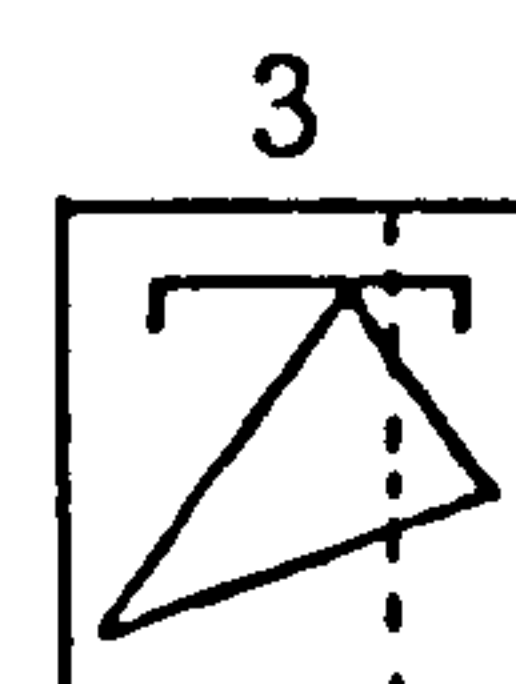
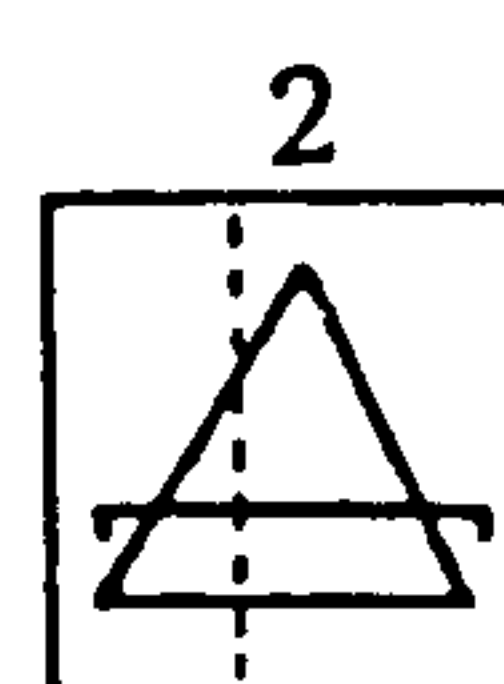
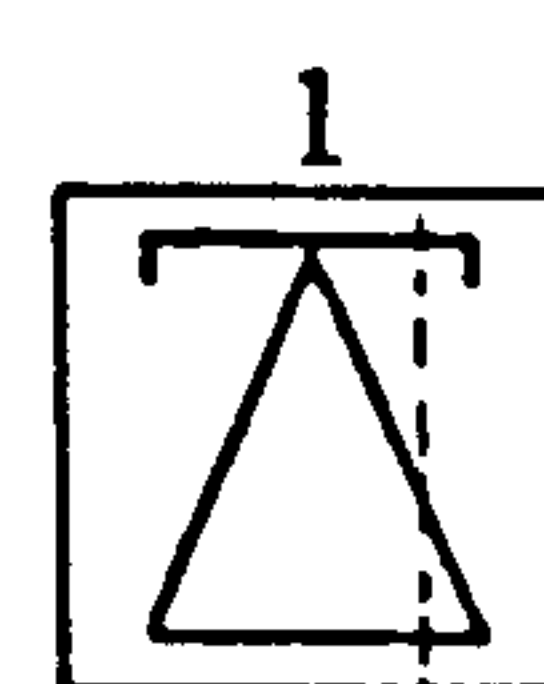
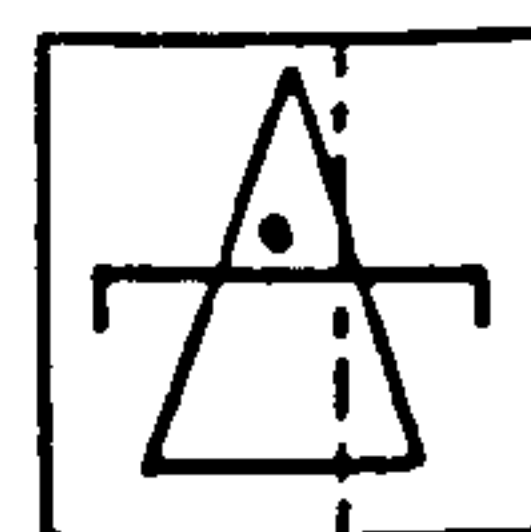
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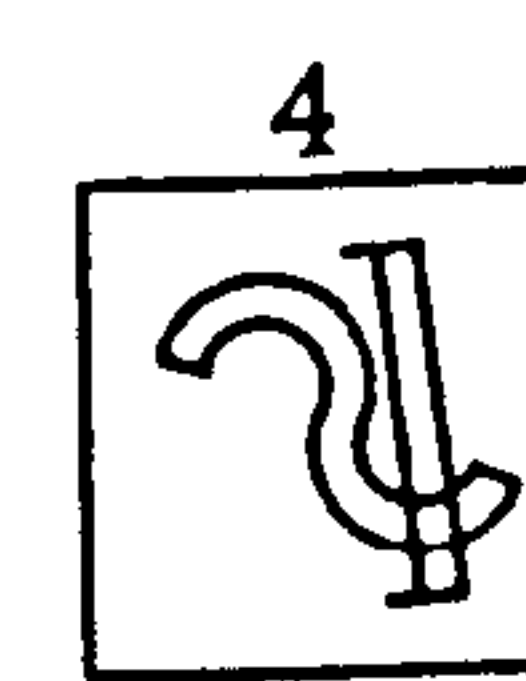
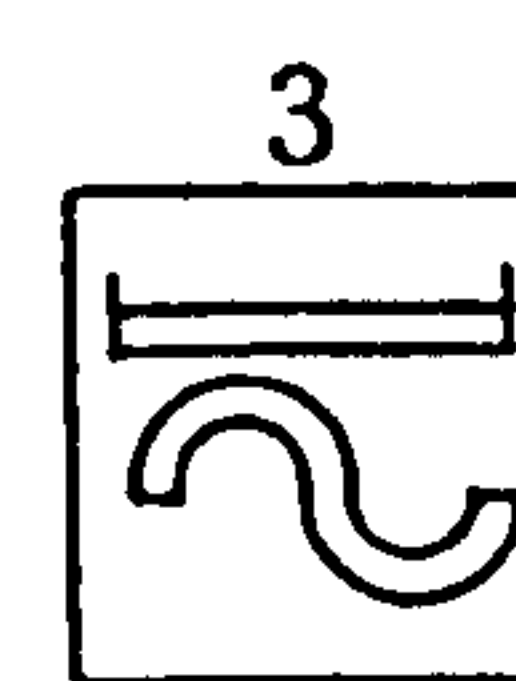
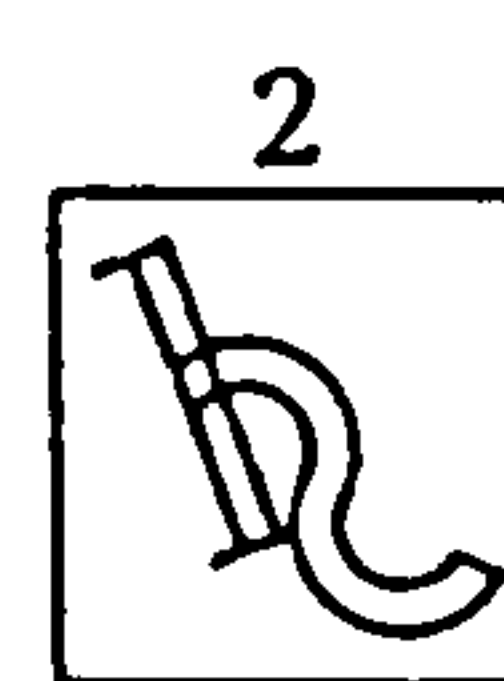
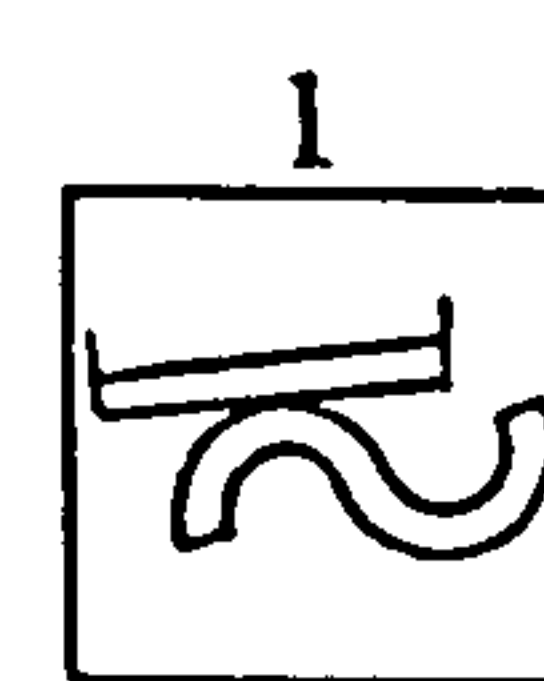
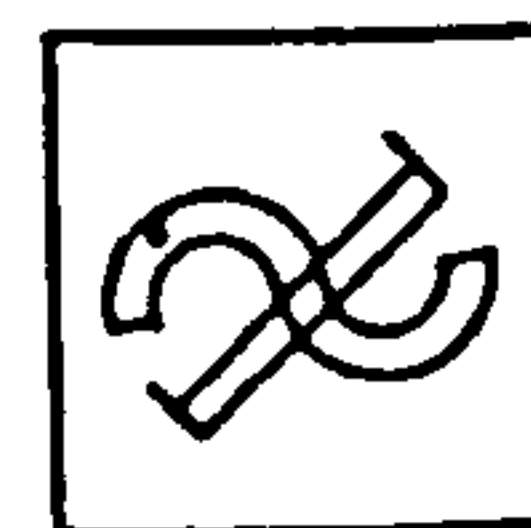
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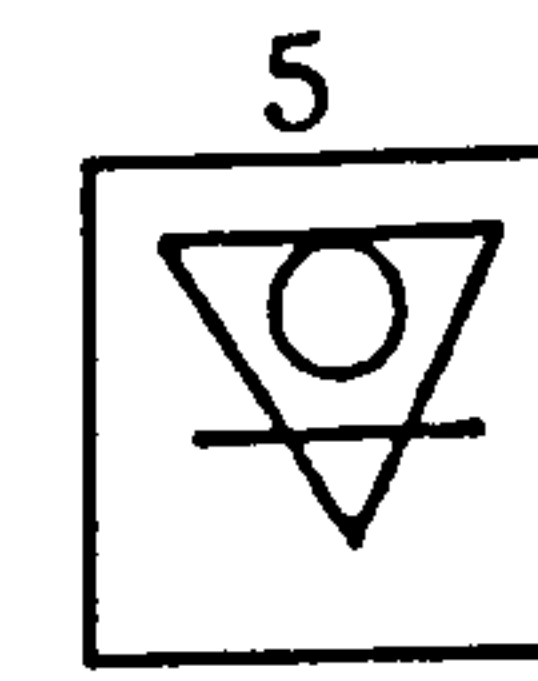
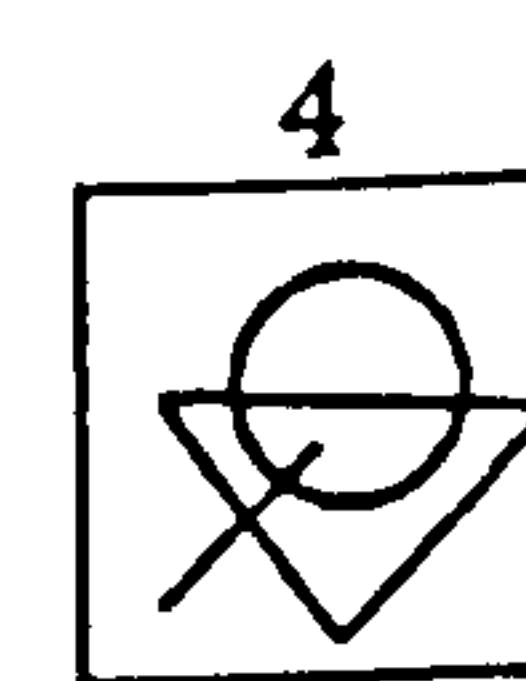
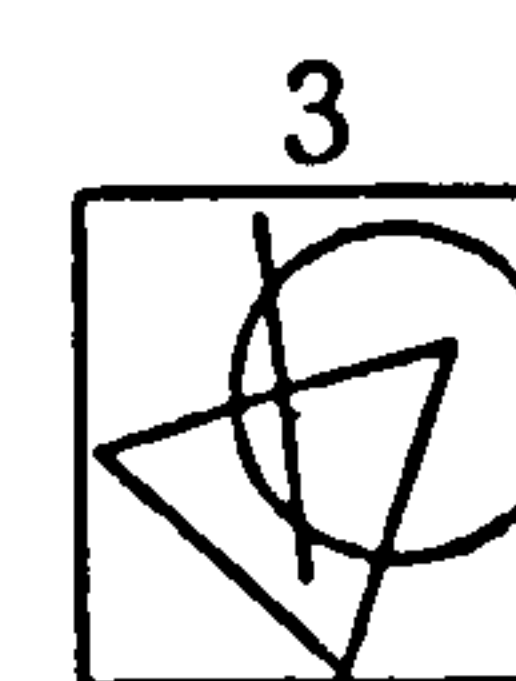
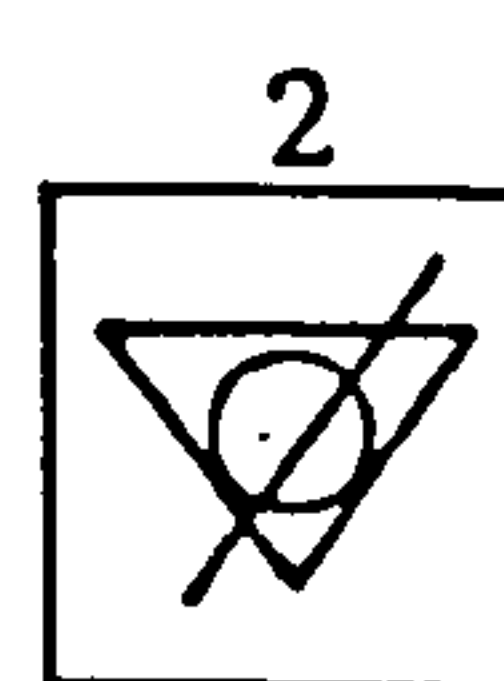
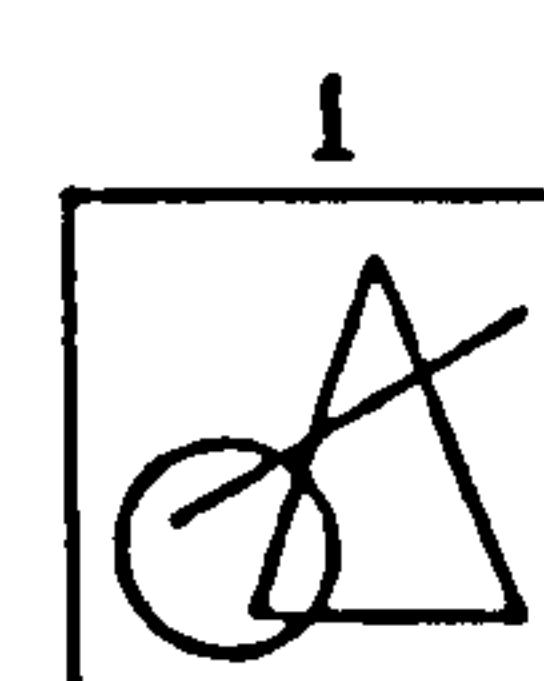
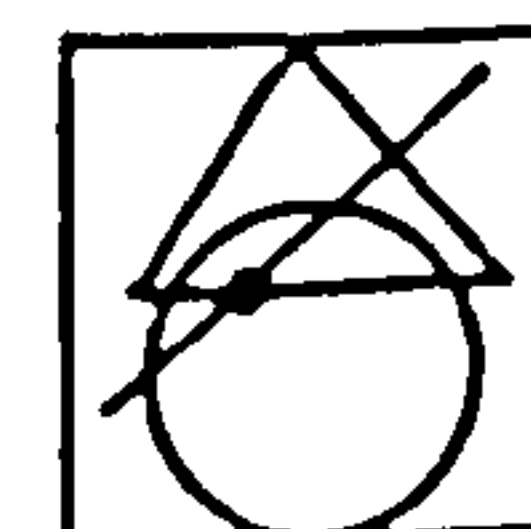
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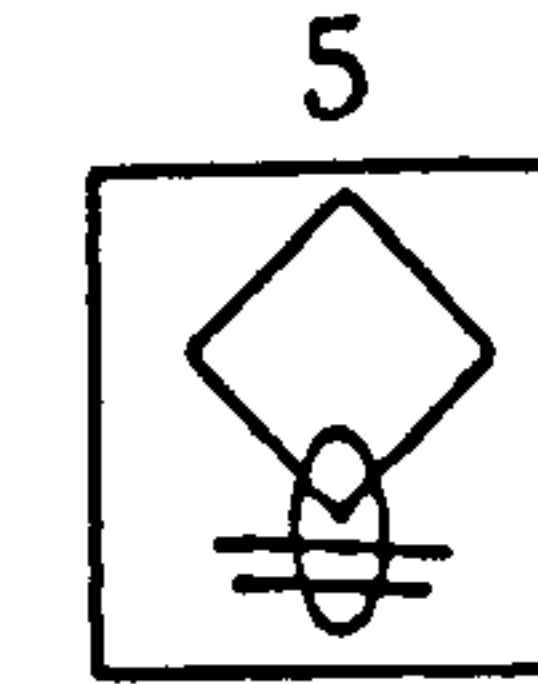
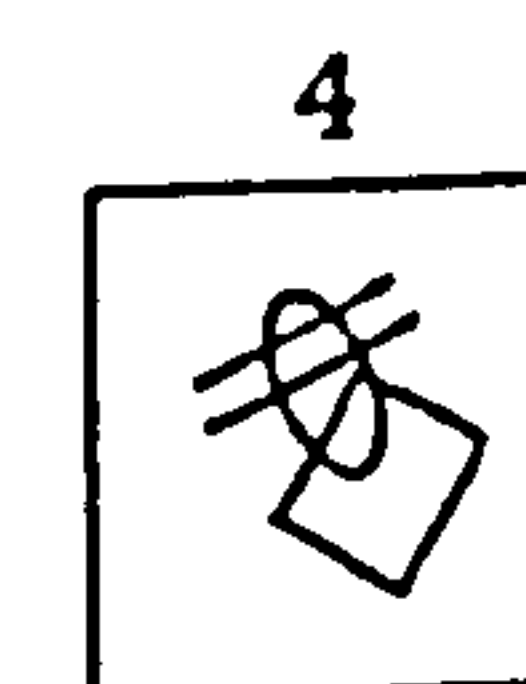
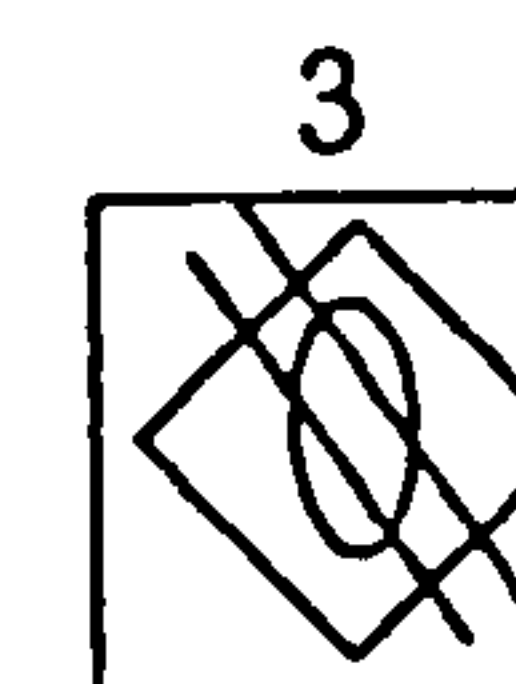
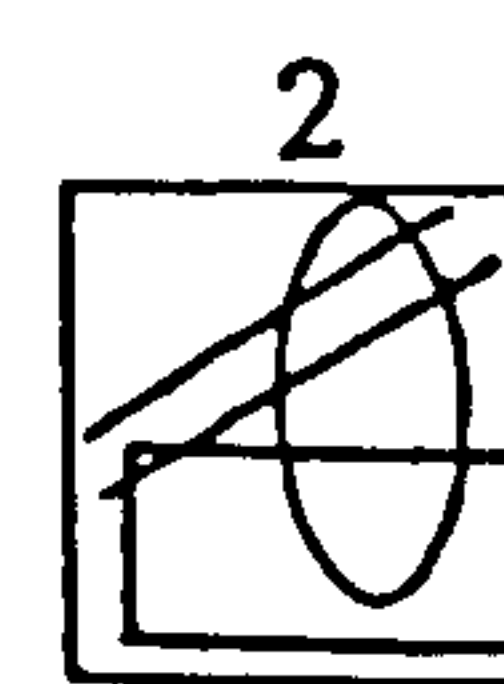
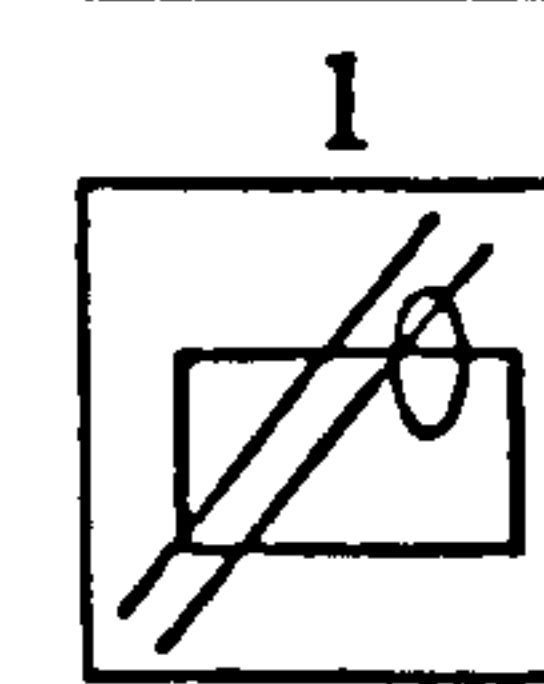
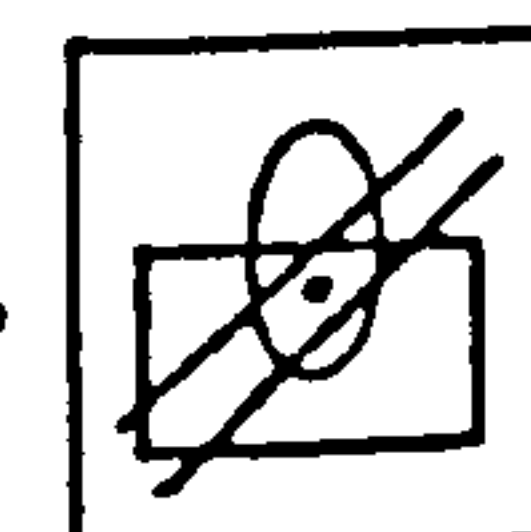
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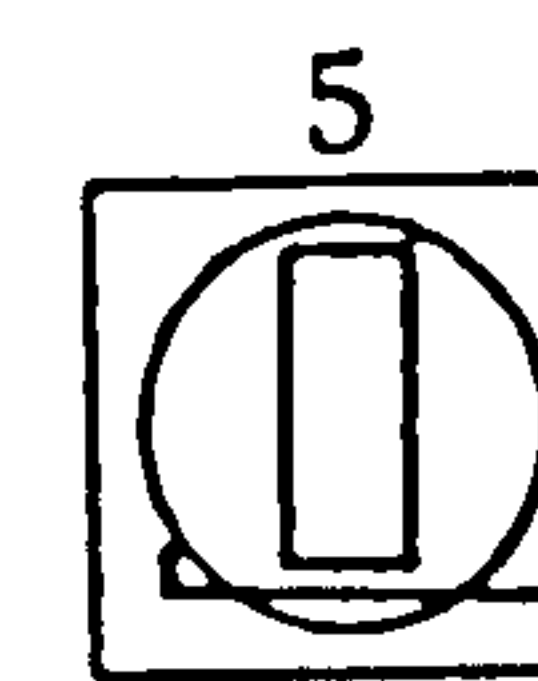
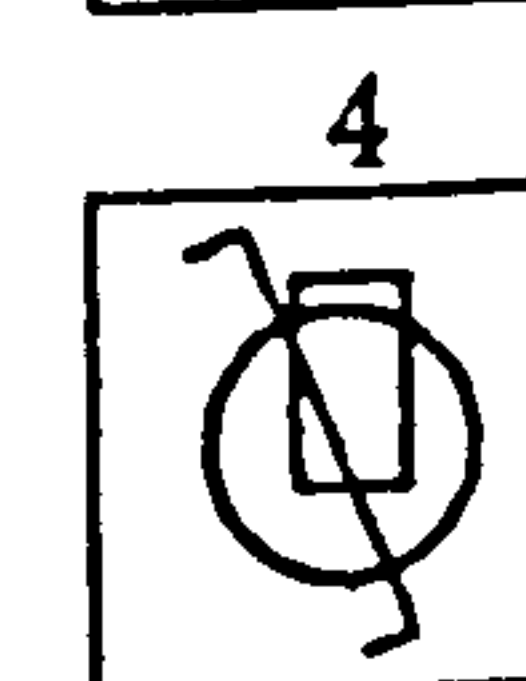
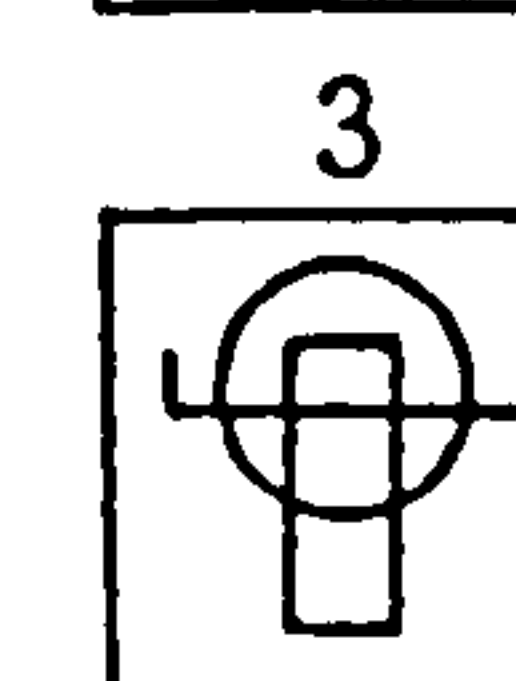
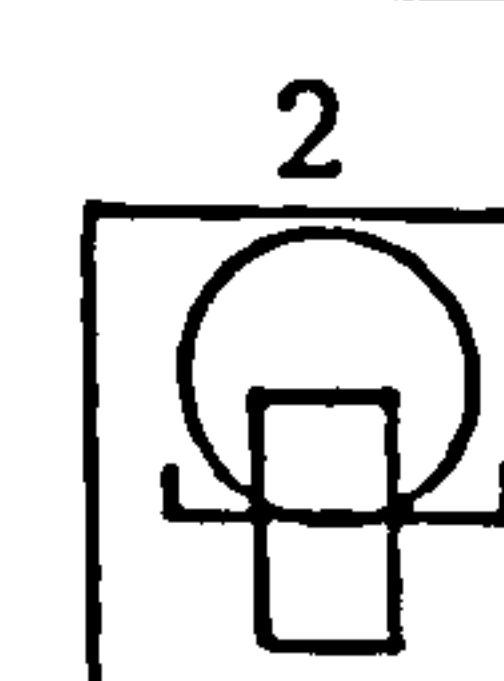
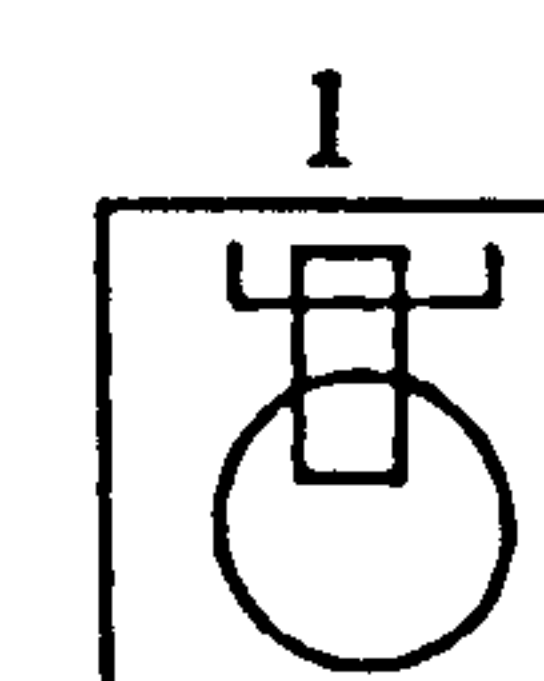
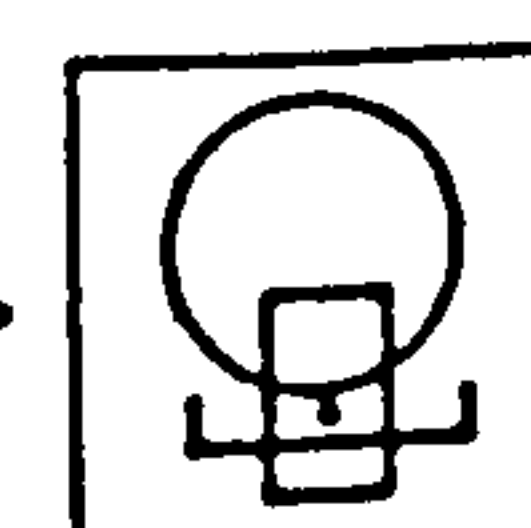
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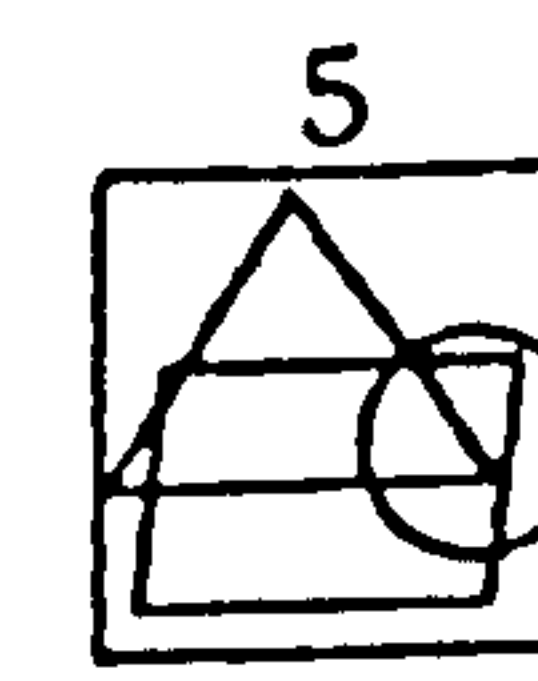
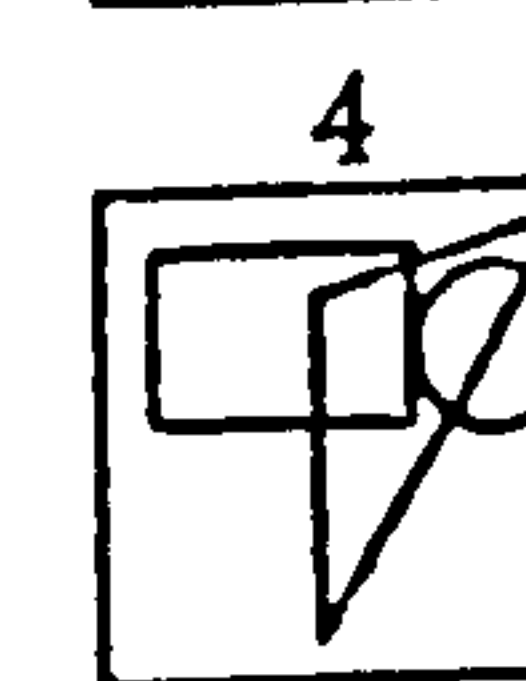
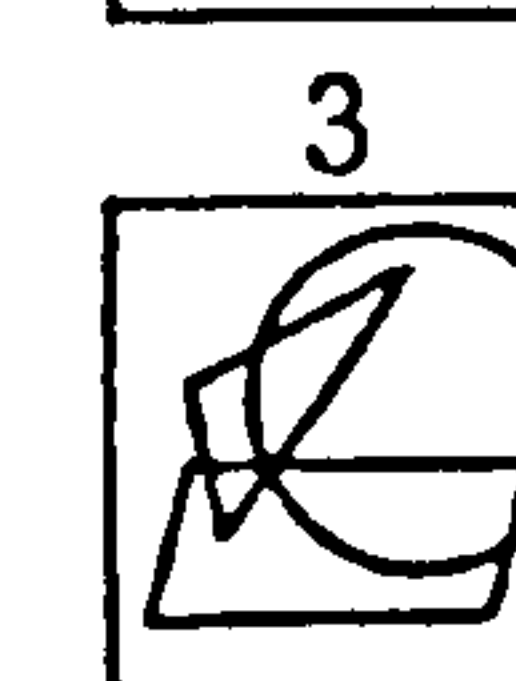
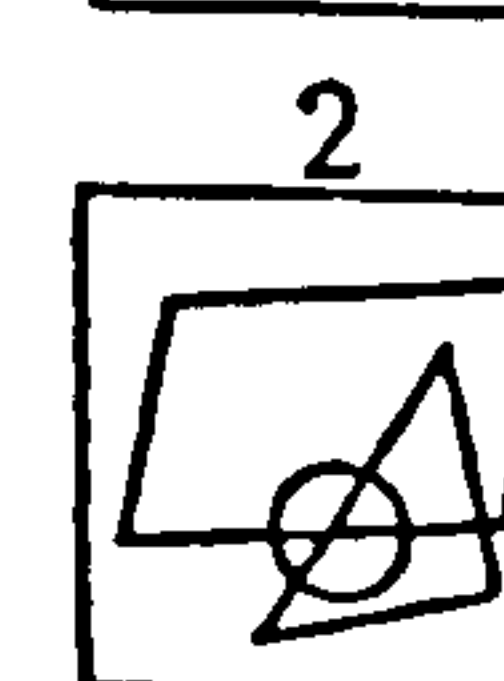
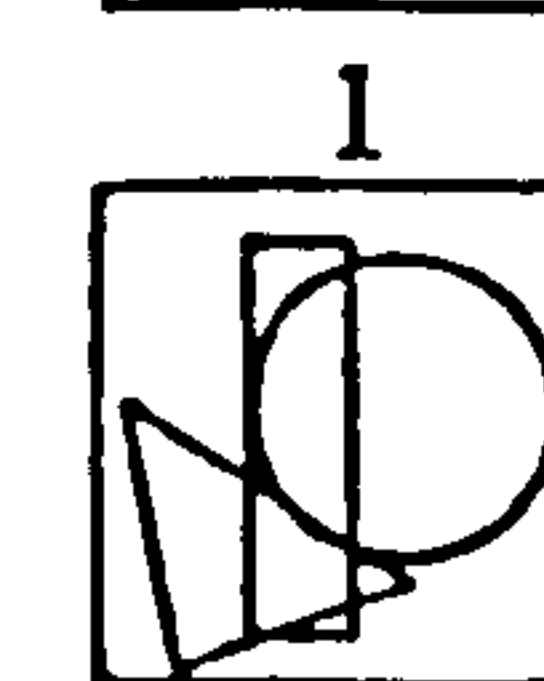
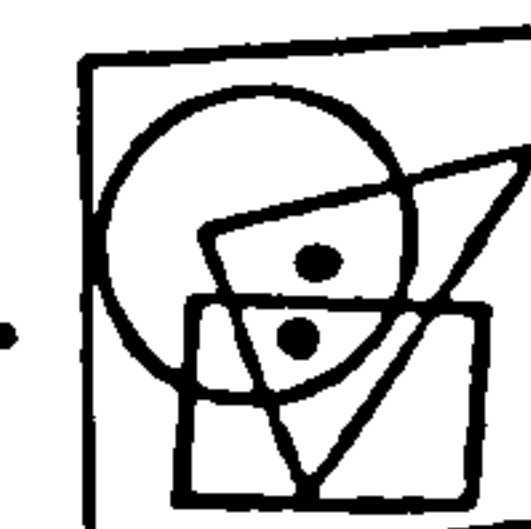
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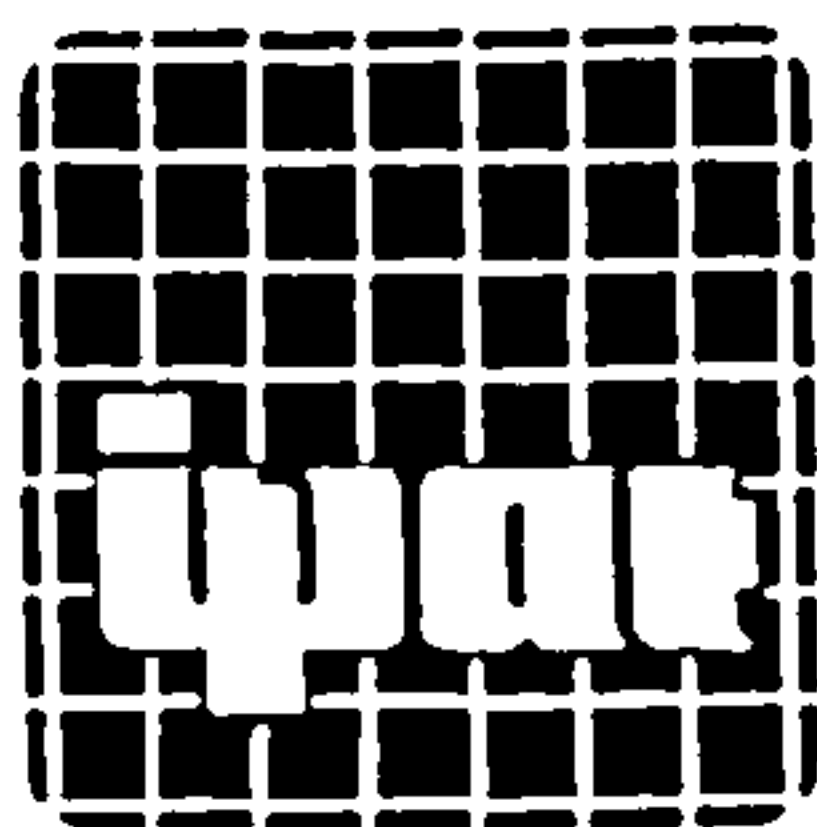


7.



8.





T.M.

Test of "g": Culture Fair

SCALE 3, FORM A

Prepared by R. B. Cattell and A. K. S. Cattell

Name _____ Sex _____
 First Last (Write M or F)

Name of School (or Address) _____

Today's Date _____ Grade (or Class) _____

Date of Birth _____ Age _____
 Month Day Year Years Months

Test	Score	Remarks
1		
2		
3		
4		
		Total Score

M. _____

Q. _____

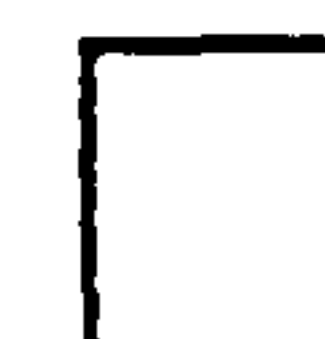
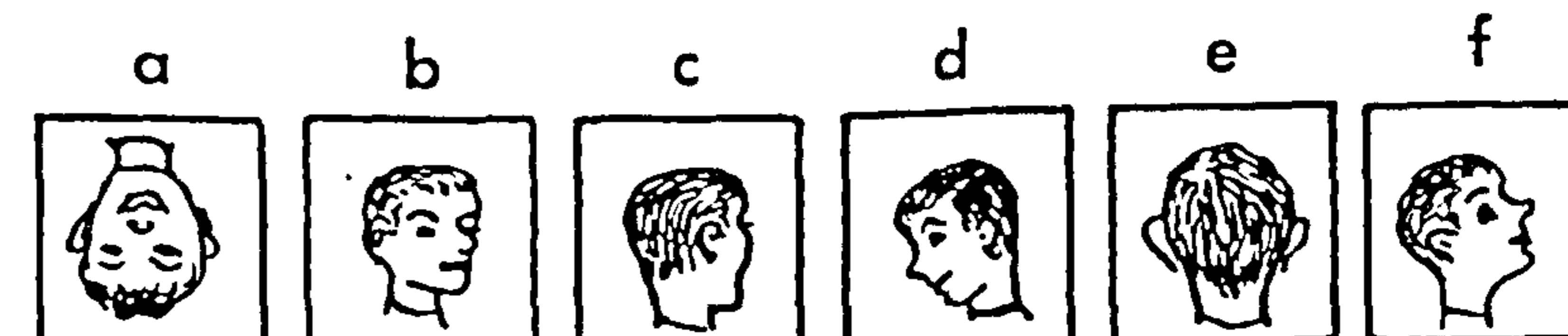
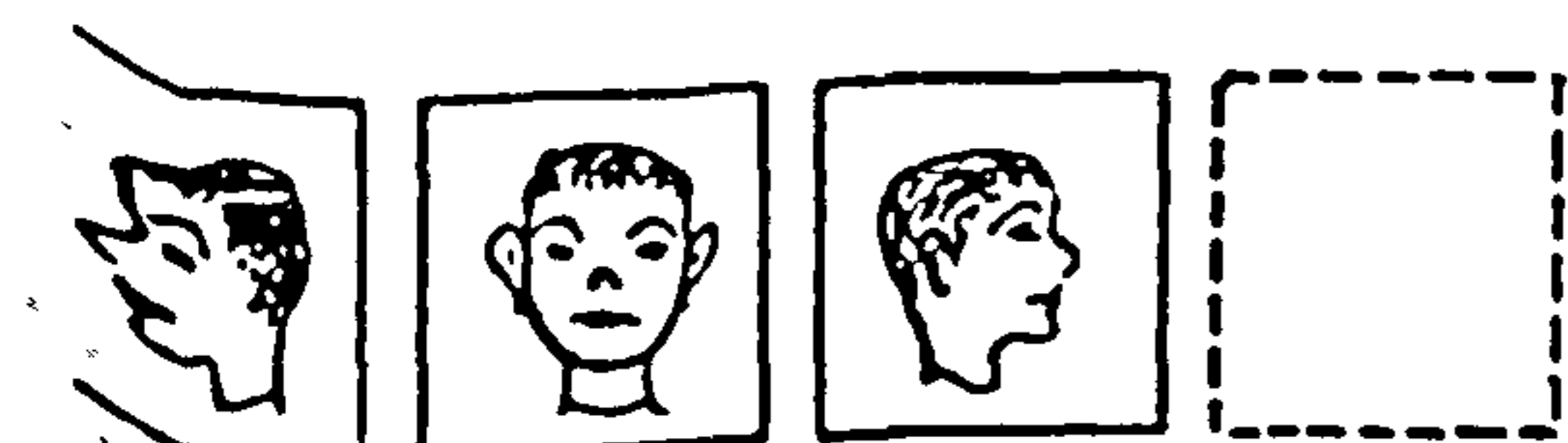
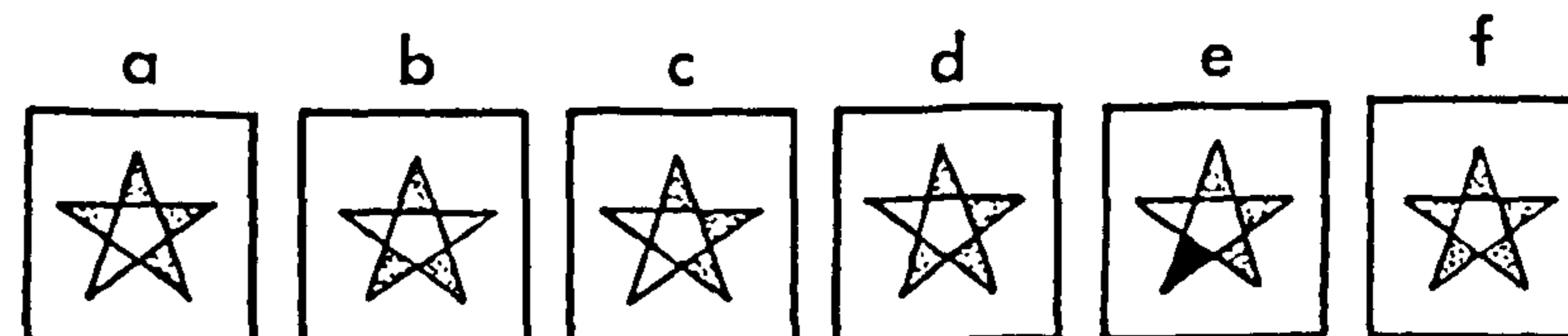
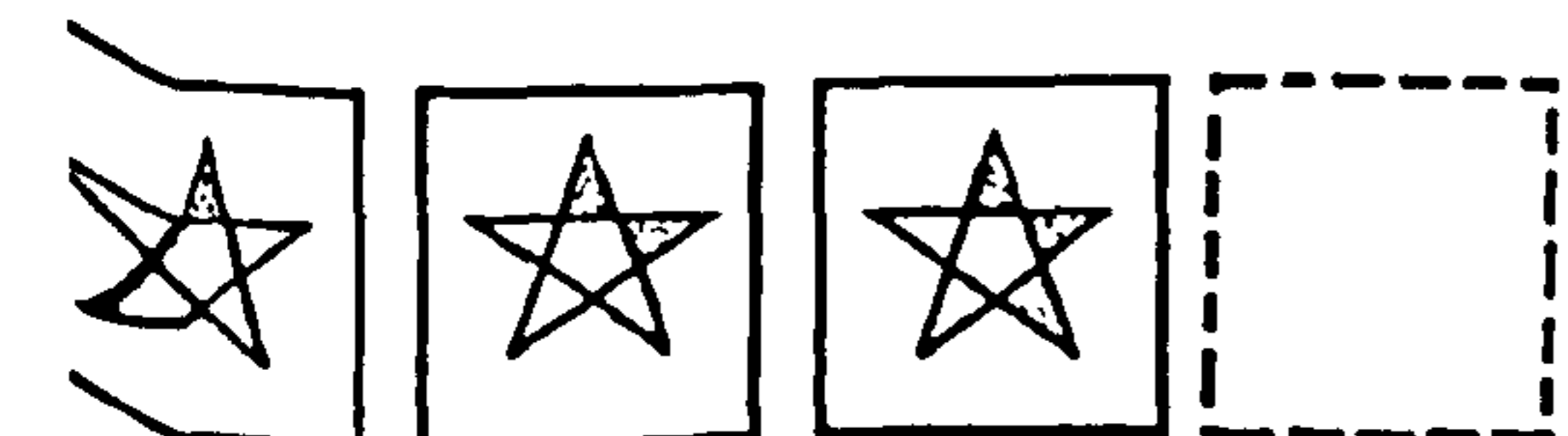
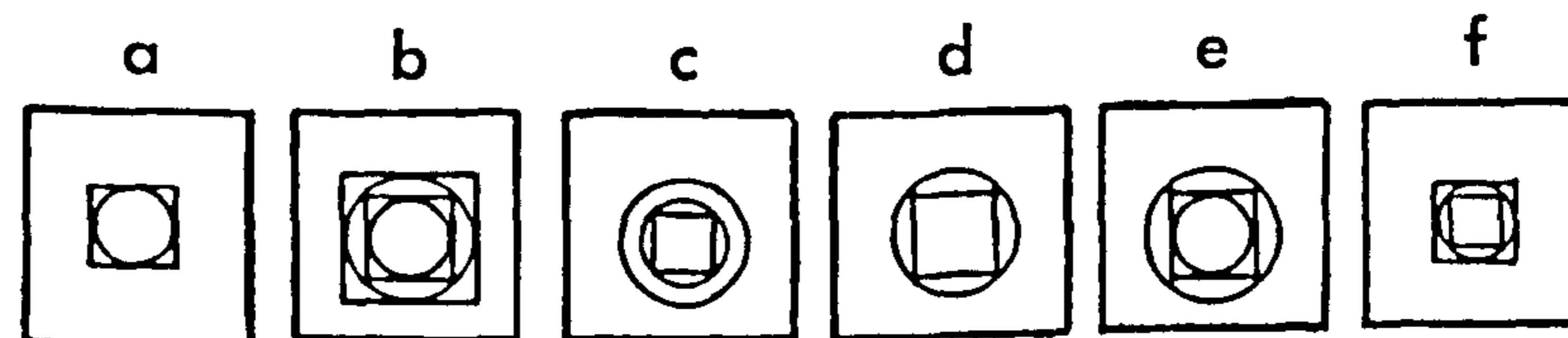
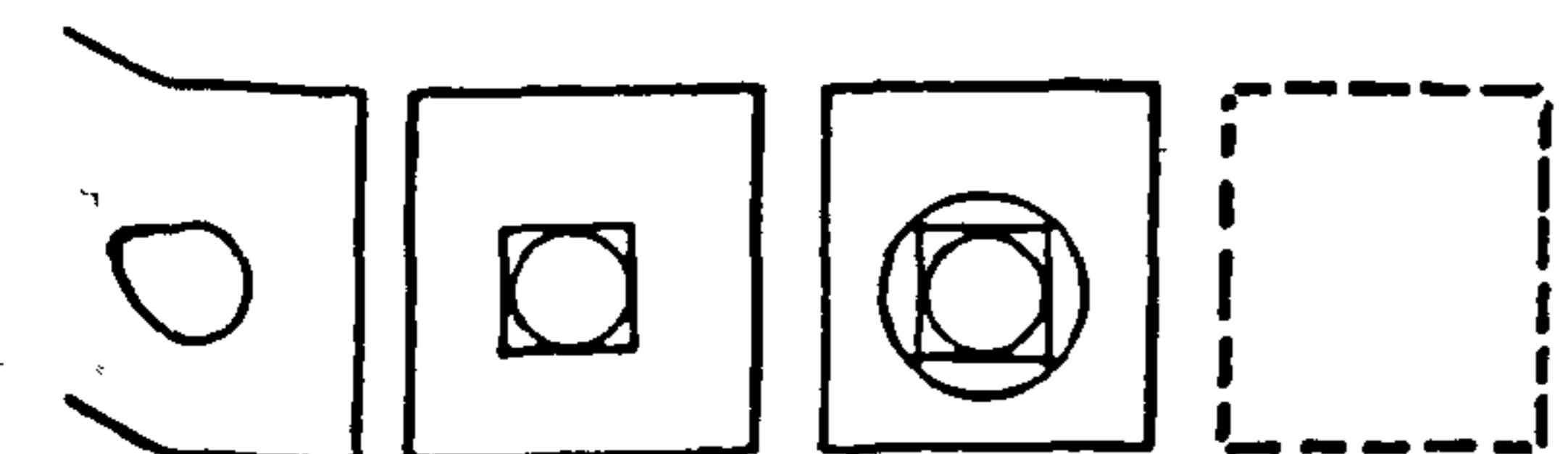
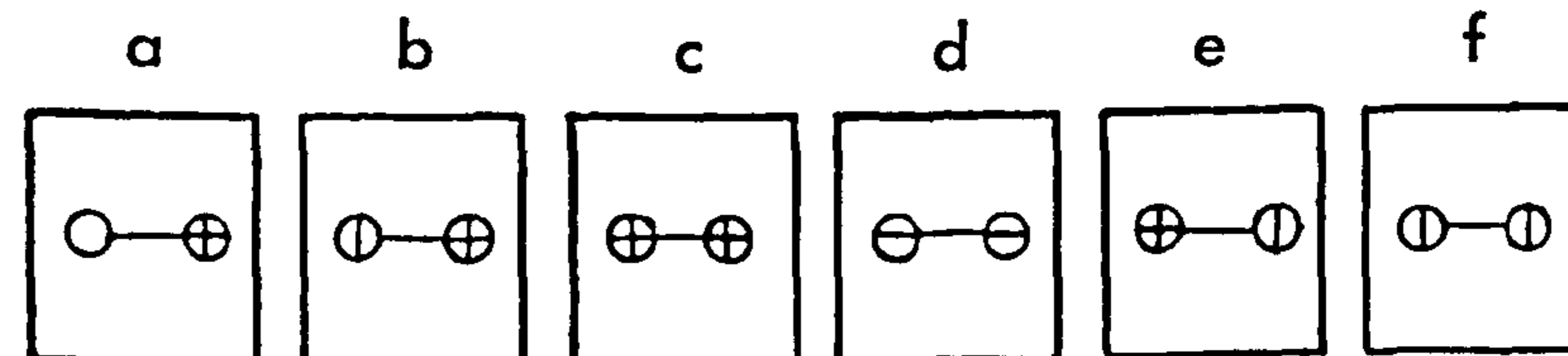
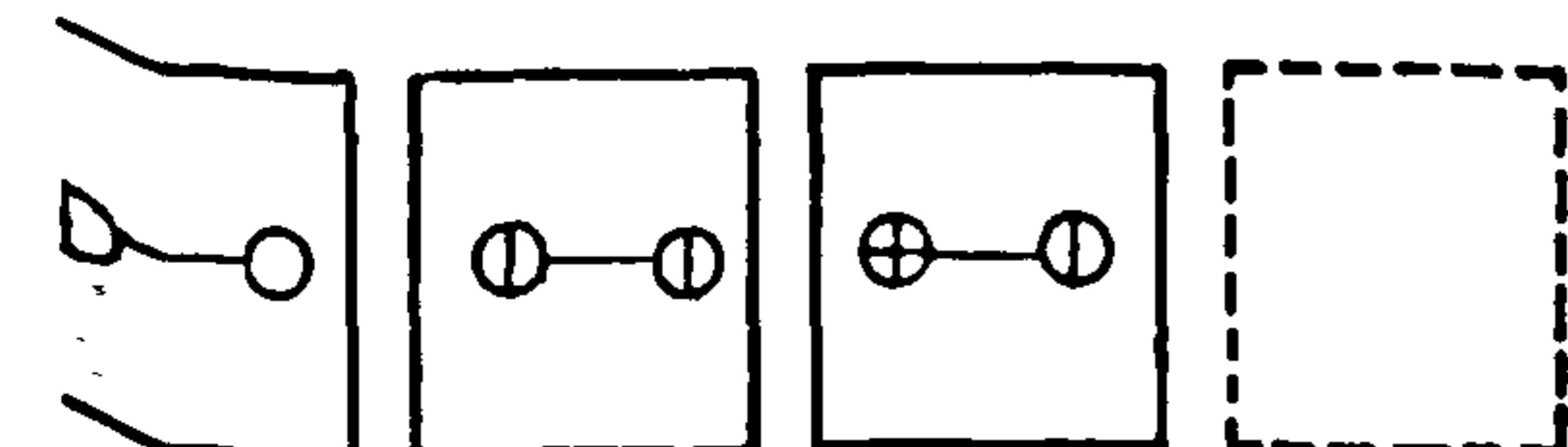
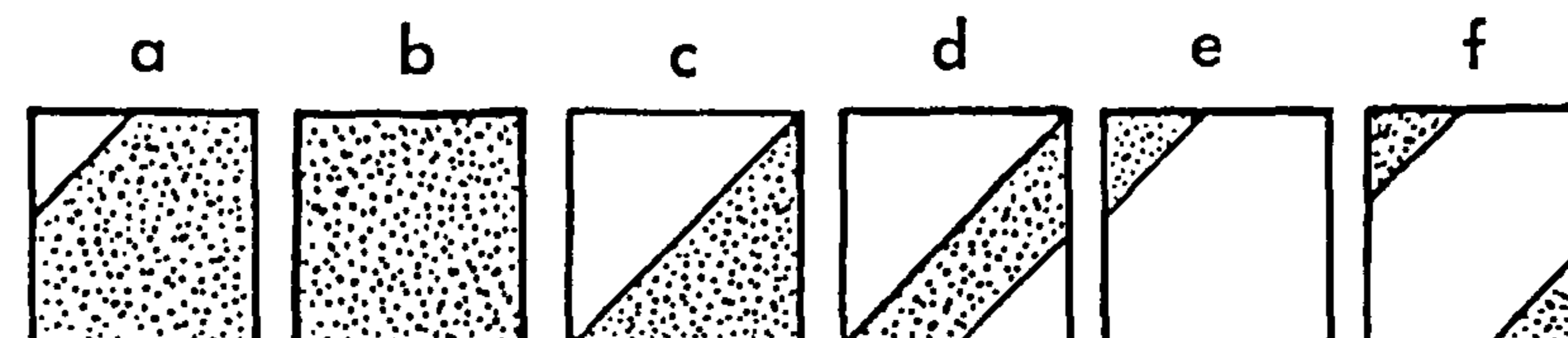
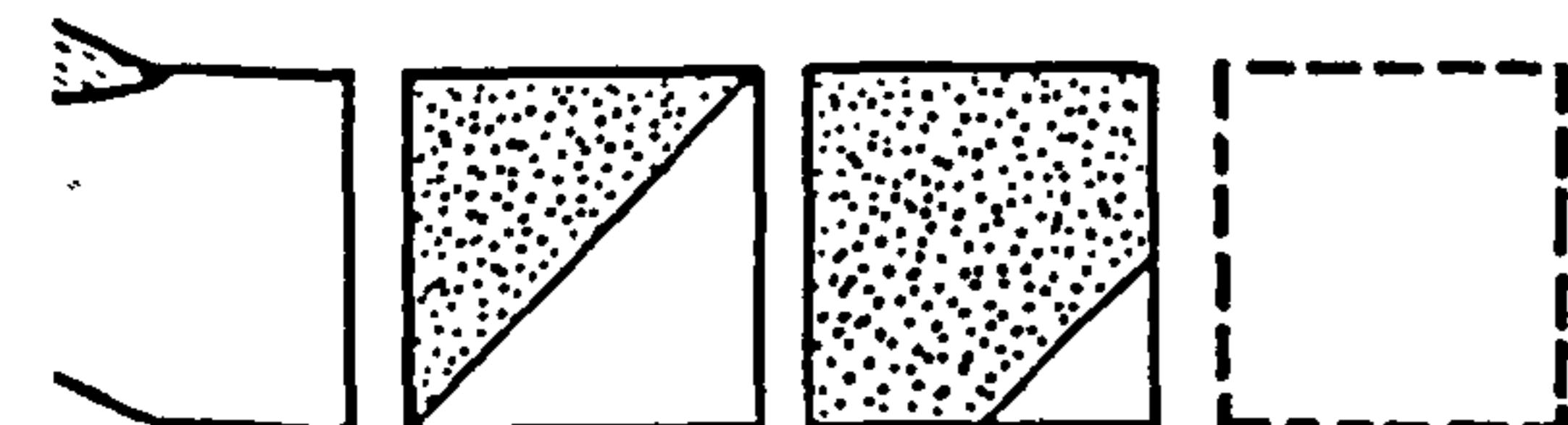
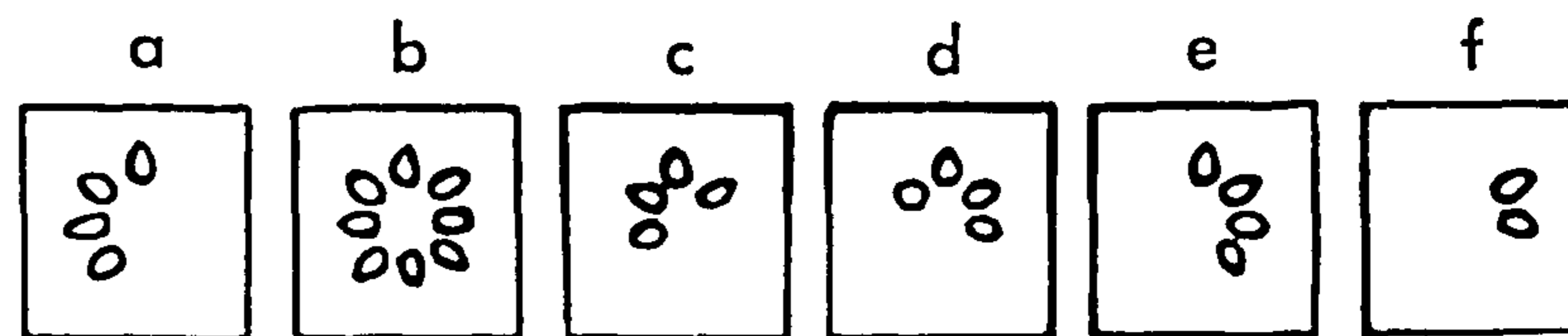
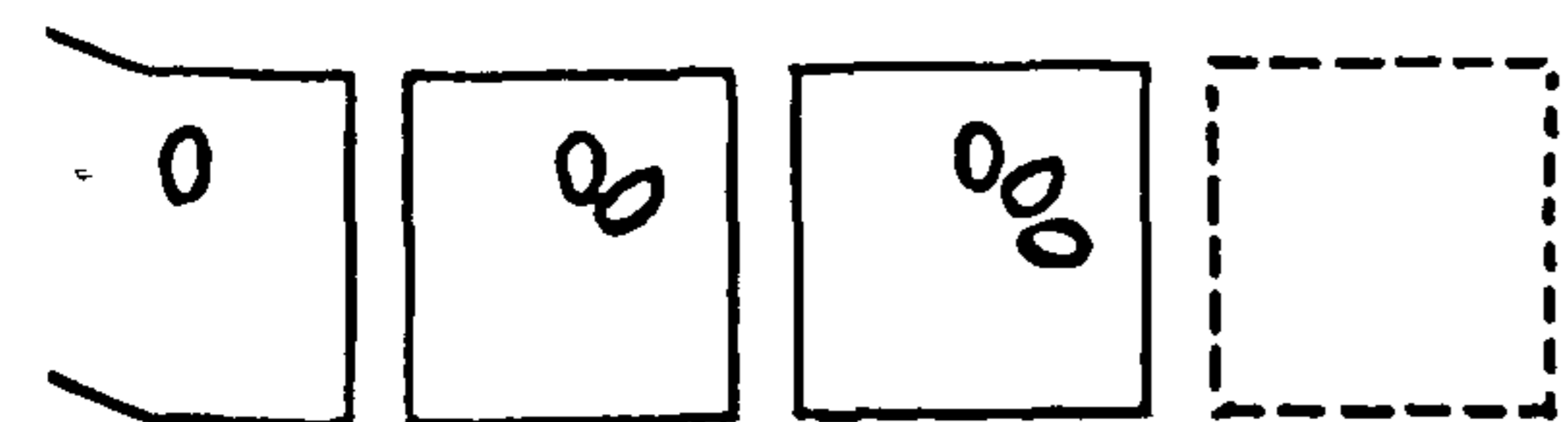
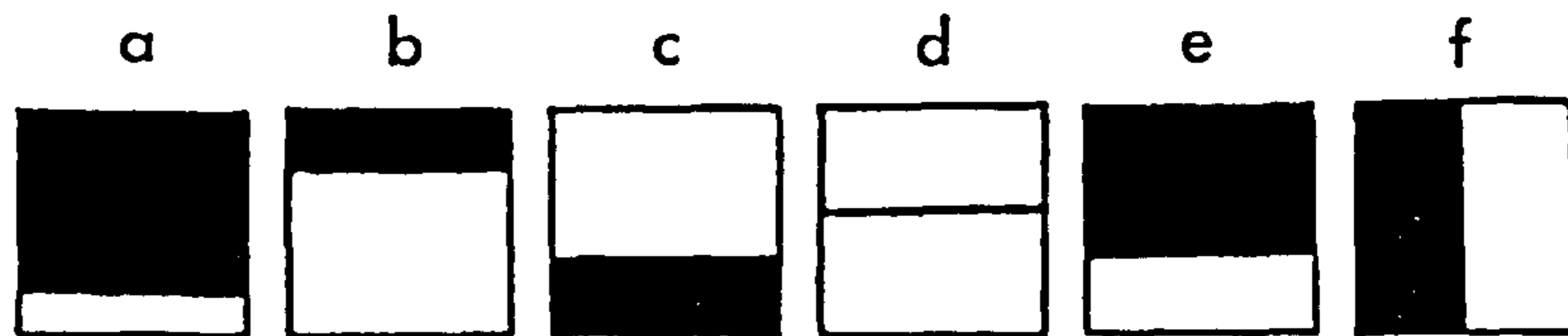
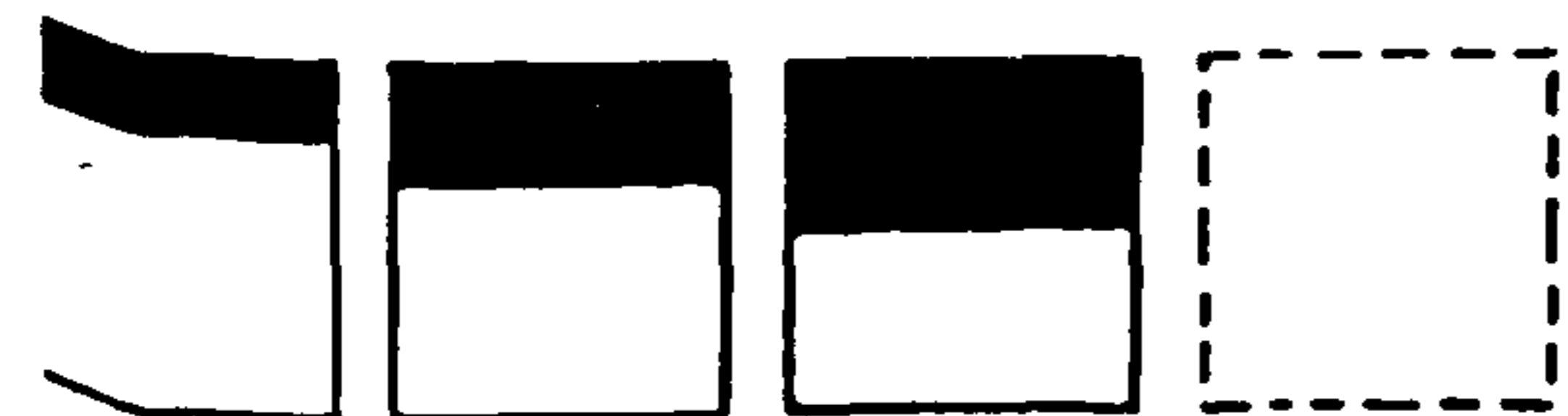
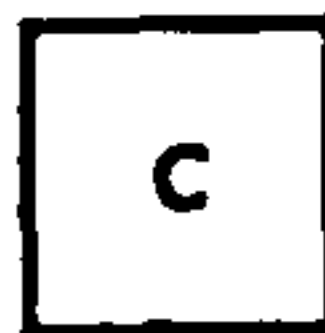
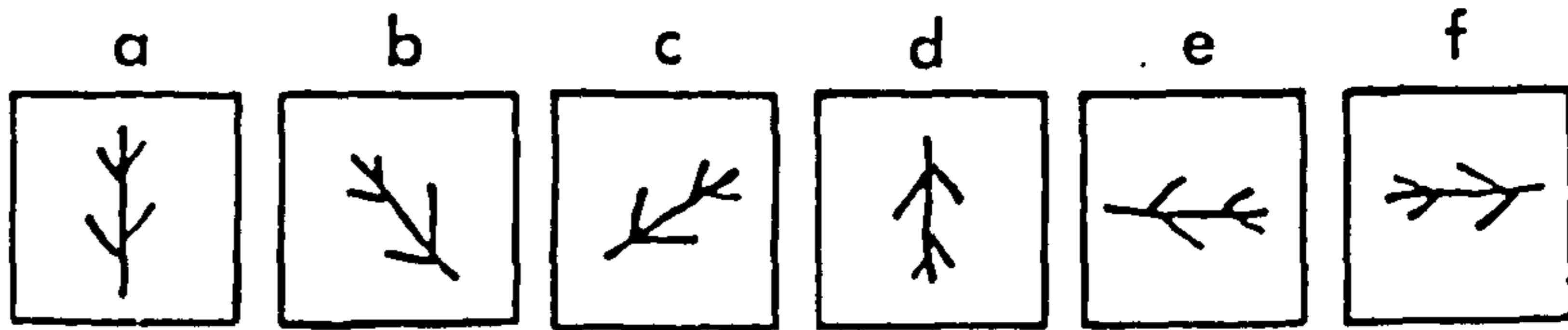
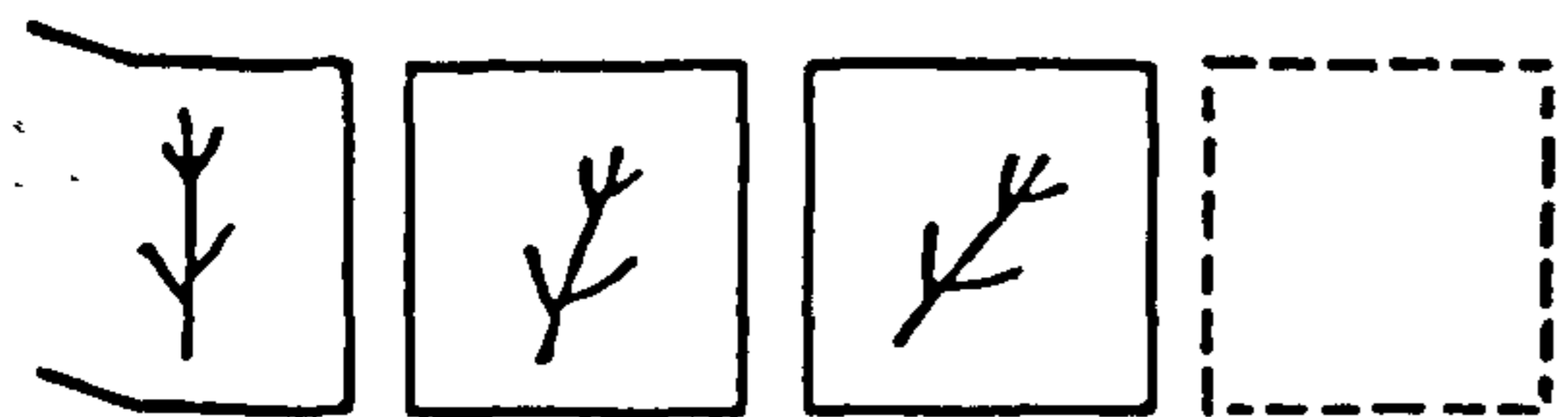
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1963 Edition

TEST 1

Examples

Answers



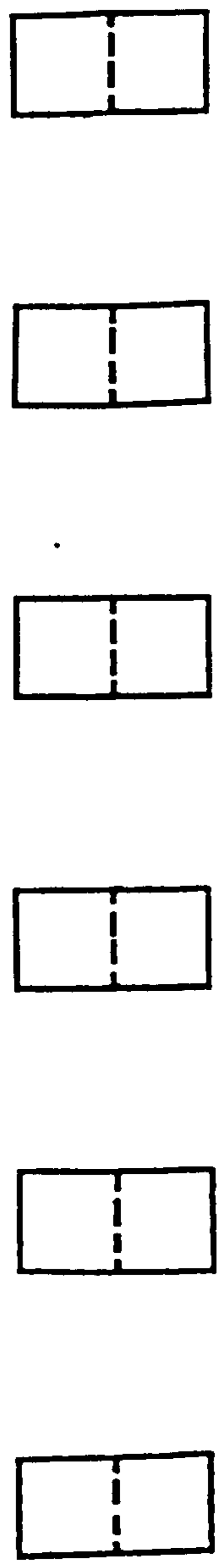
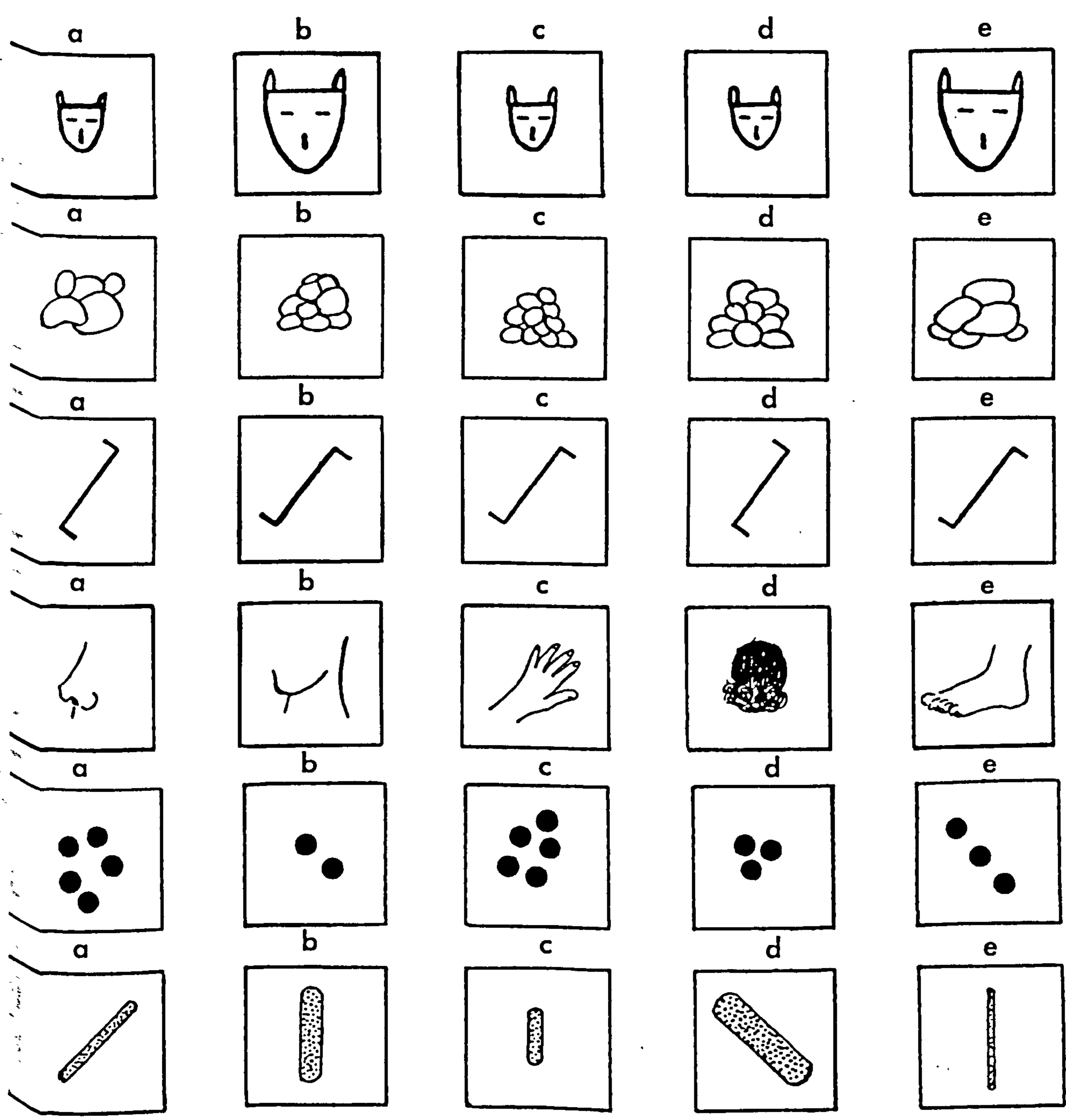
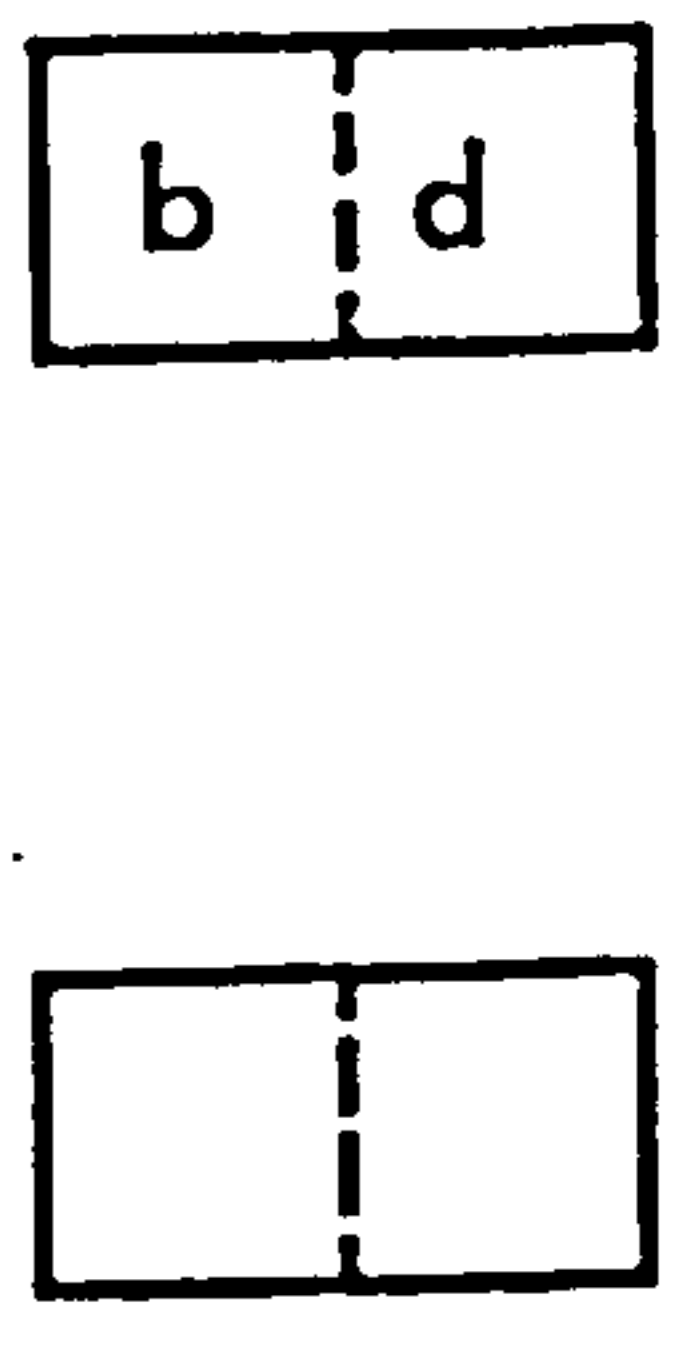
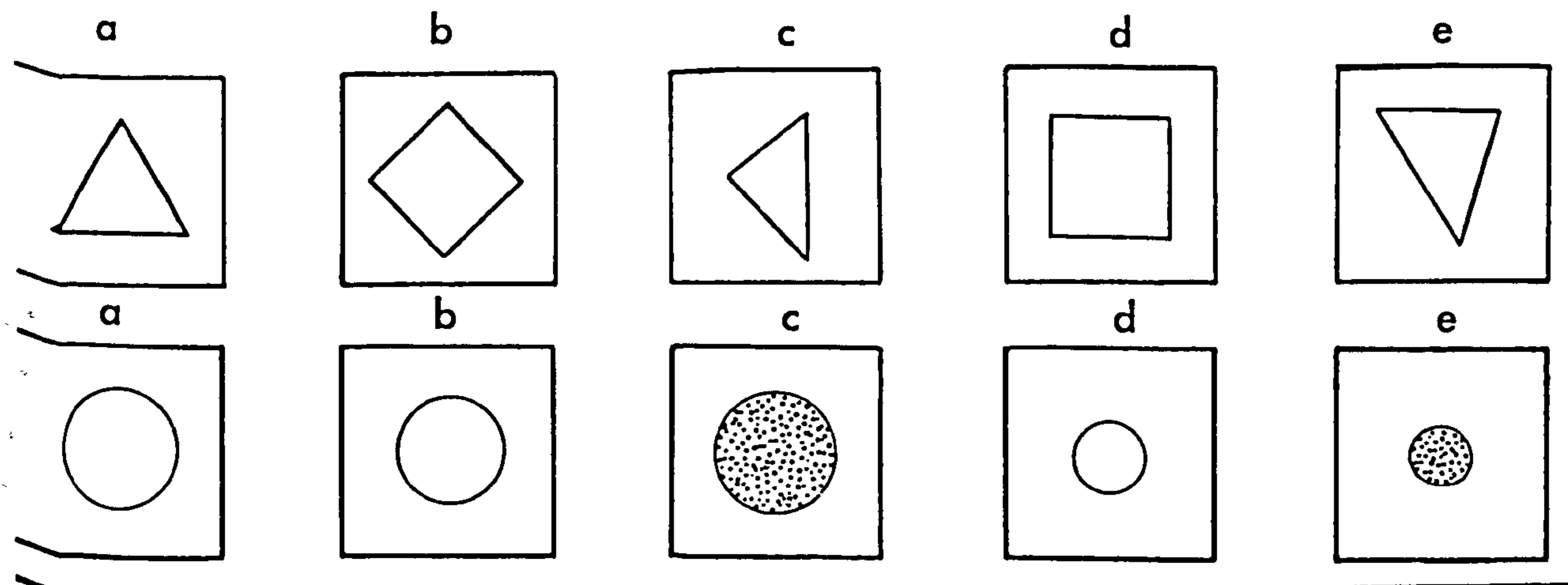
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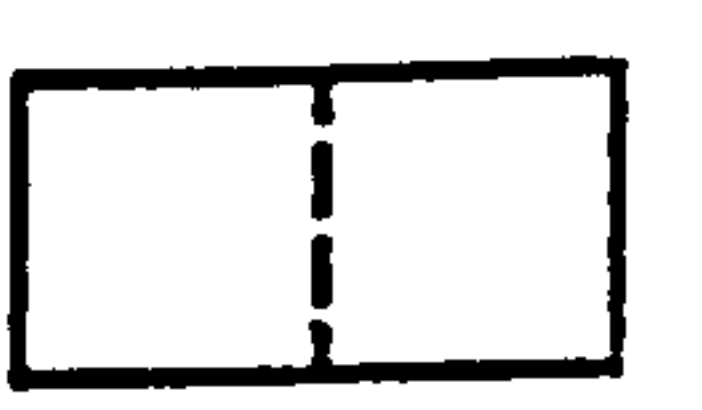
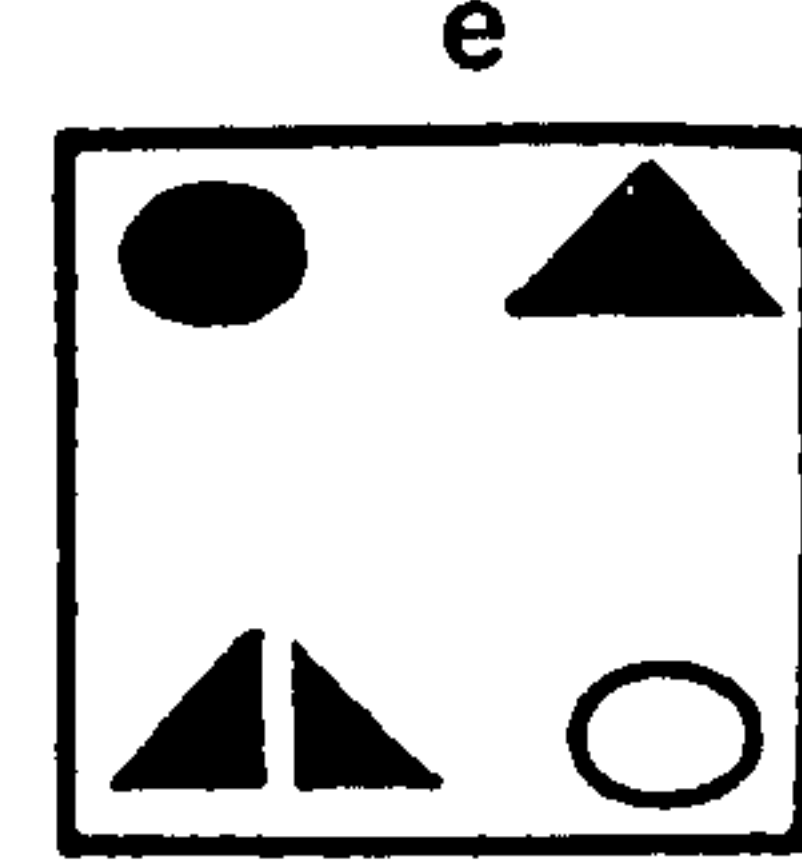
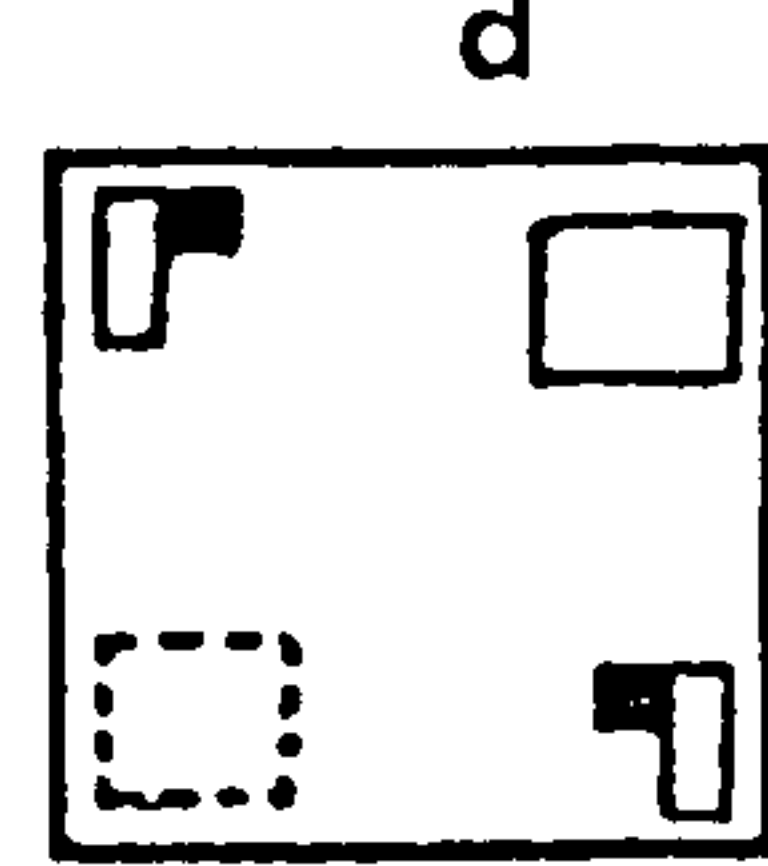
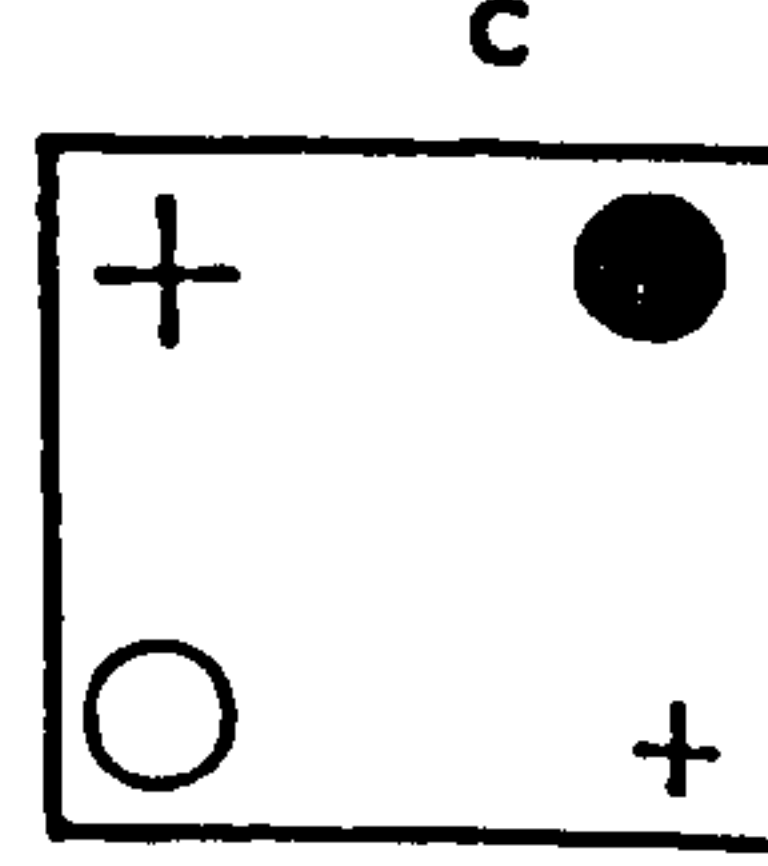
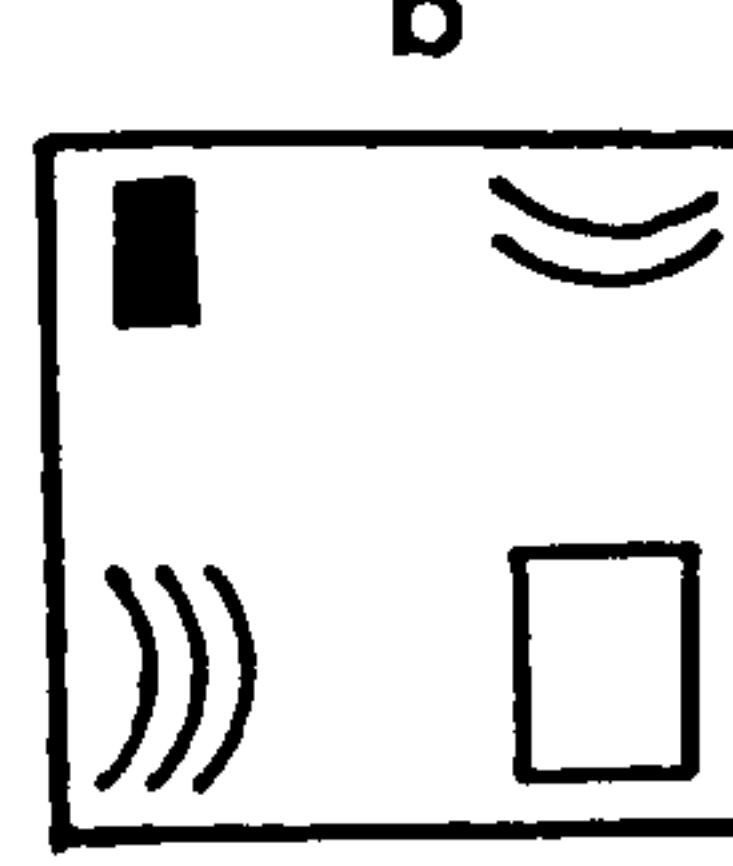
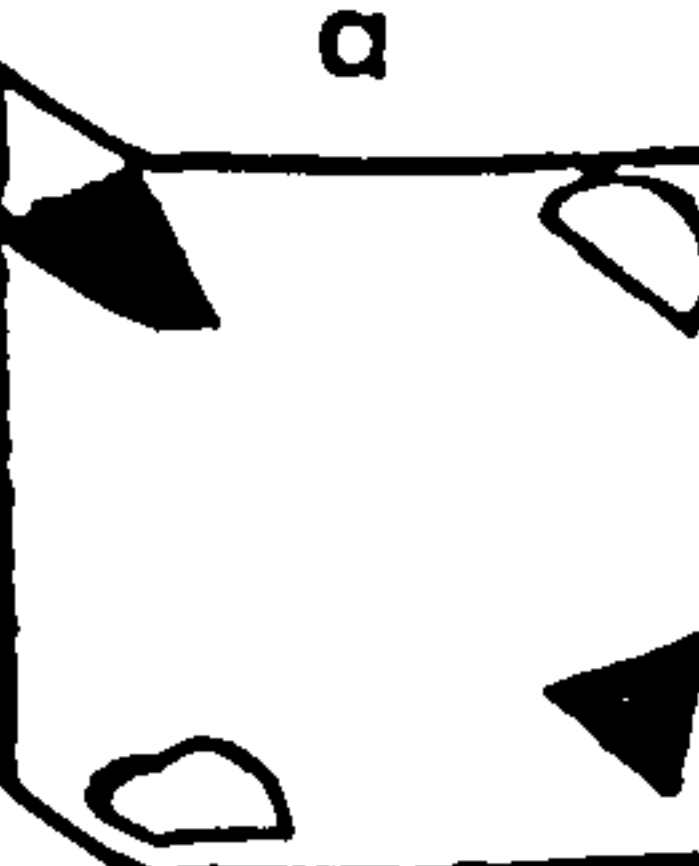
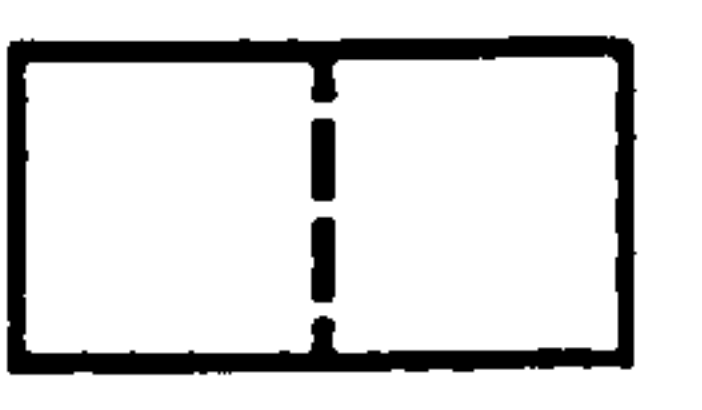
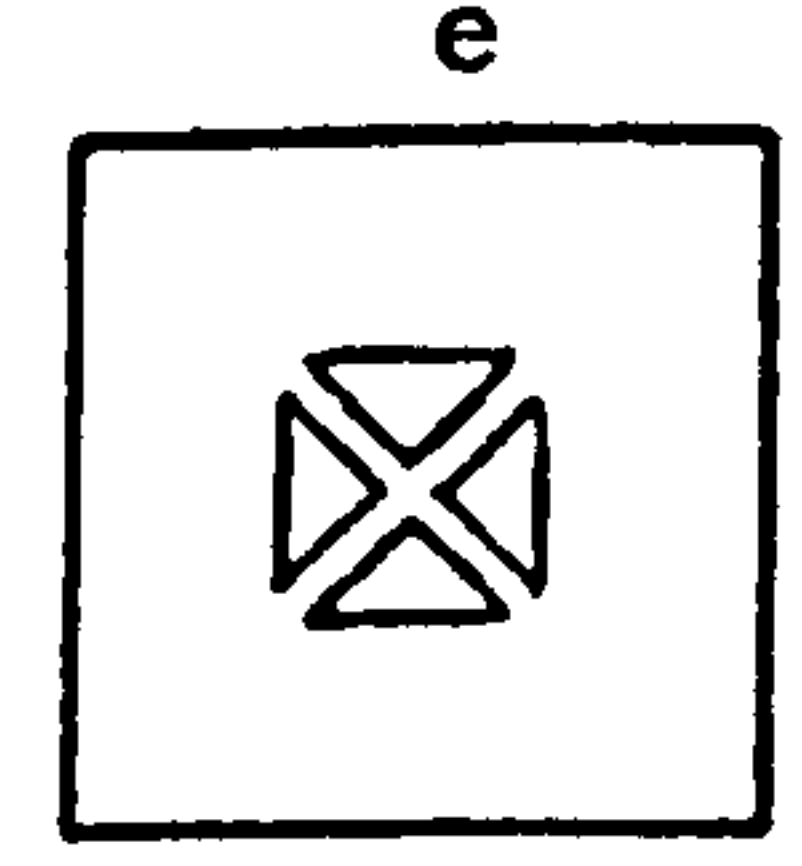
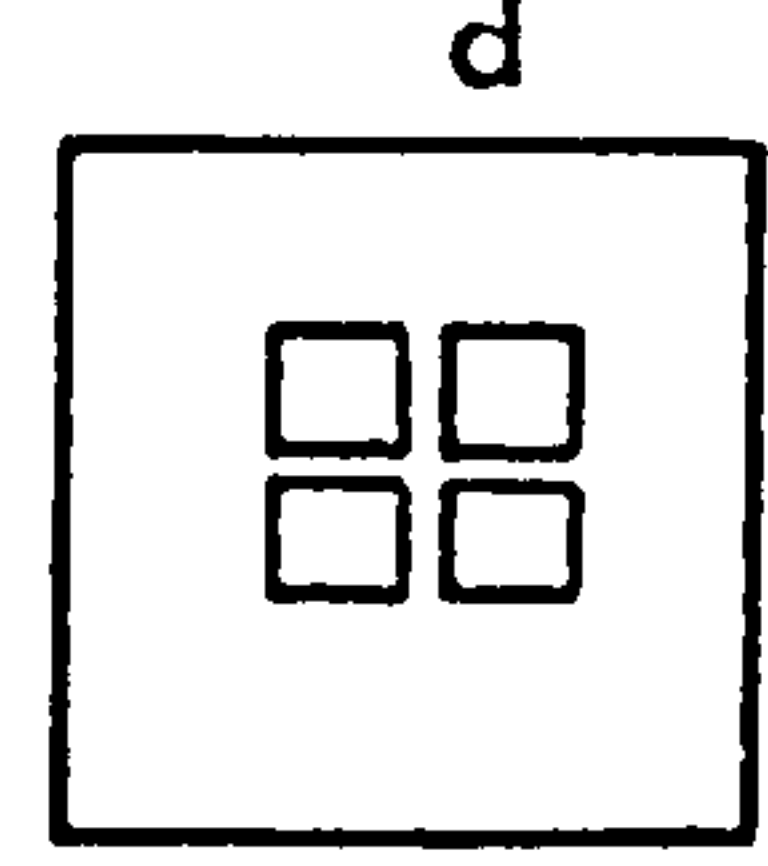
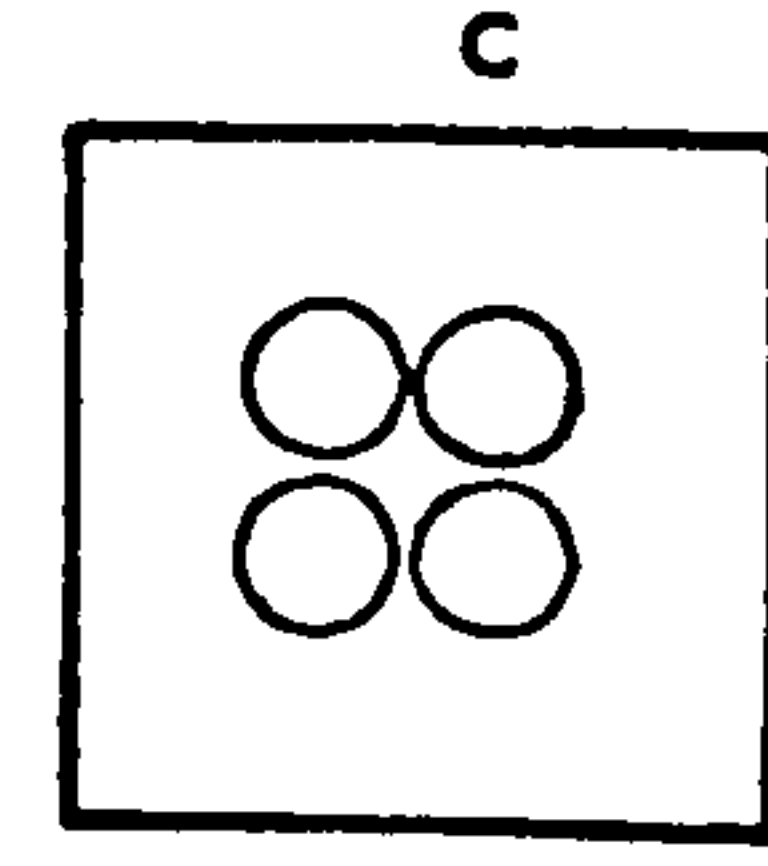
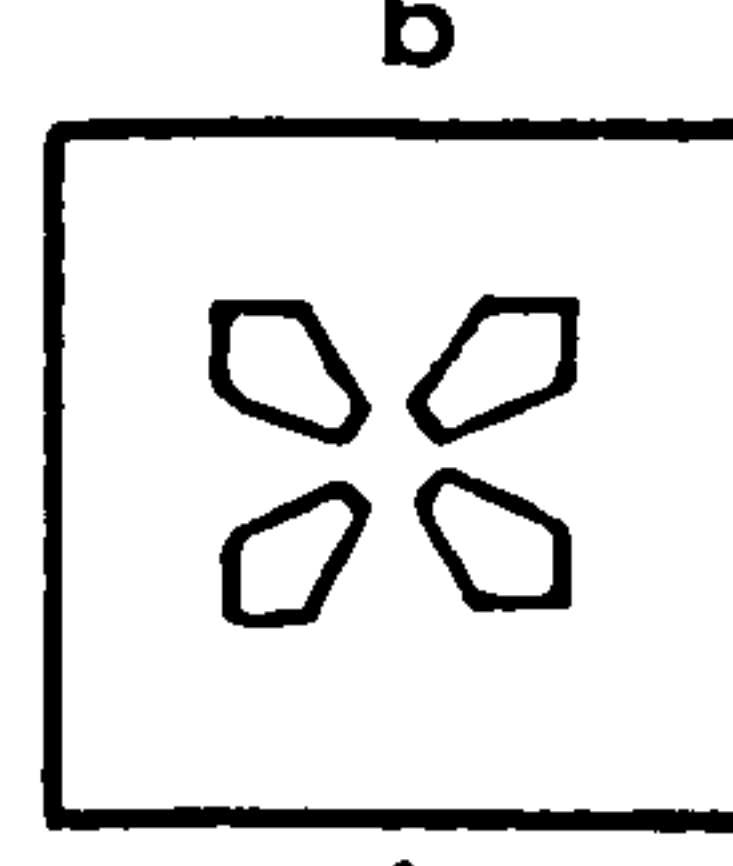
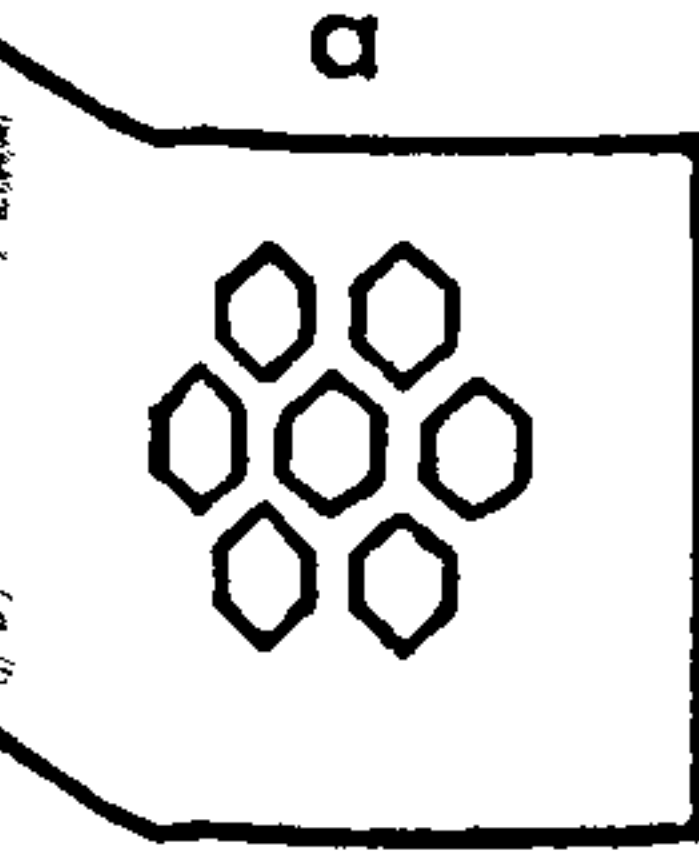
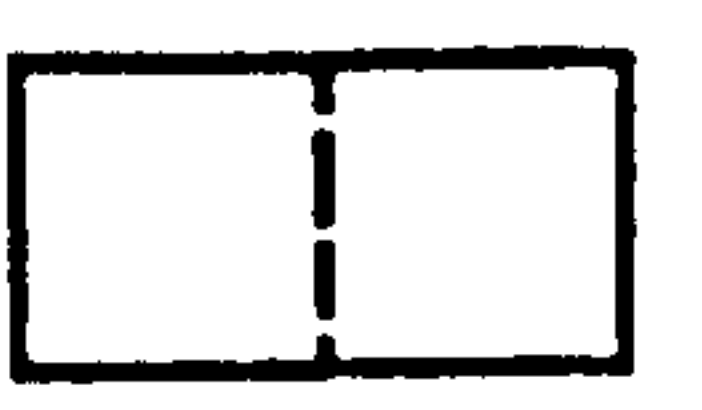
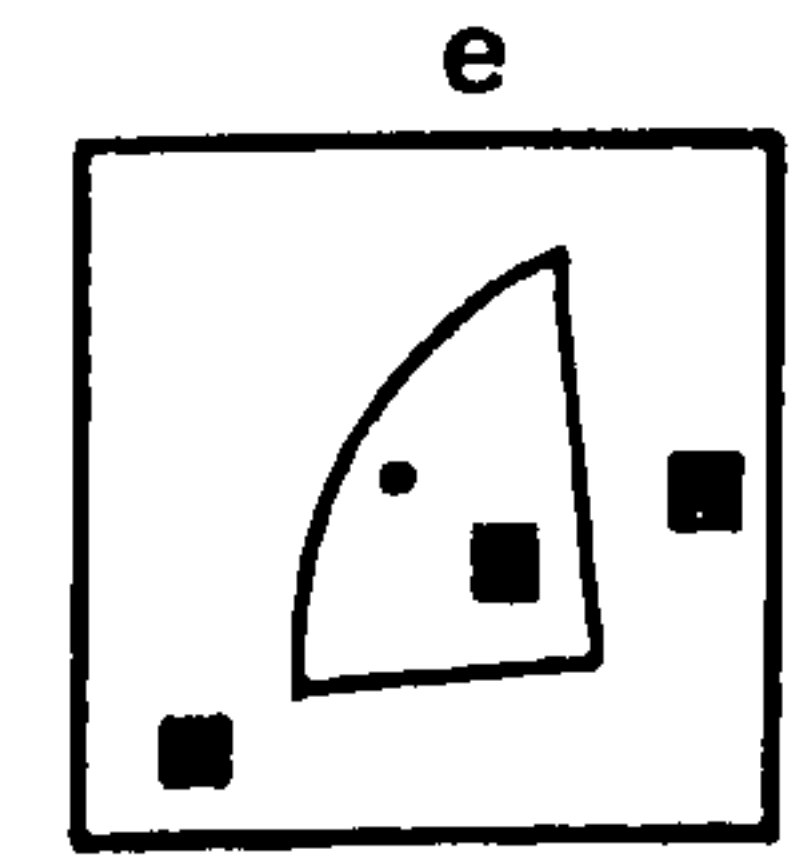
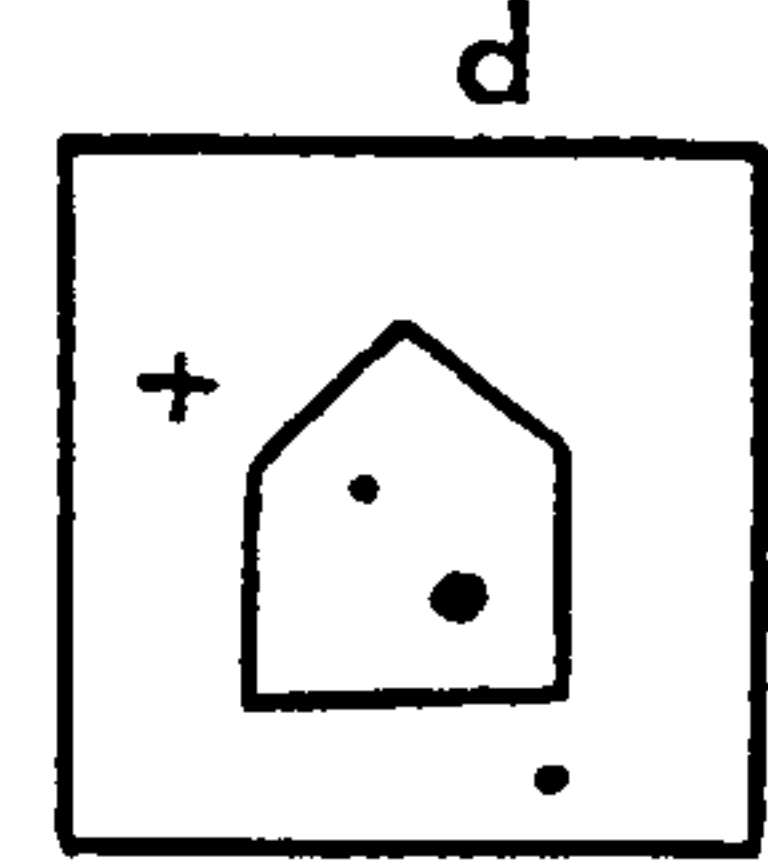
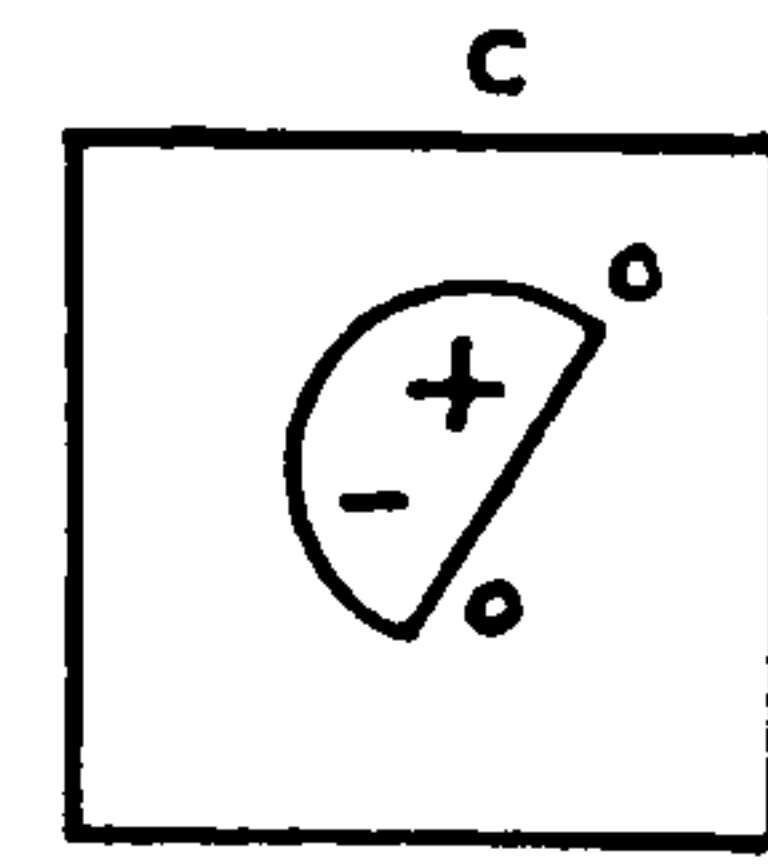
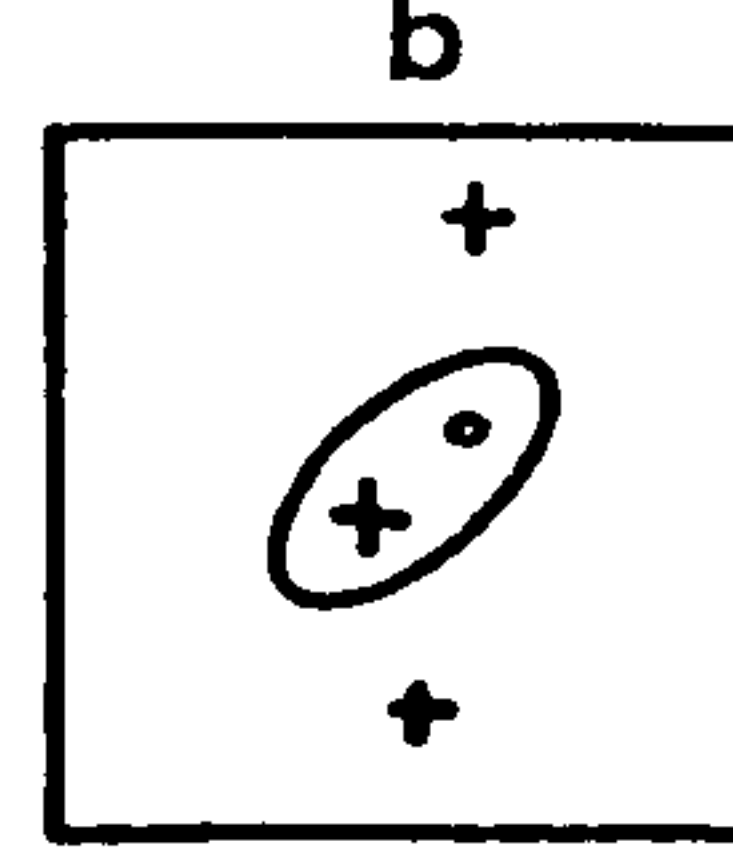
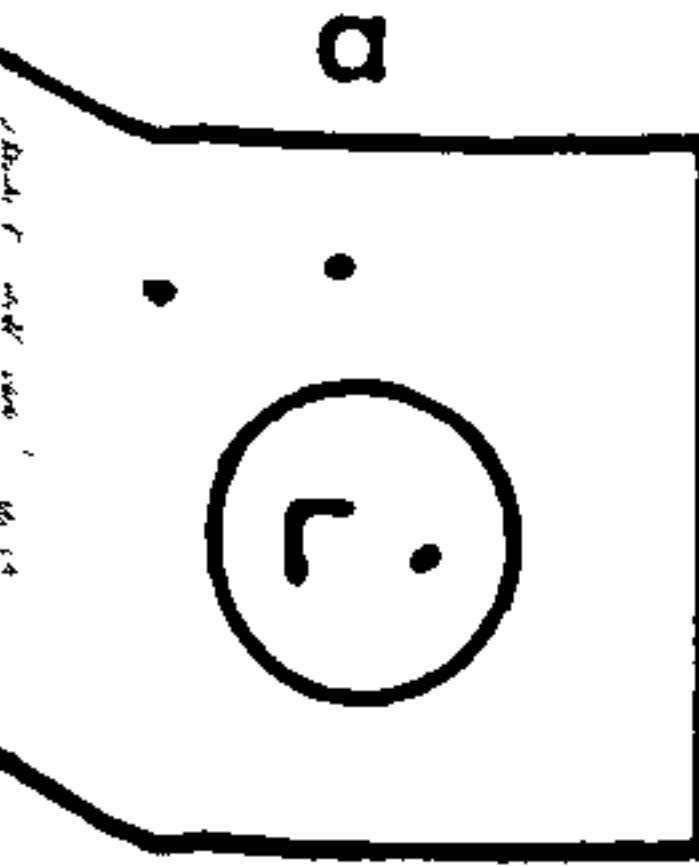
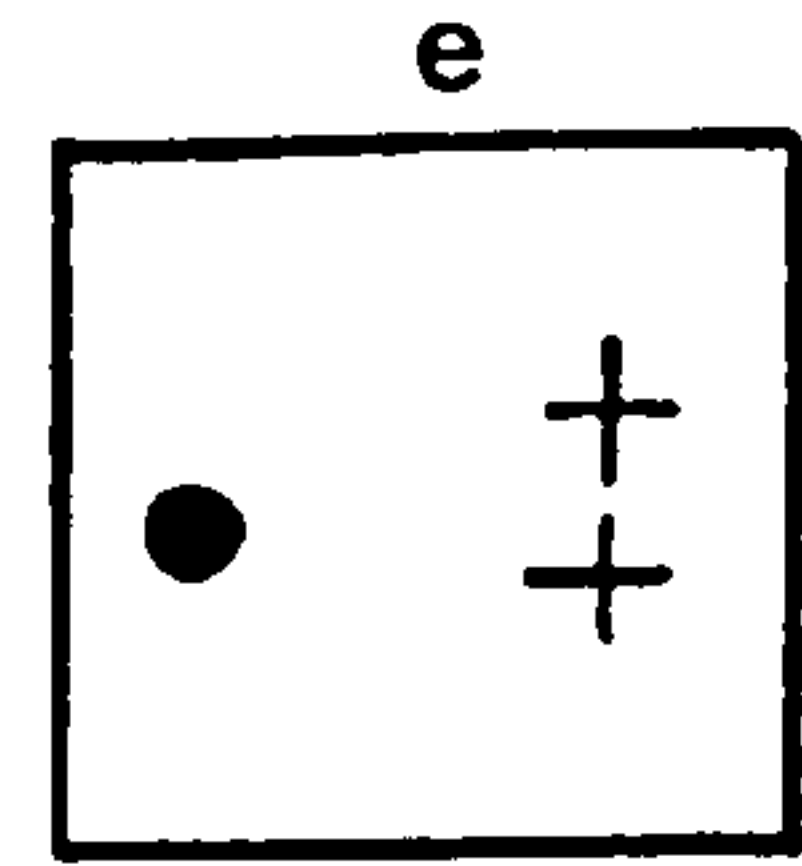
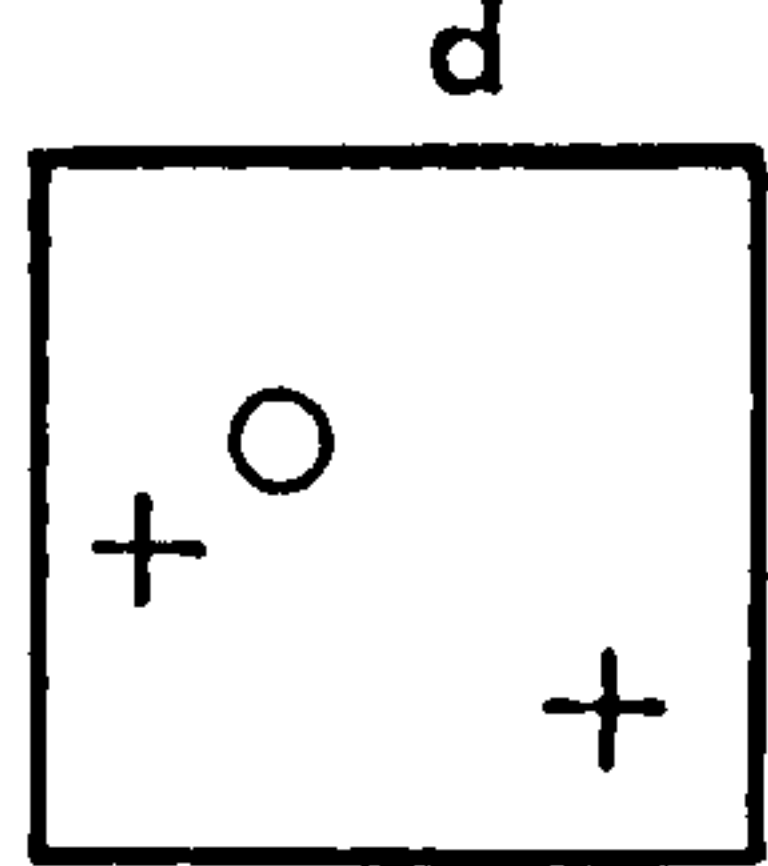
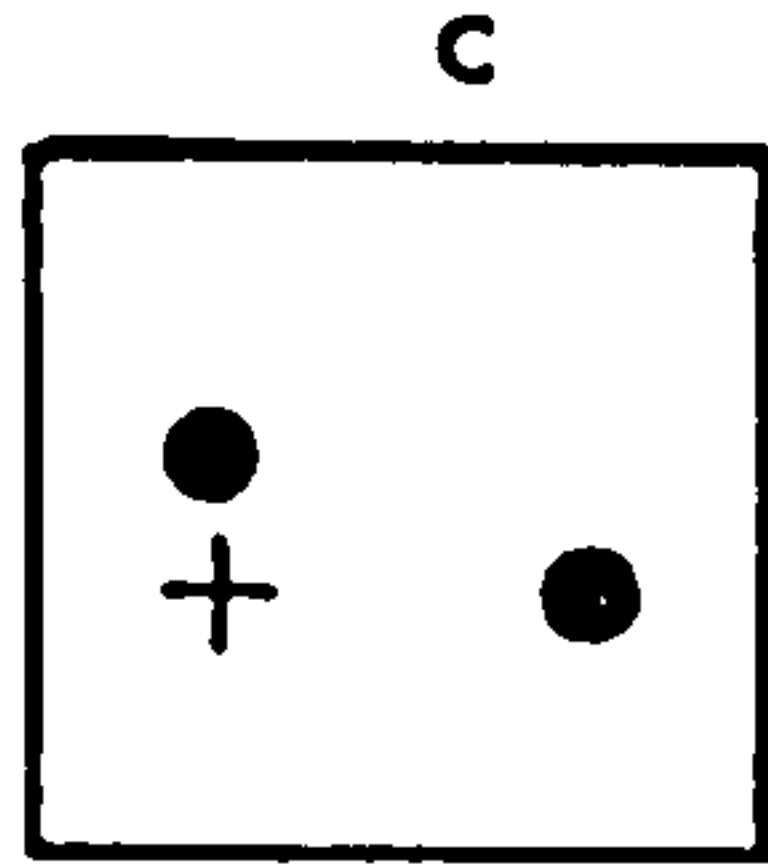
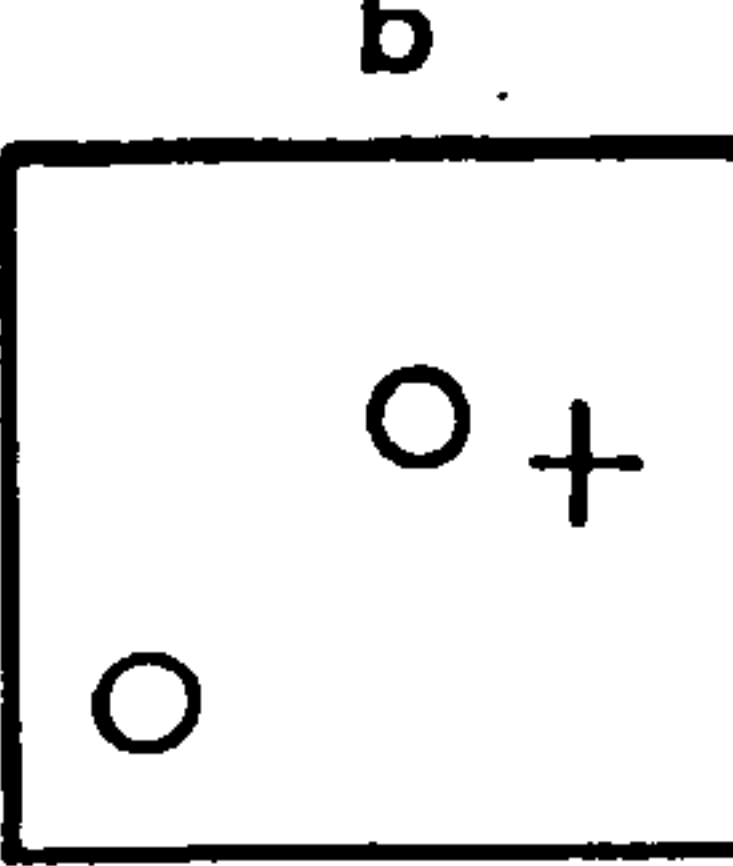
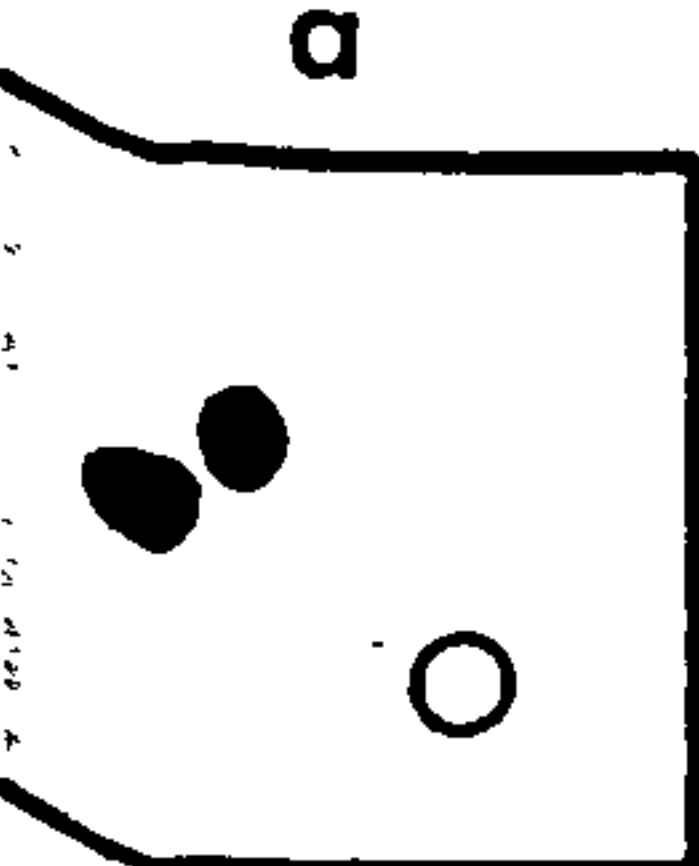
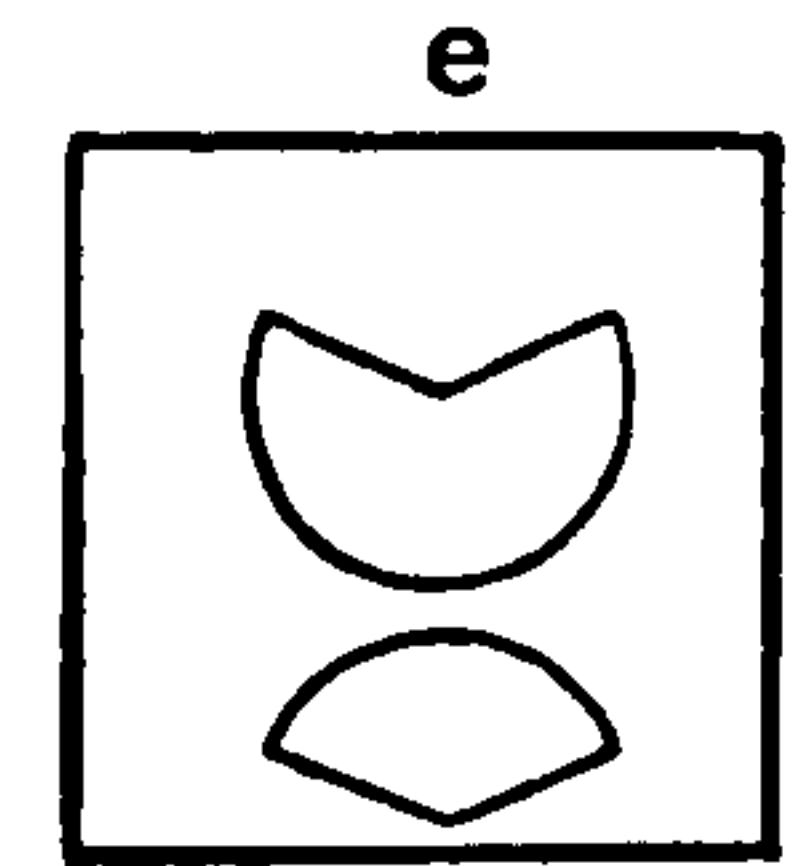
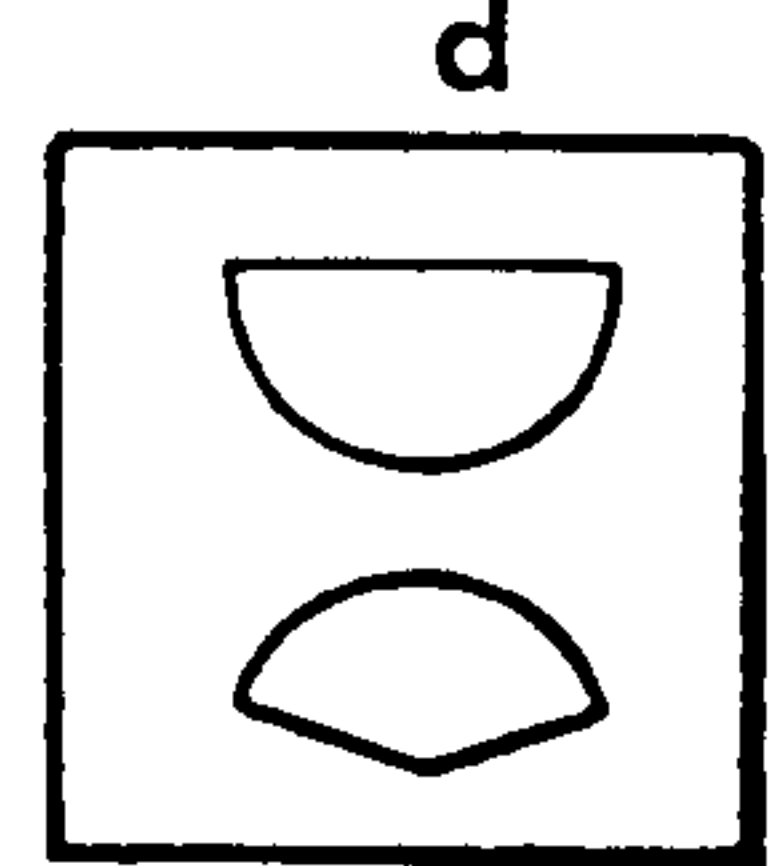
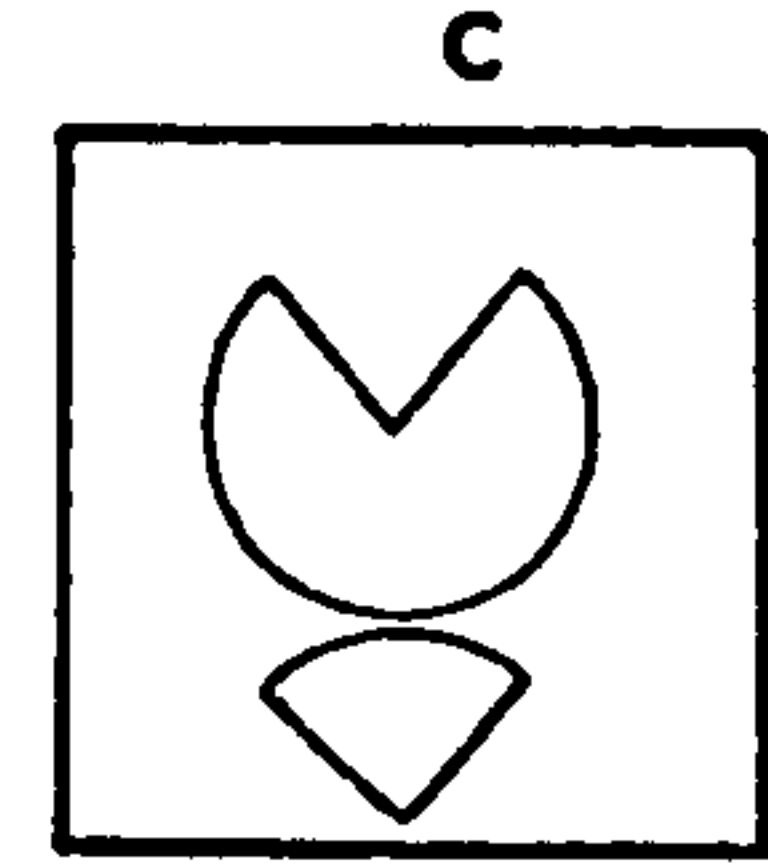
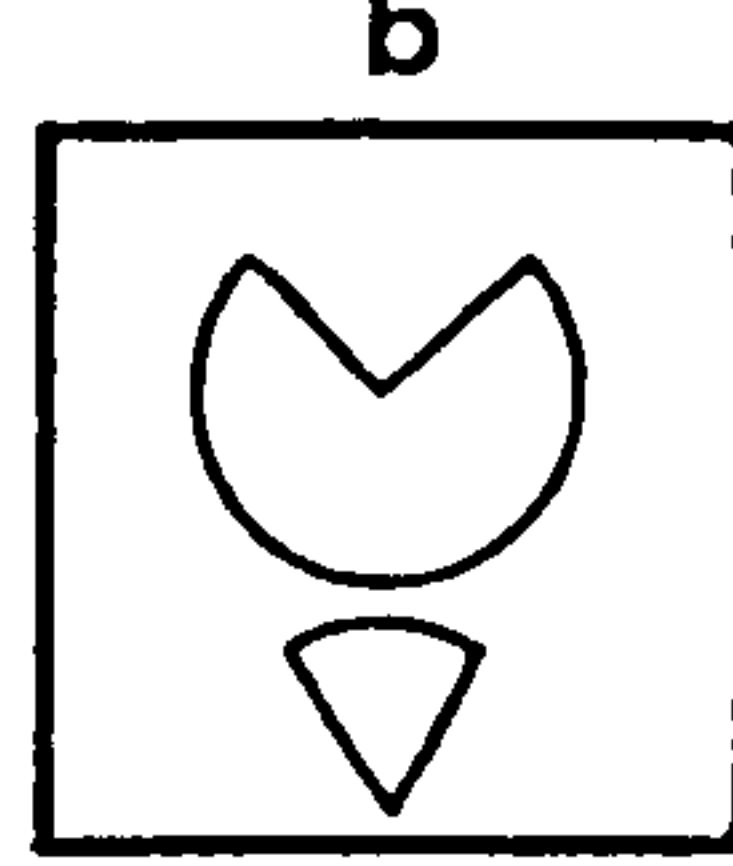
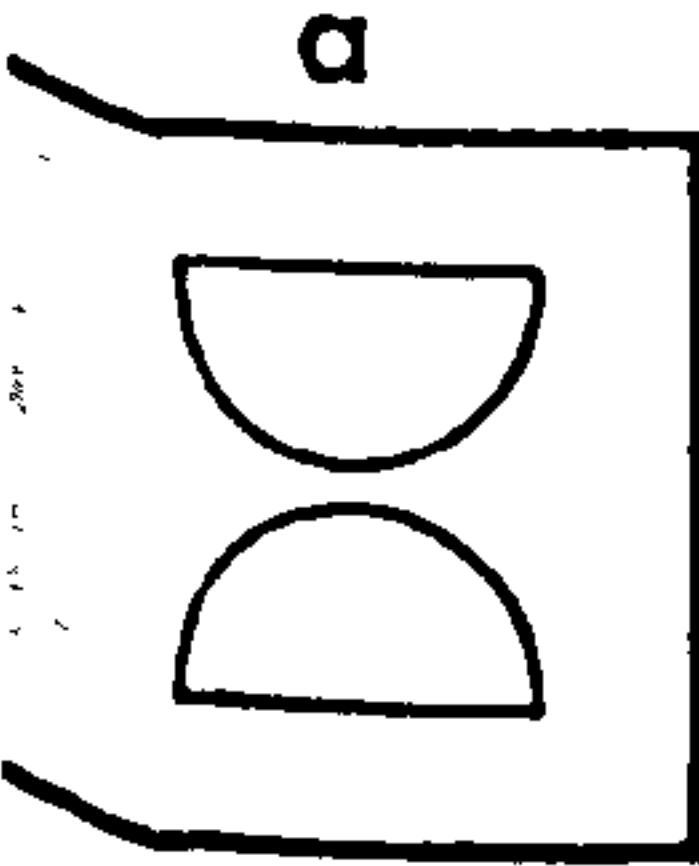
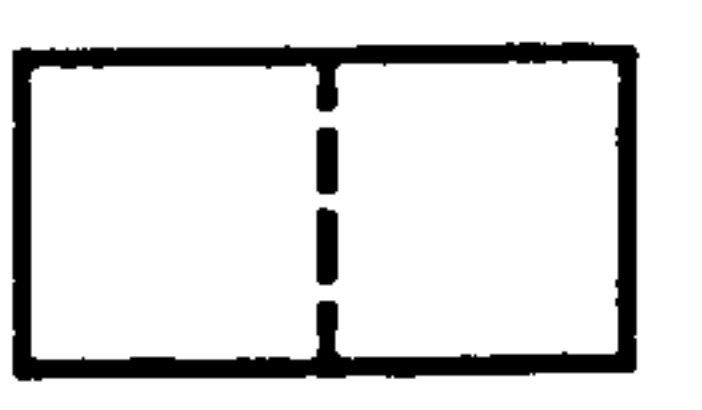
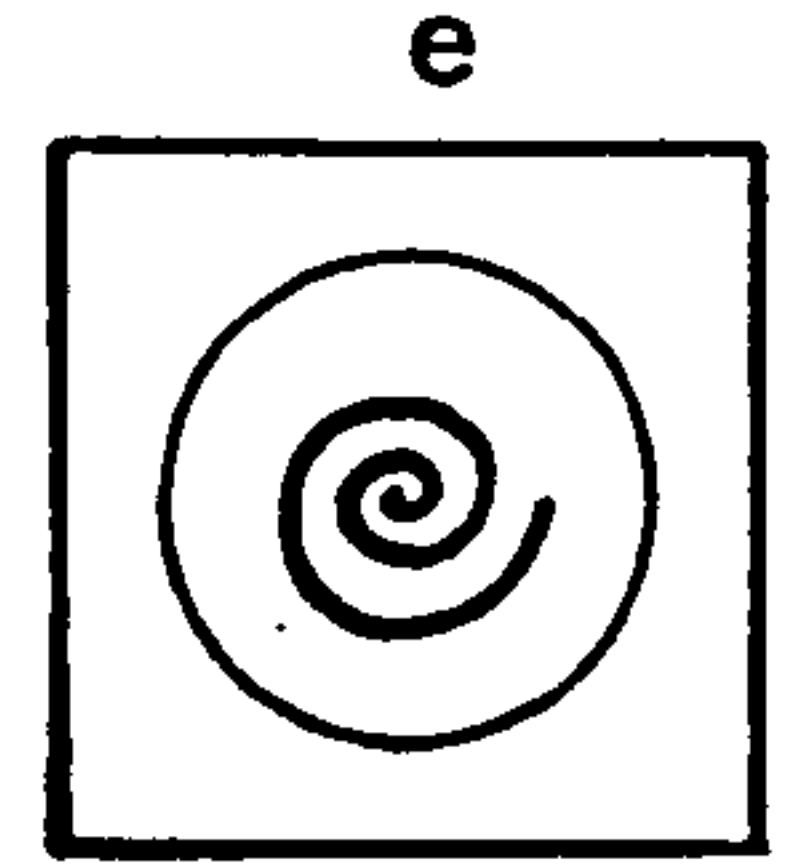
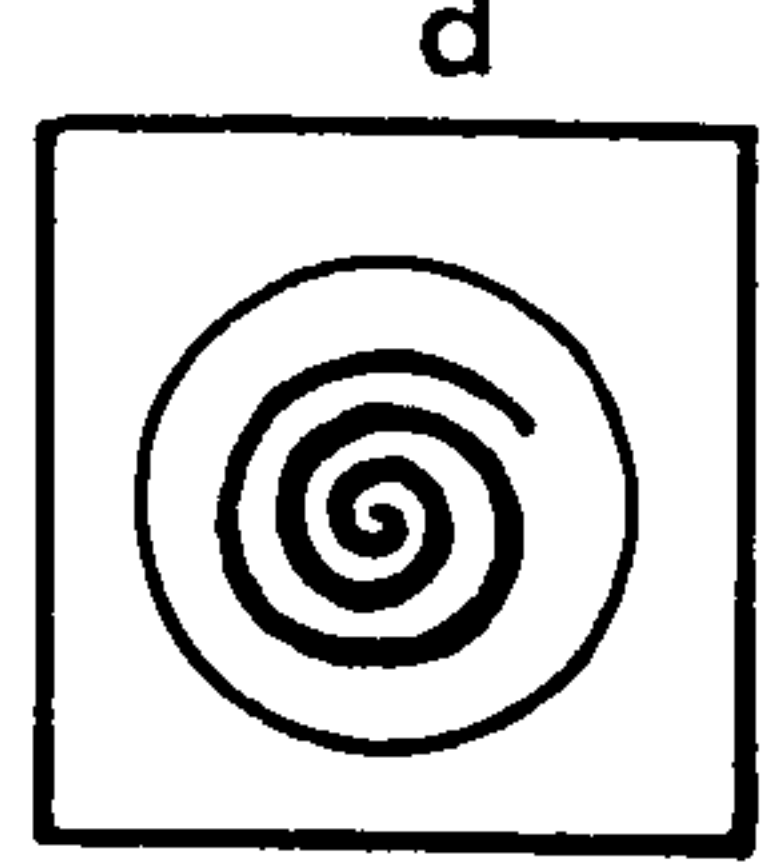
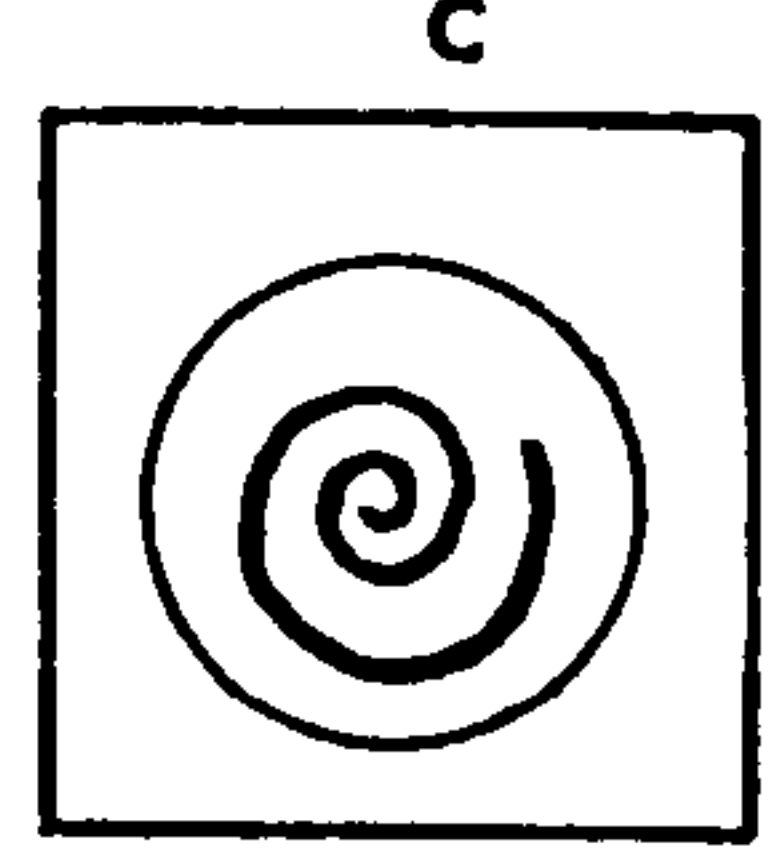
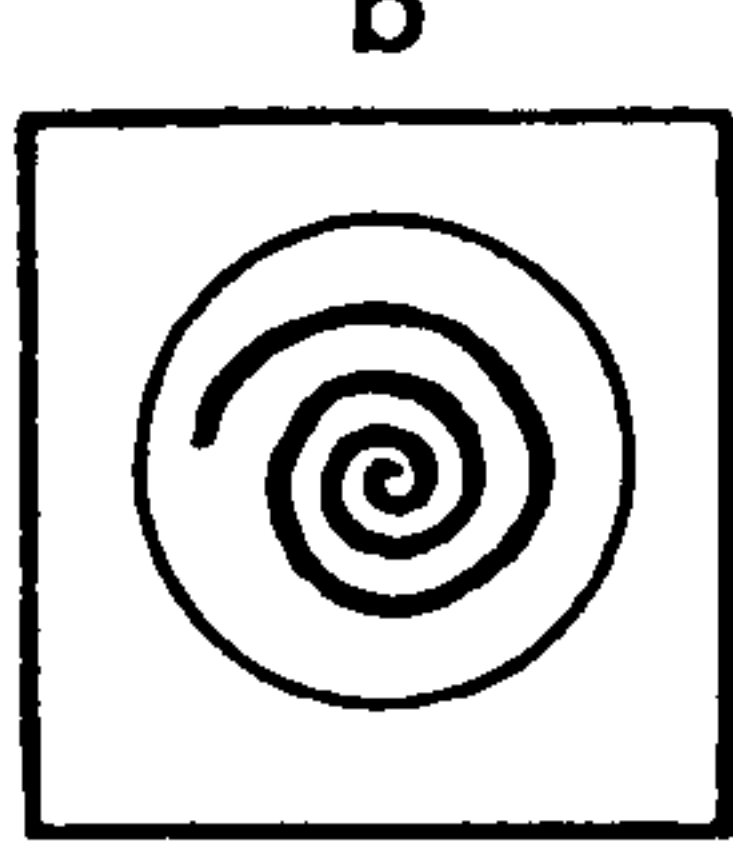
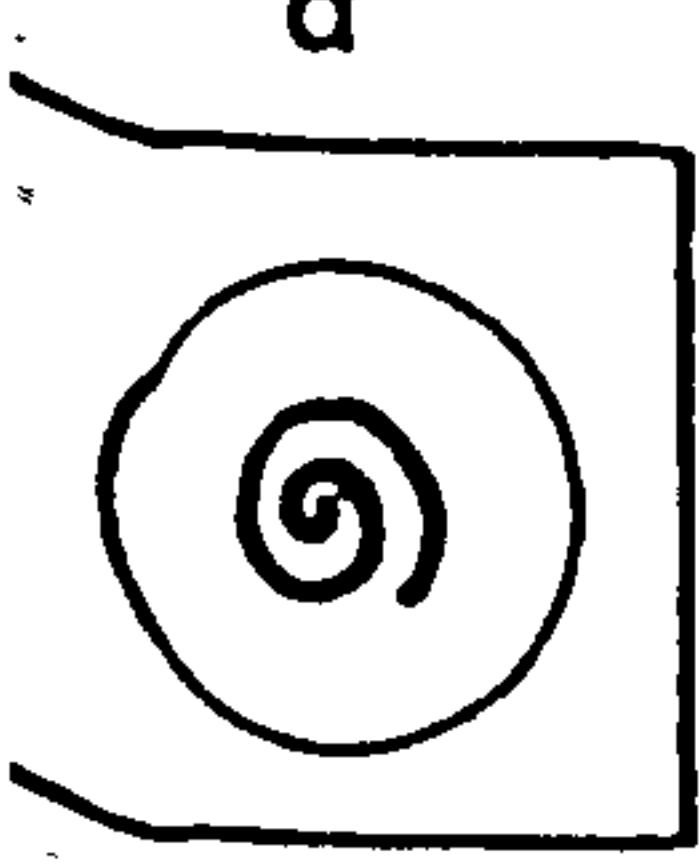
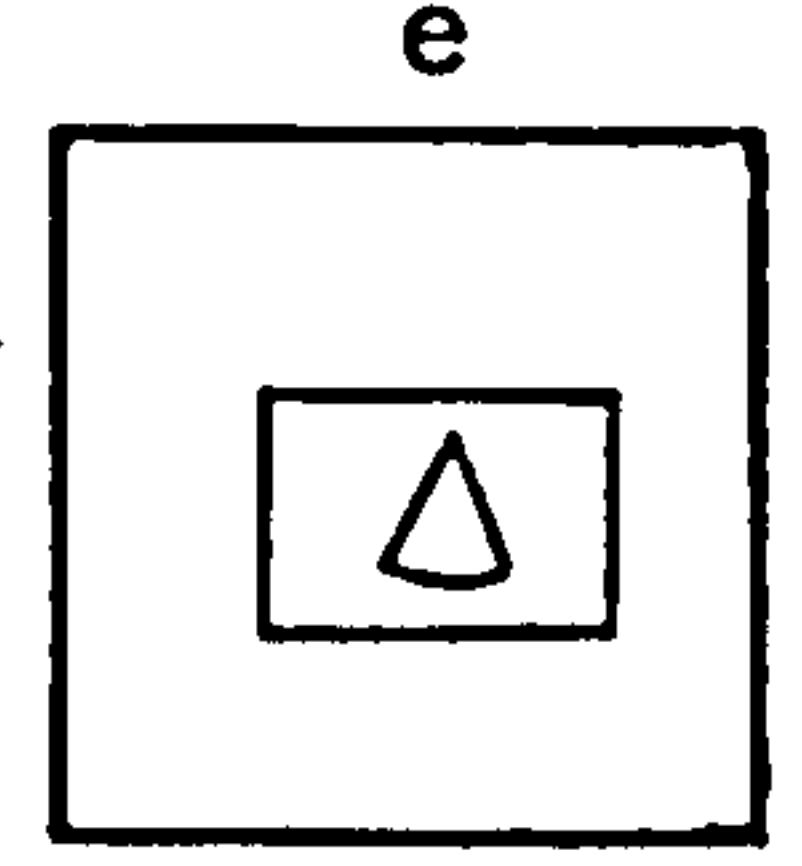
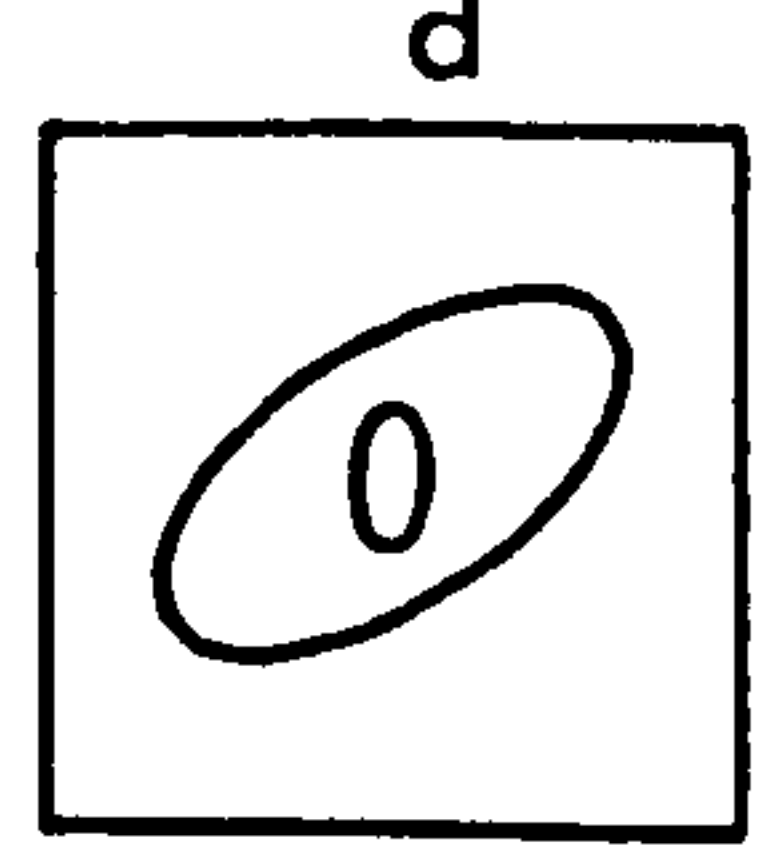
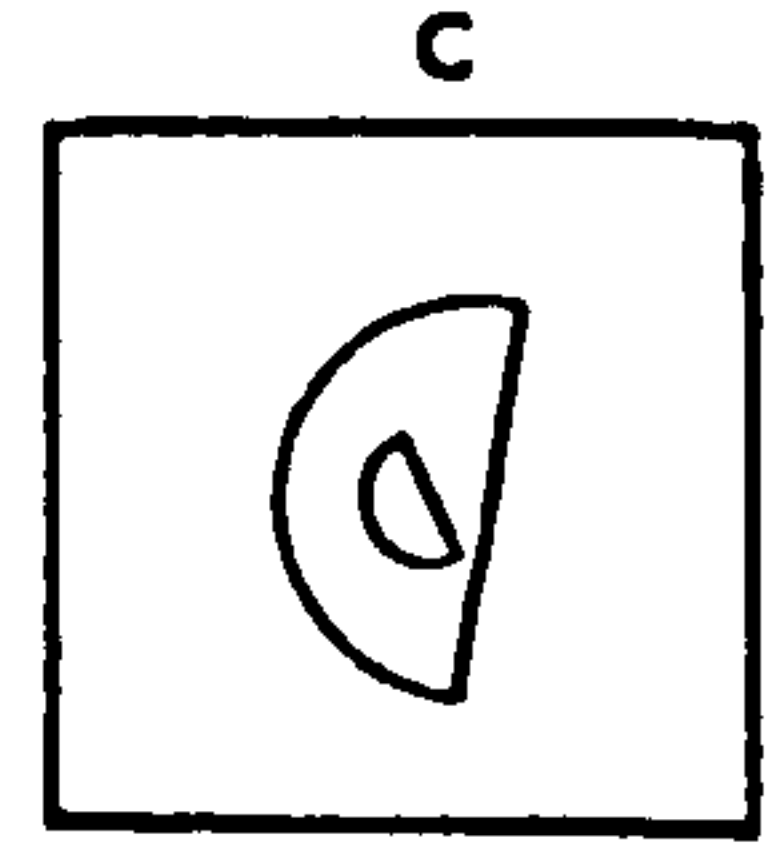
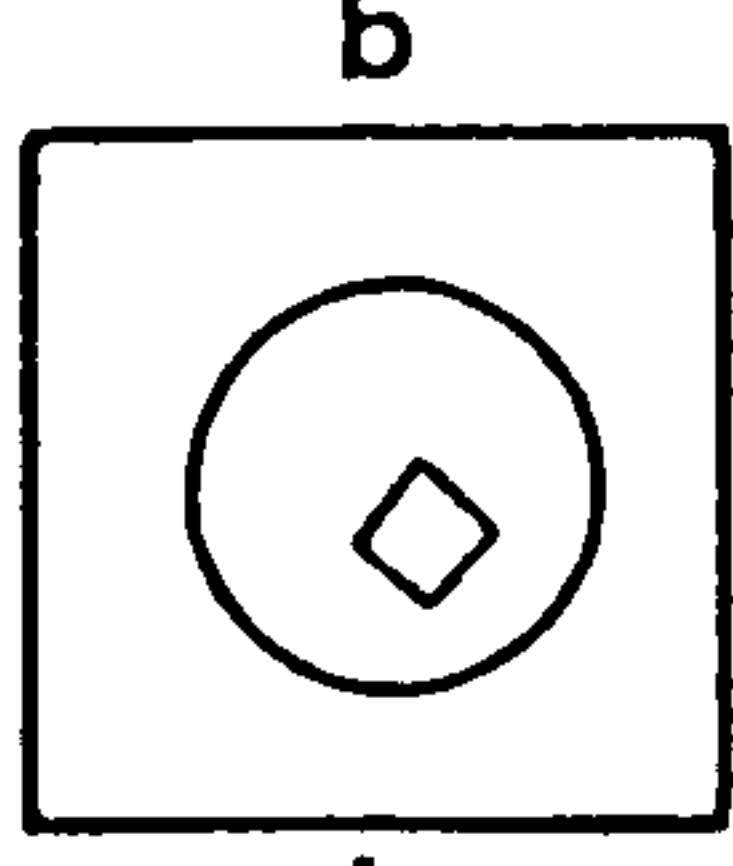
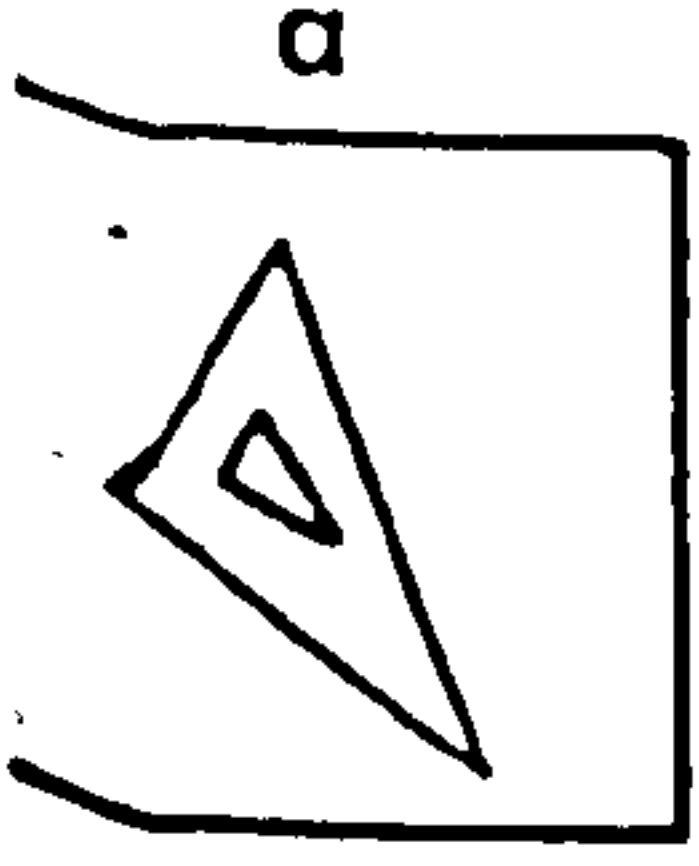
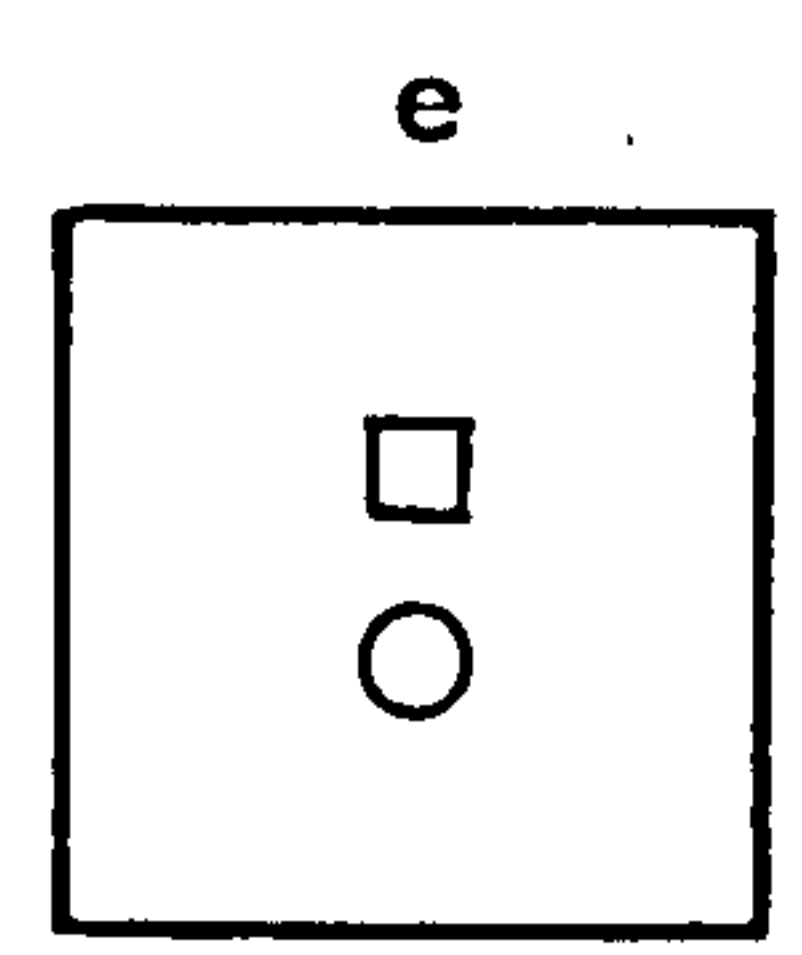
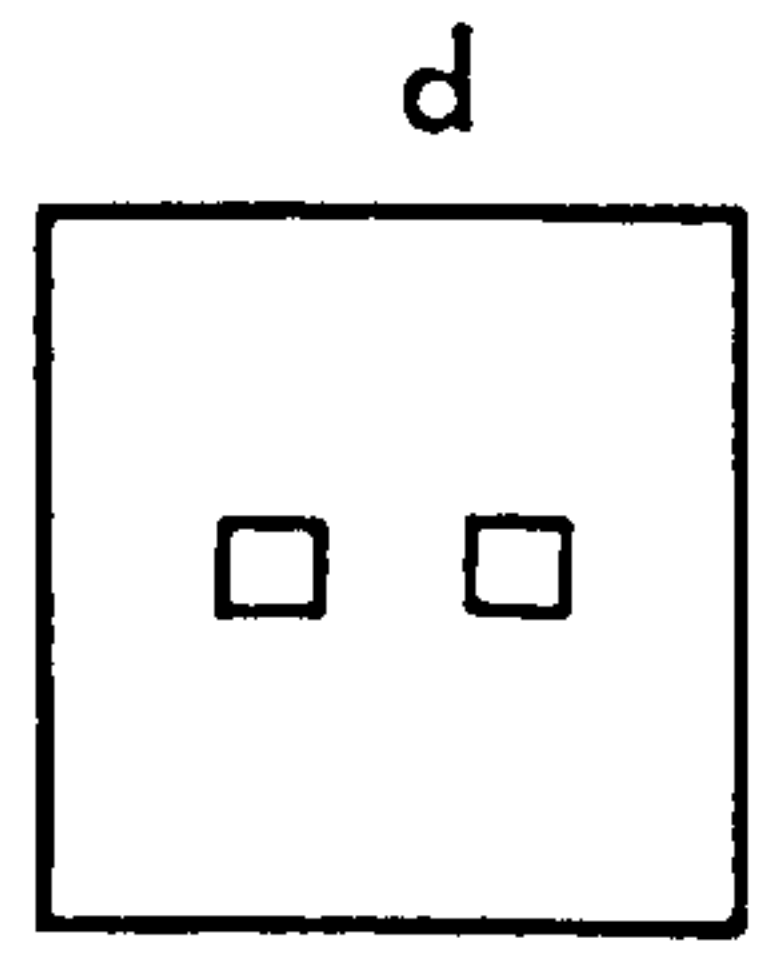
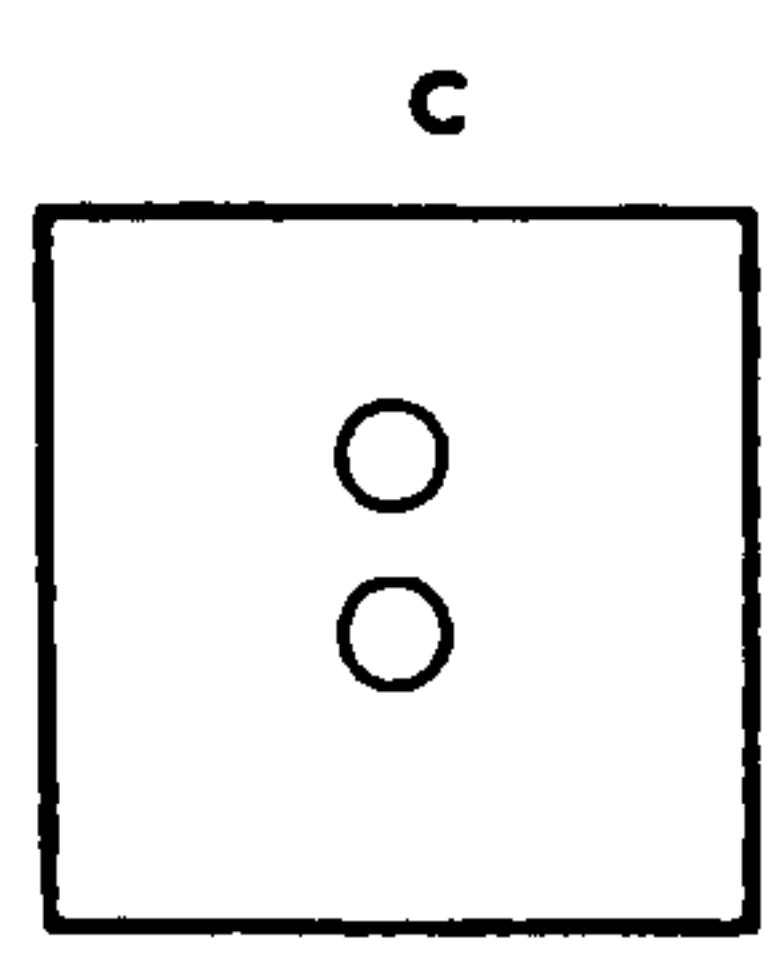
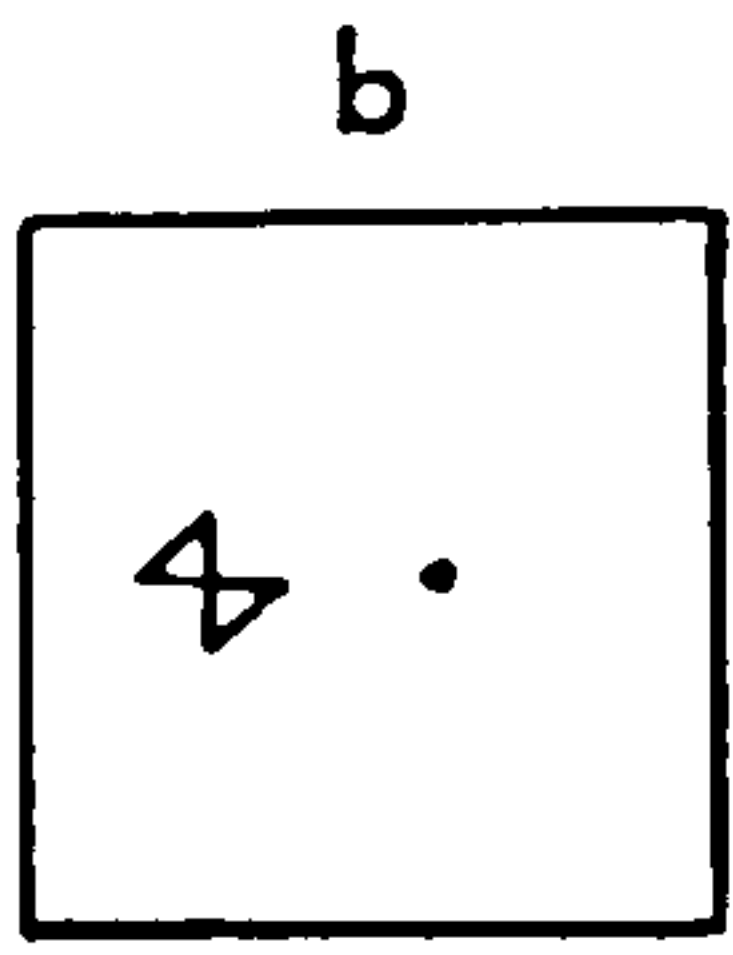
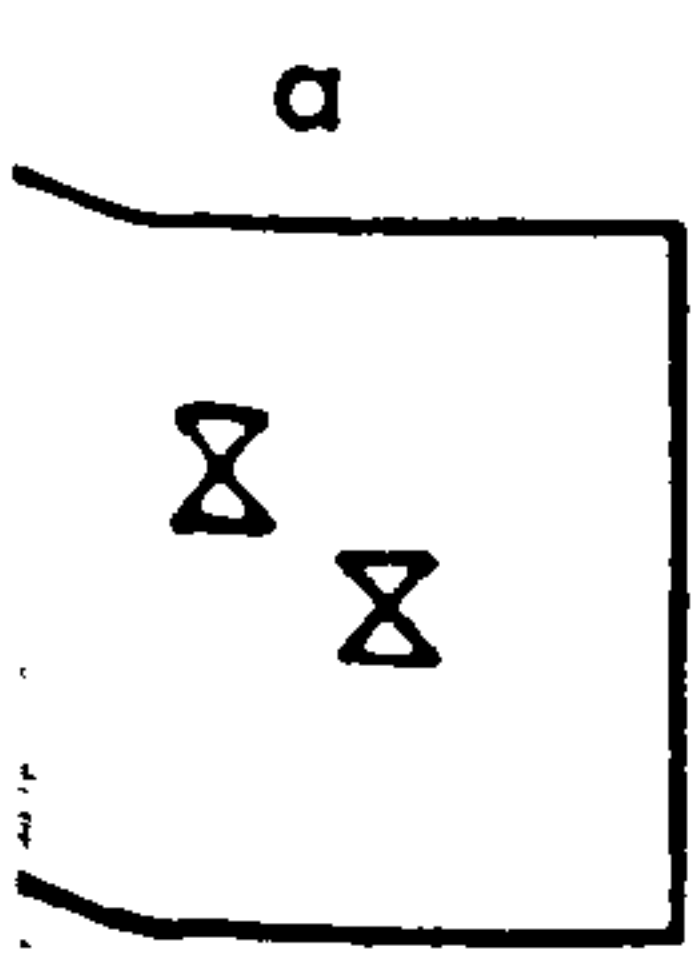
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TEST 2

Examples

Answers





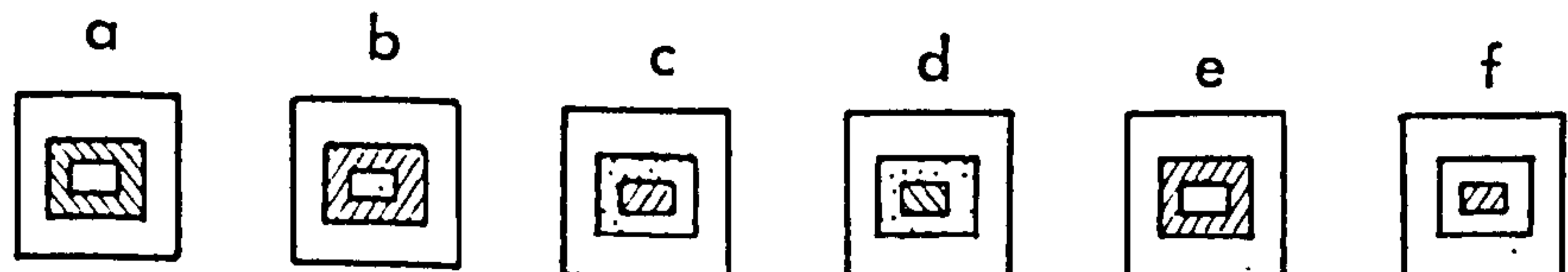
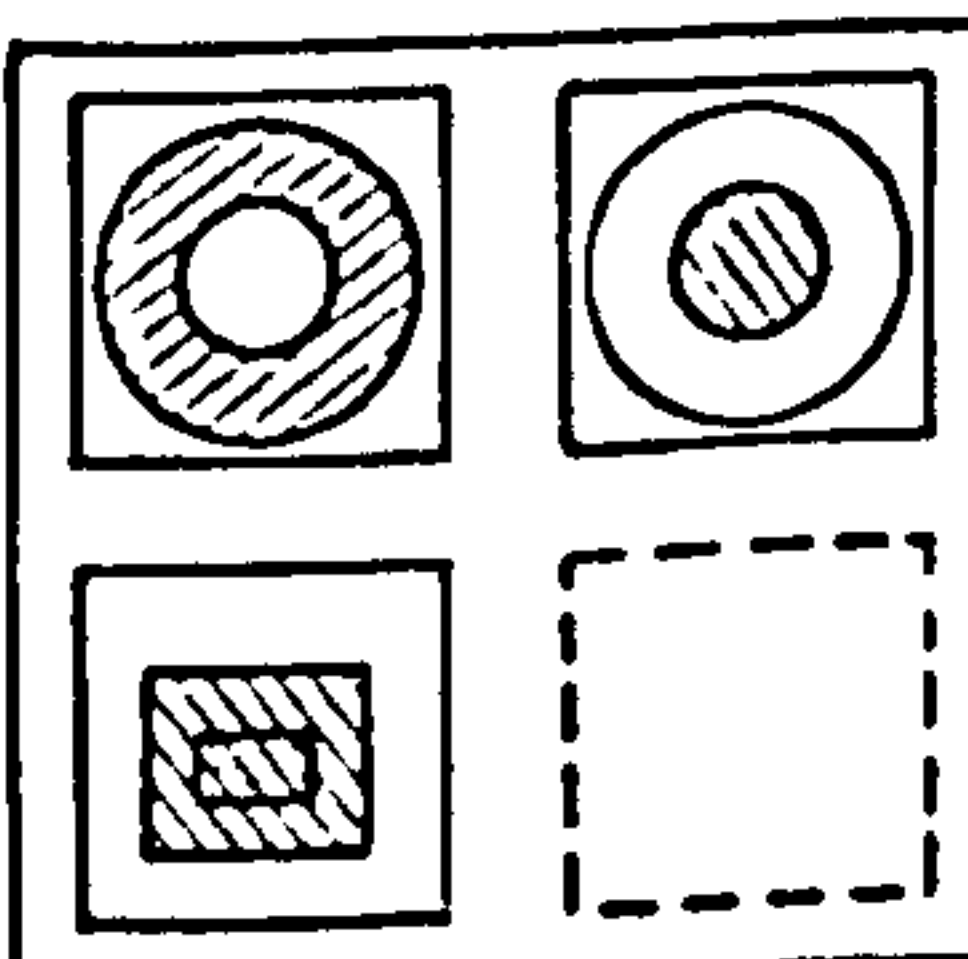
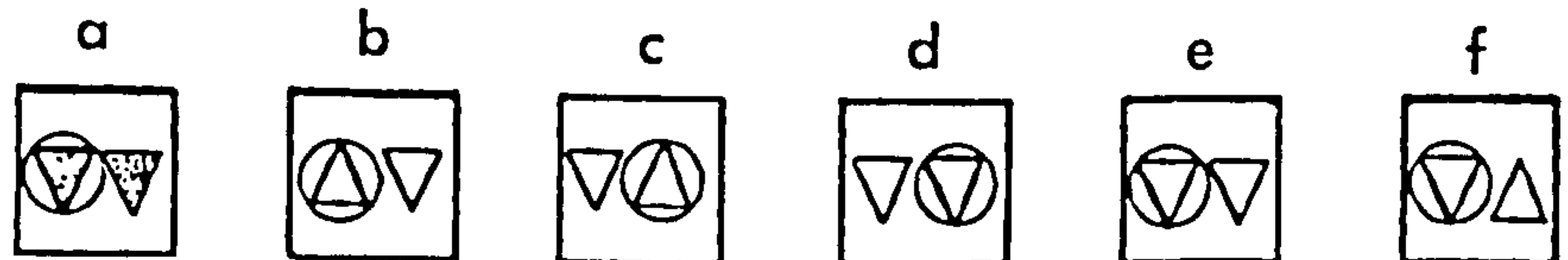
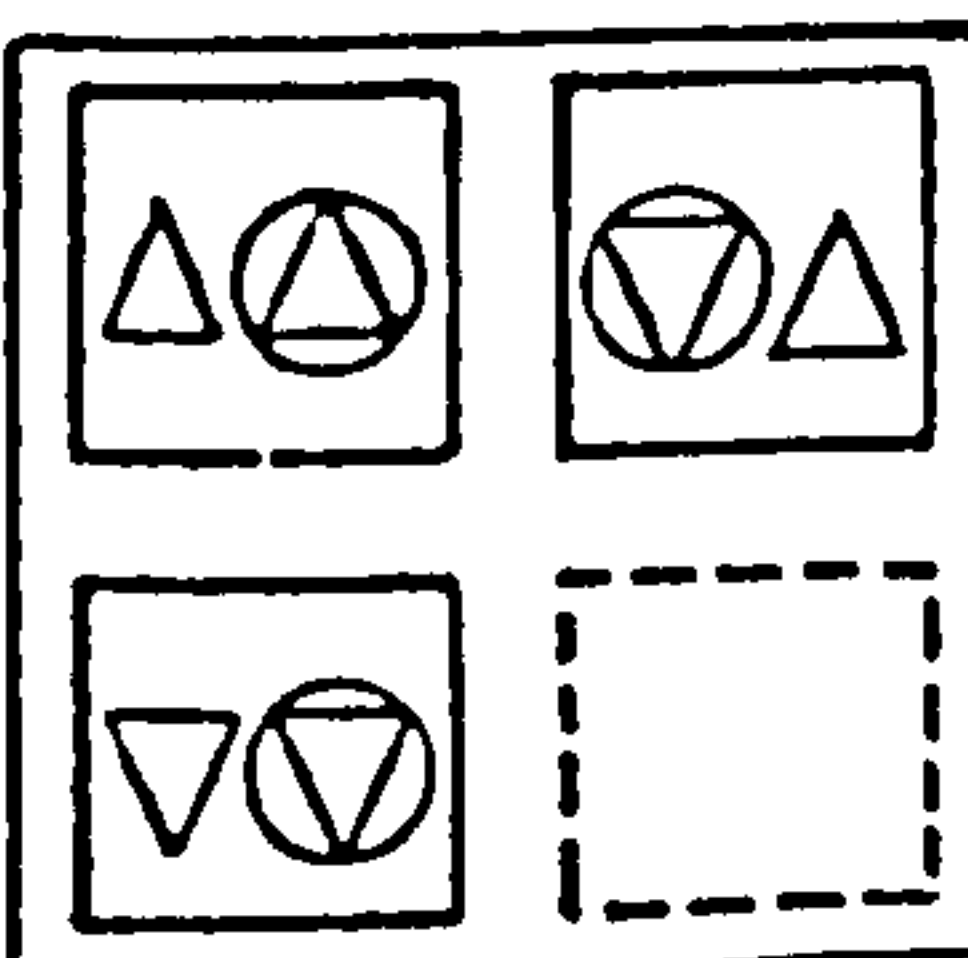
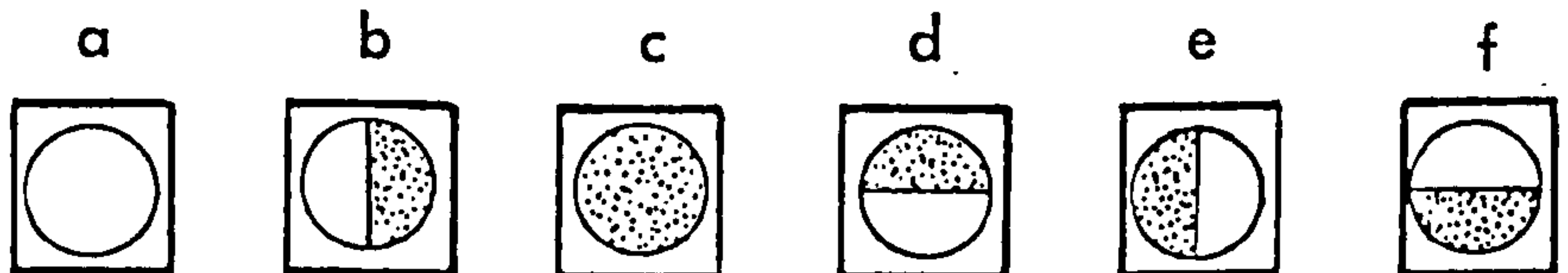
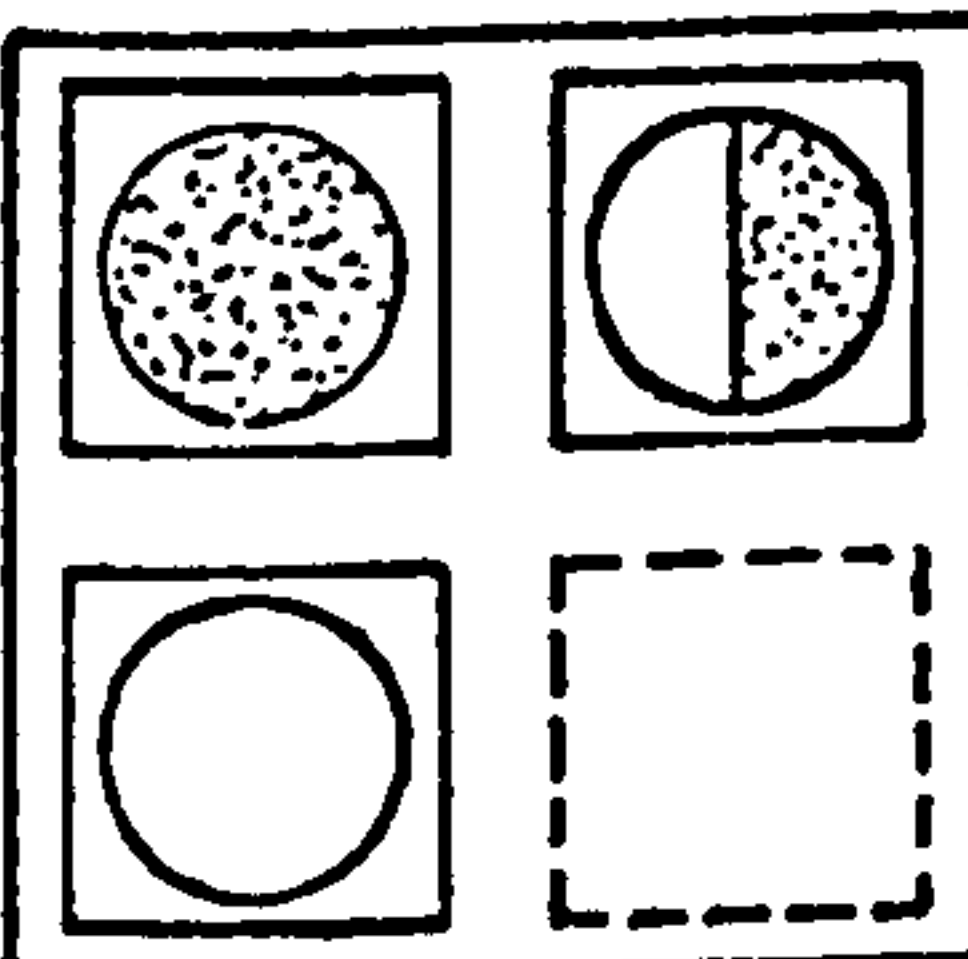
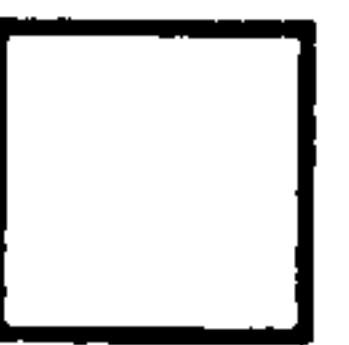
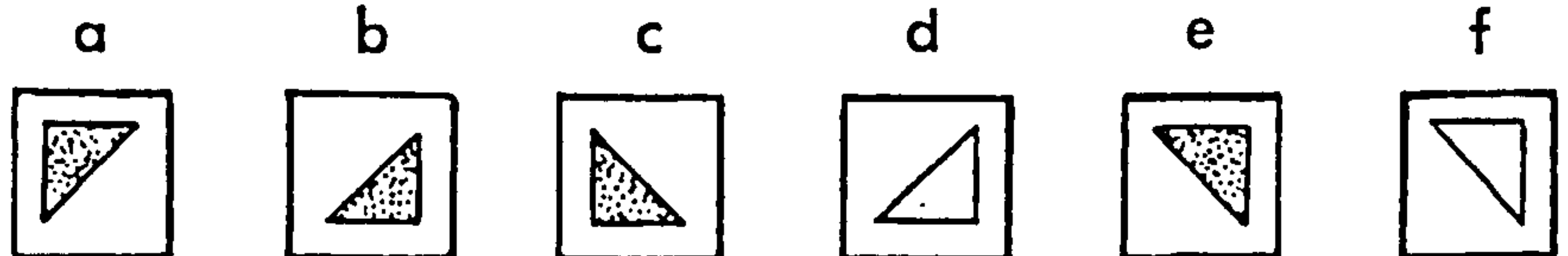
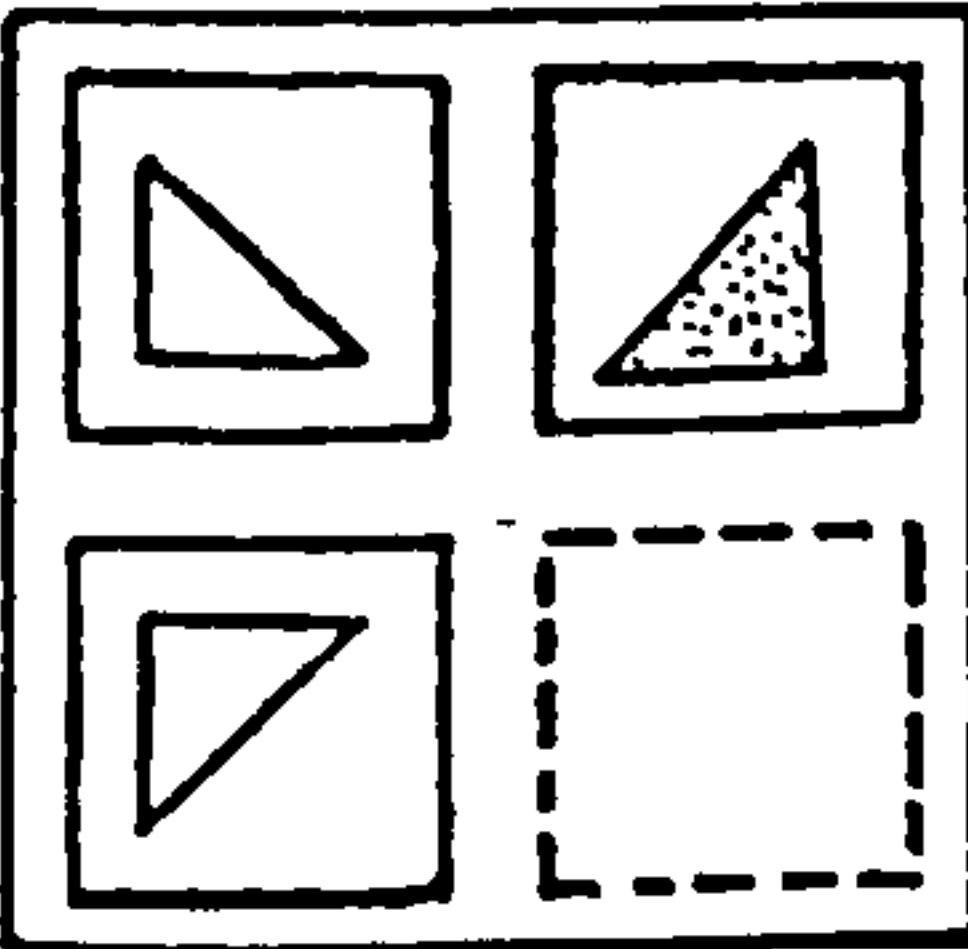
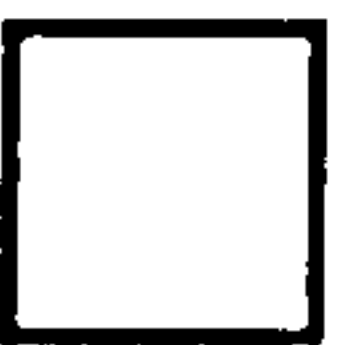
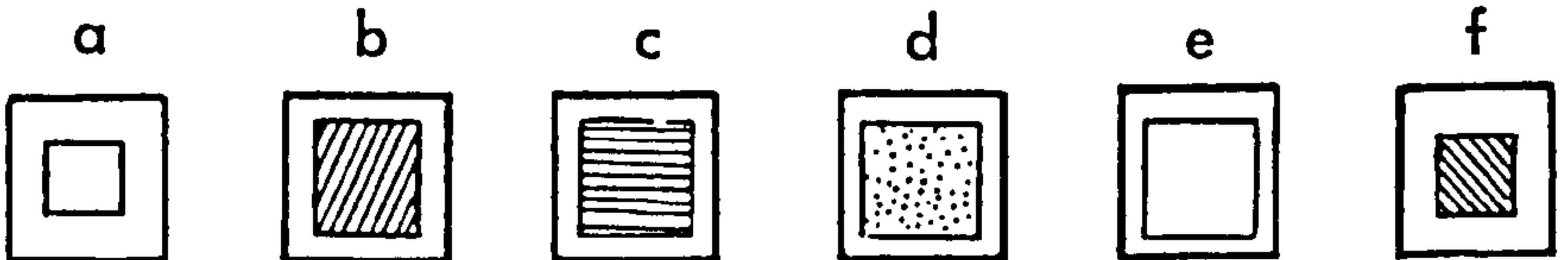
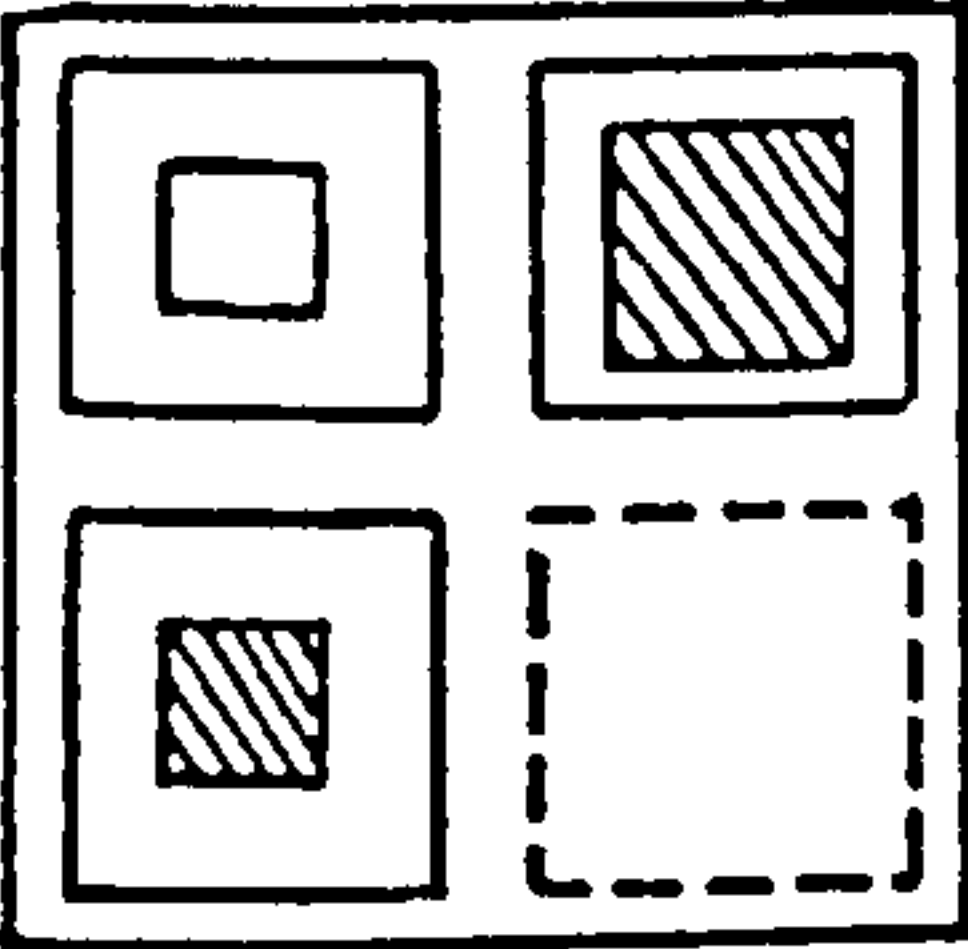
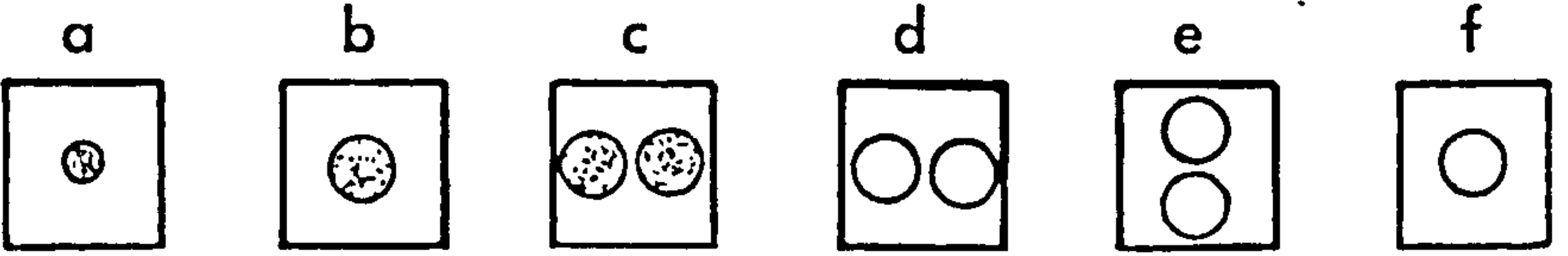
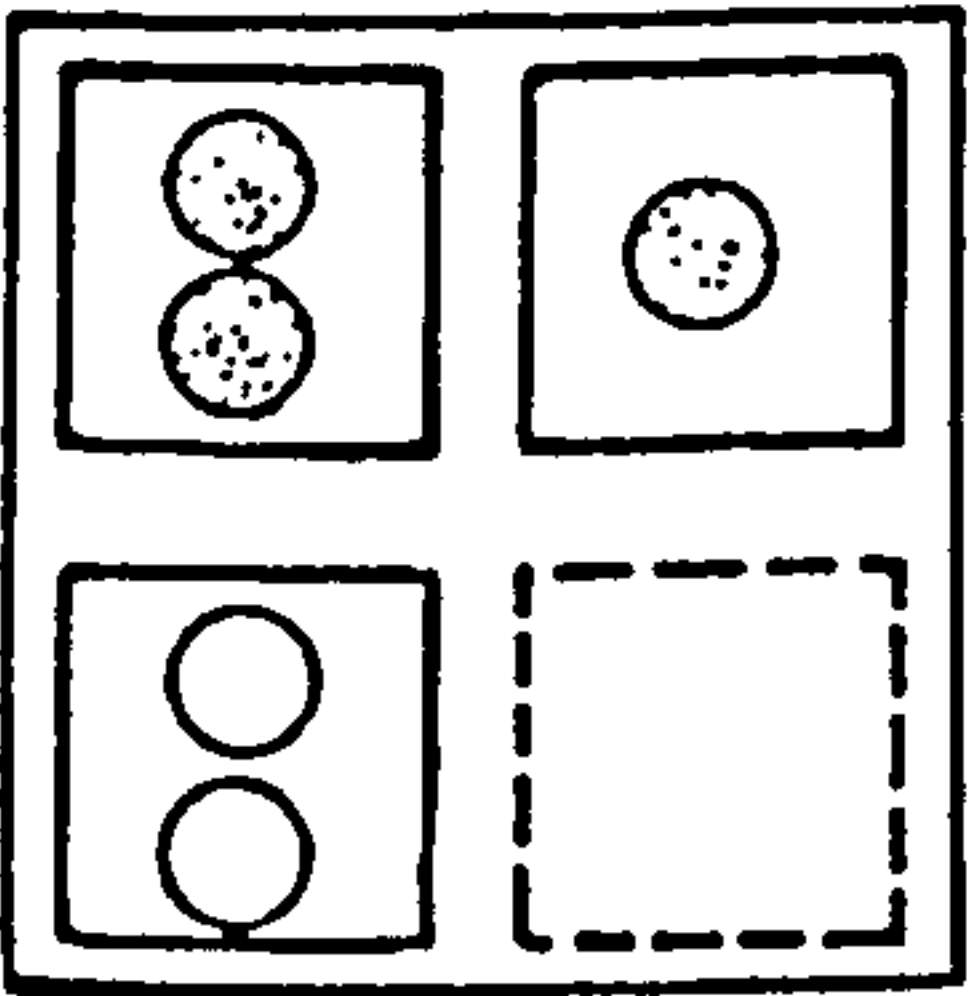
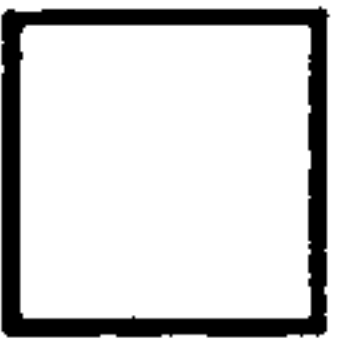
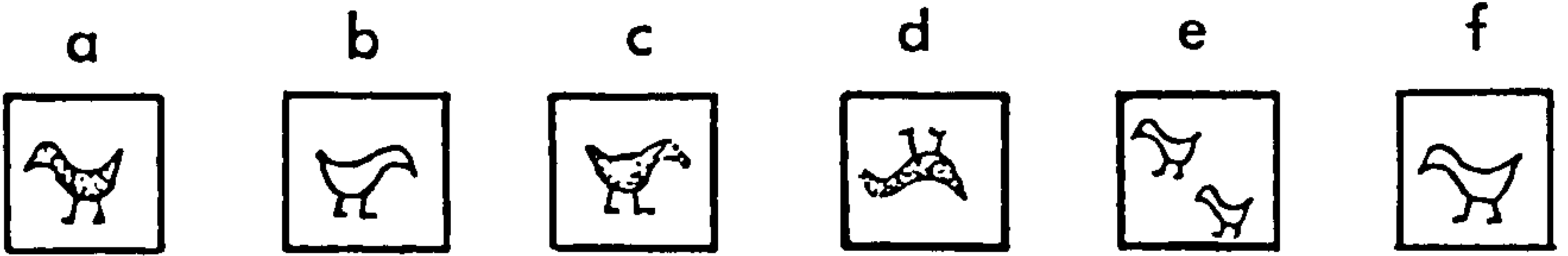
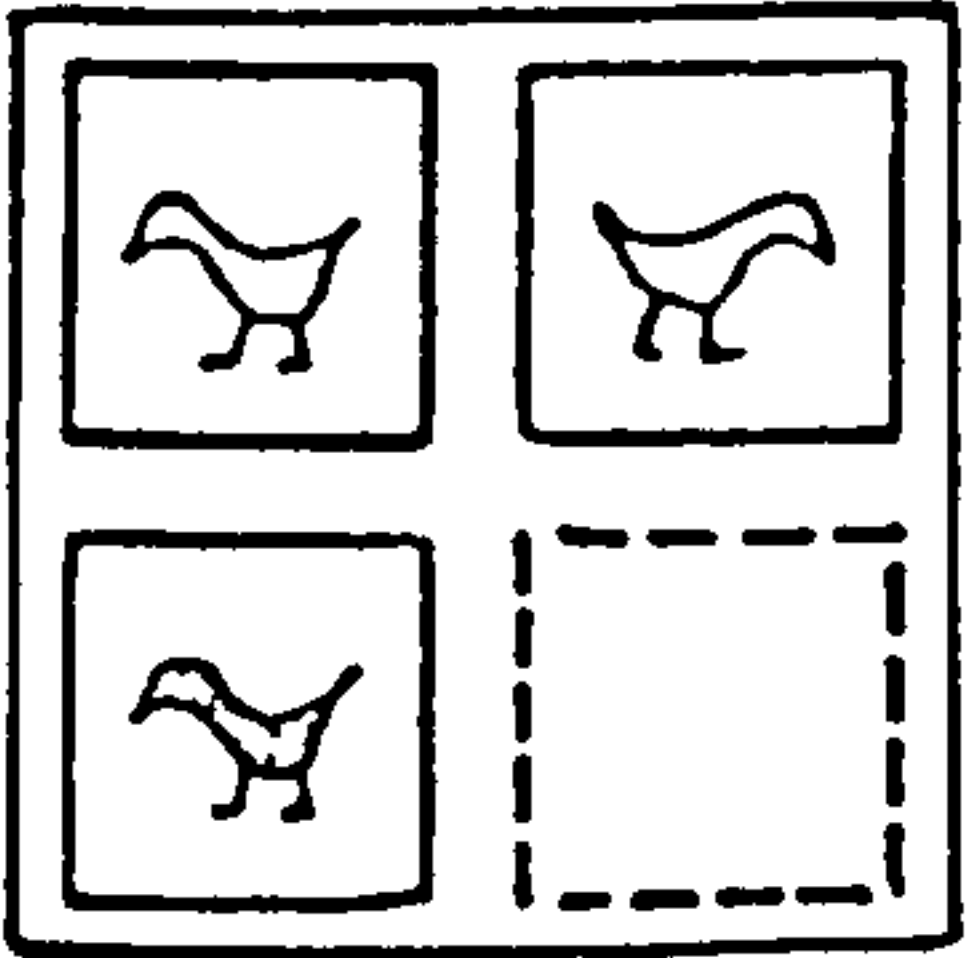
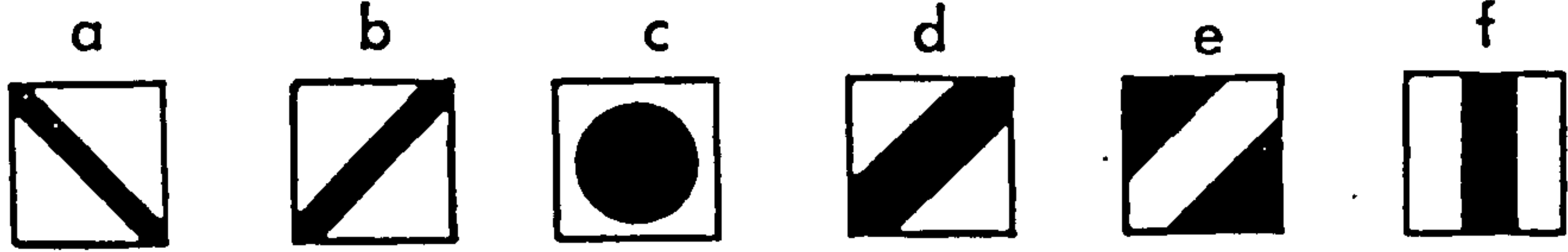
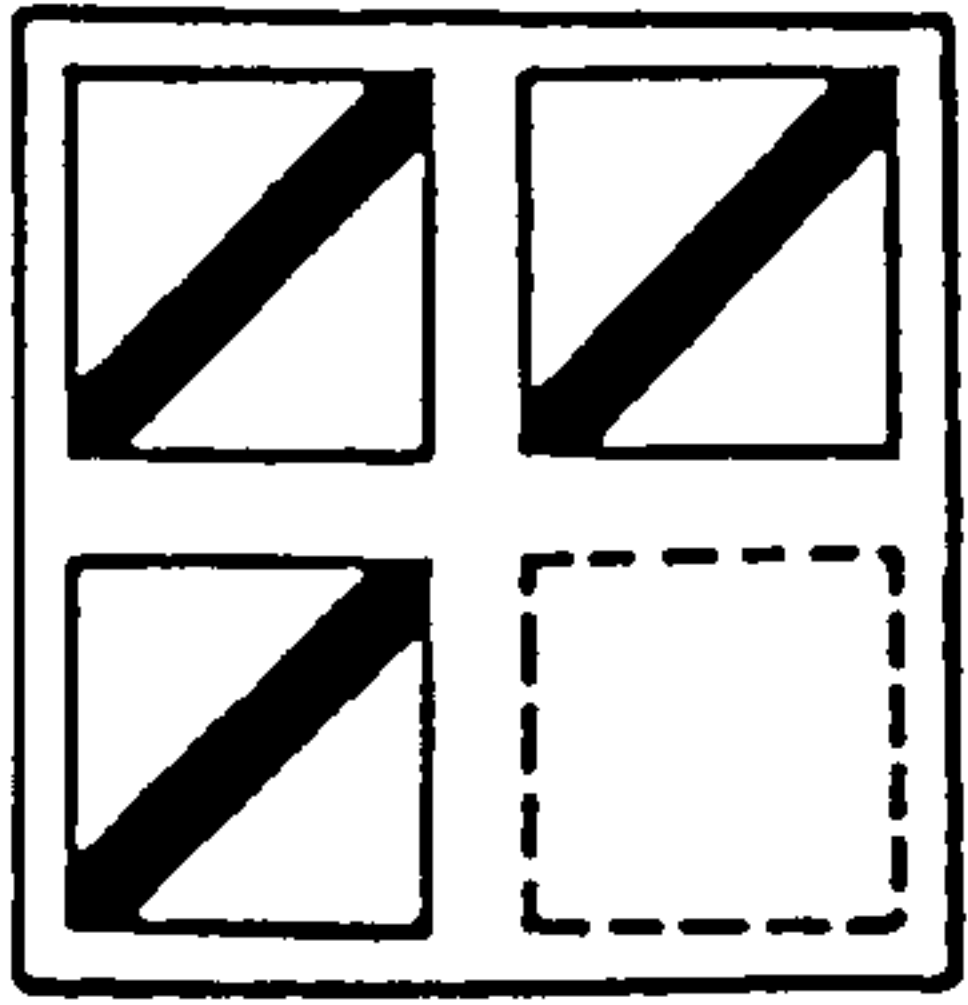
End of Test 2

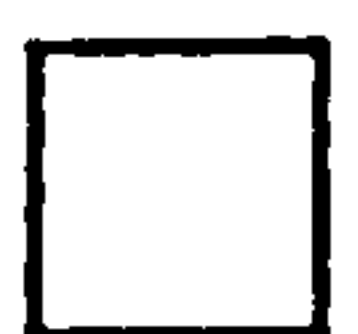
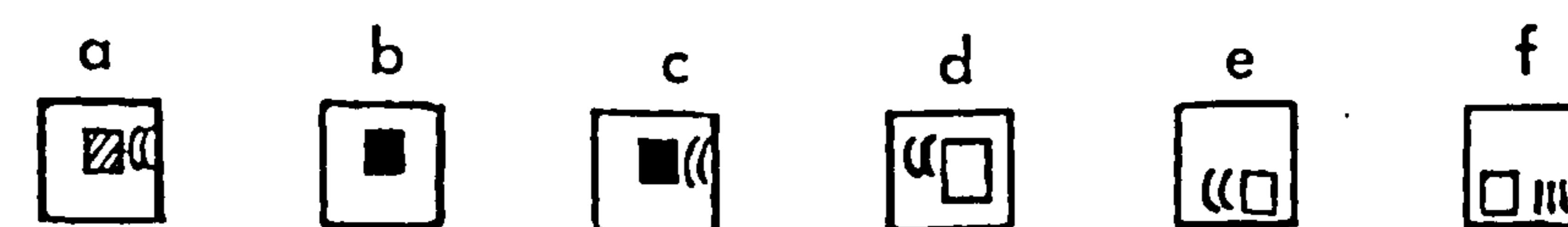
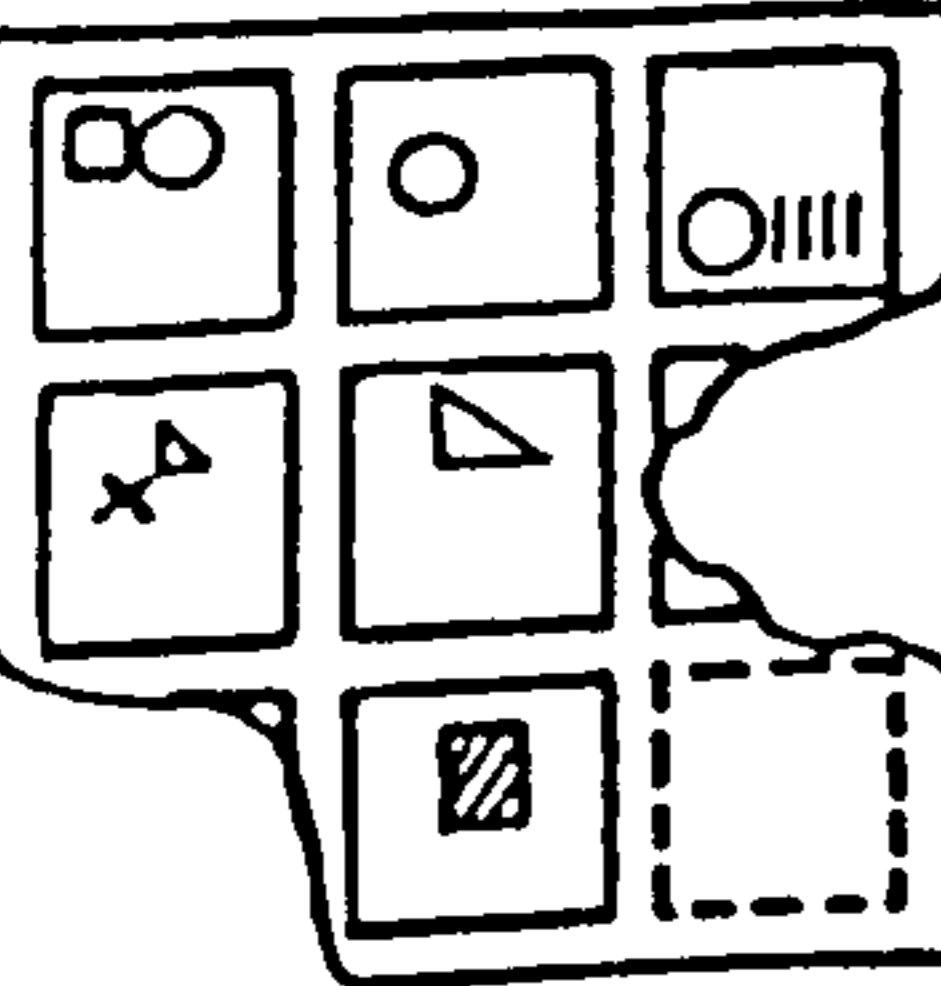
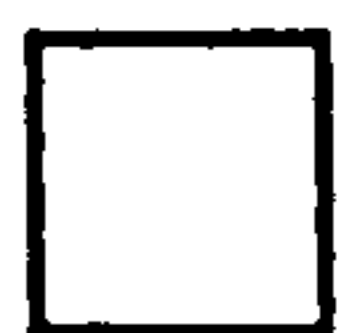
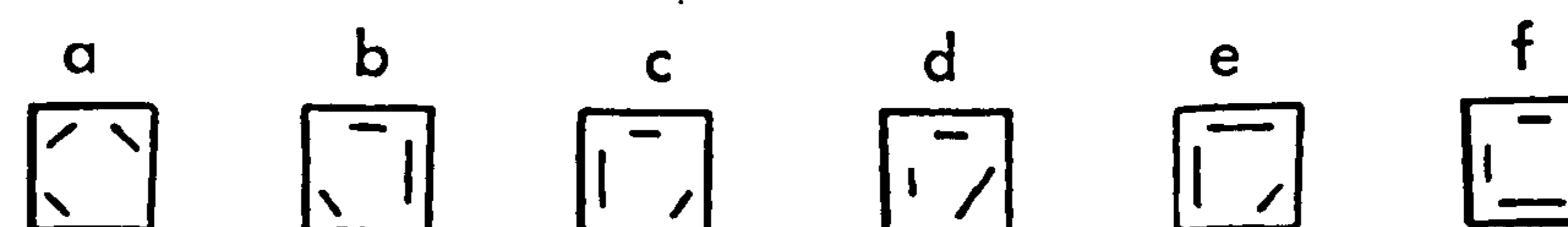
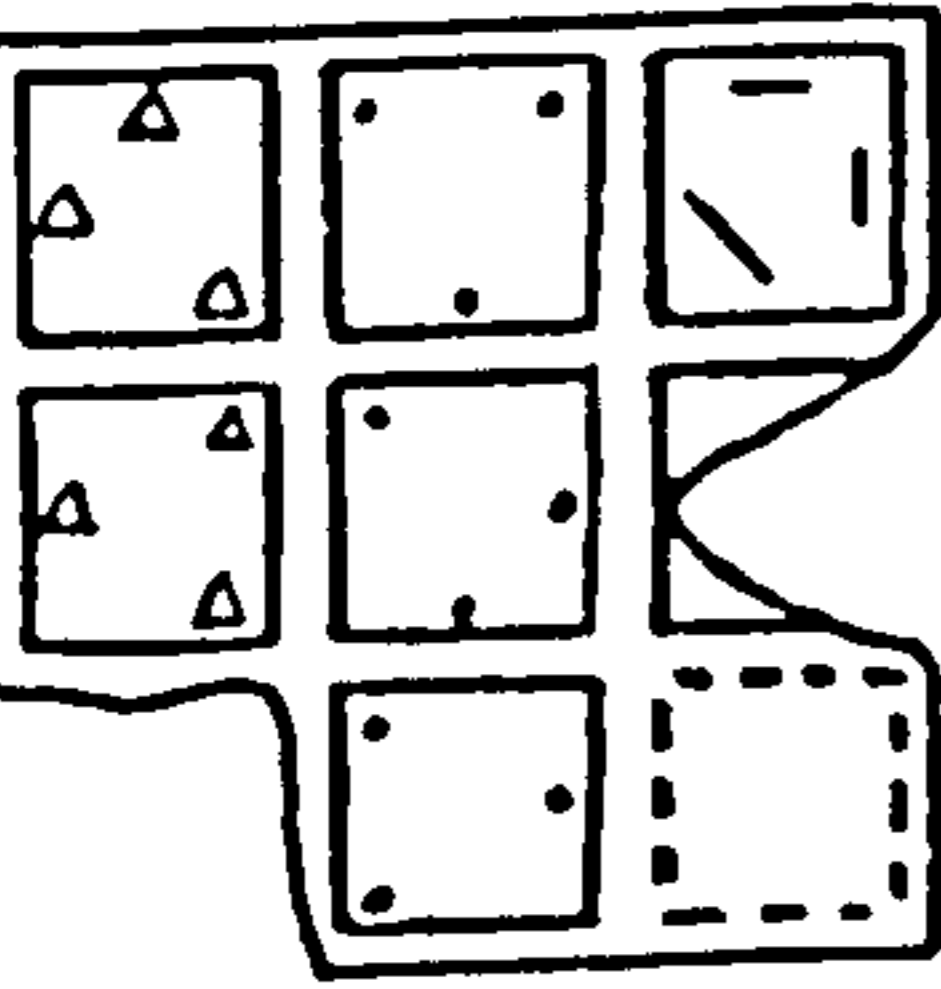
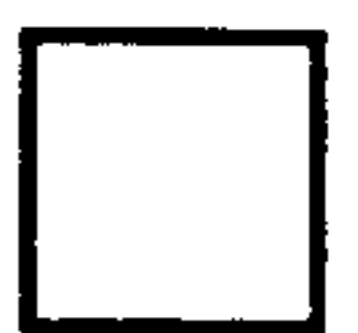
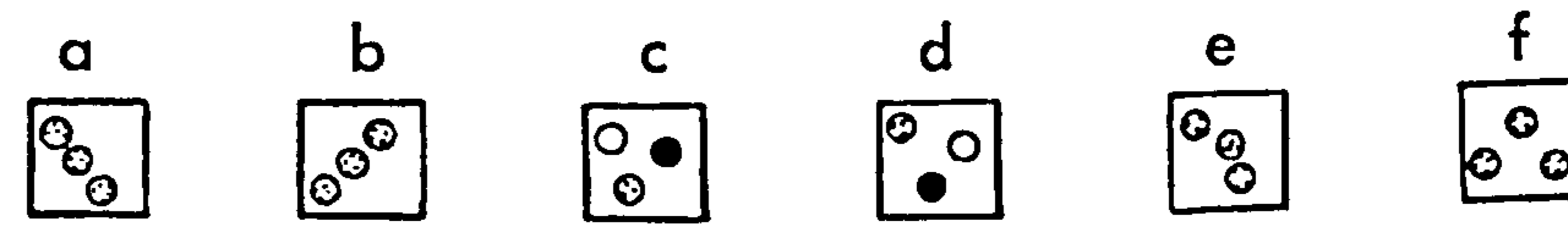
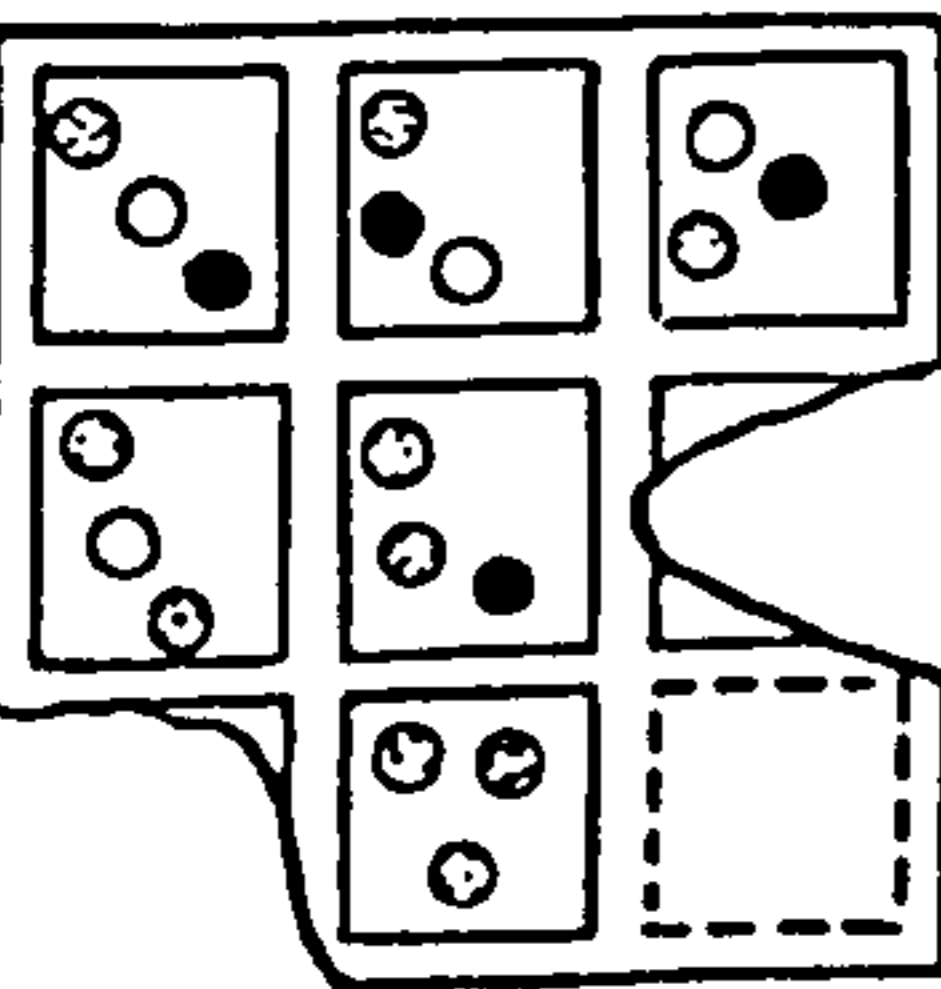
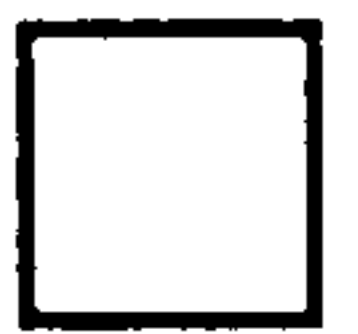
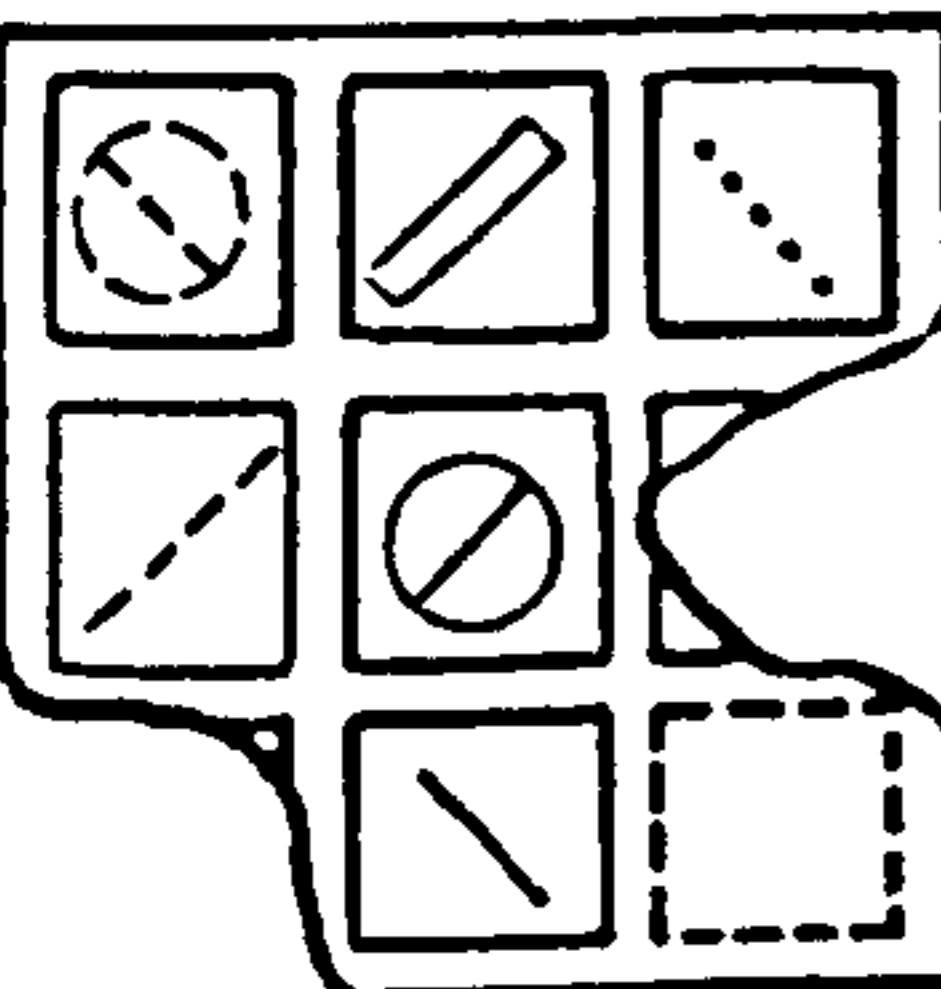
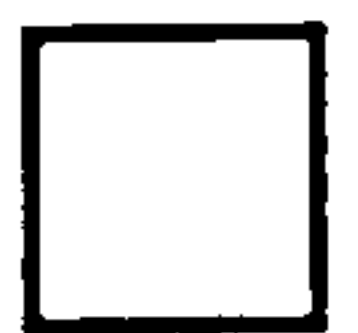
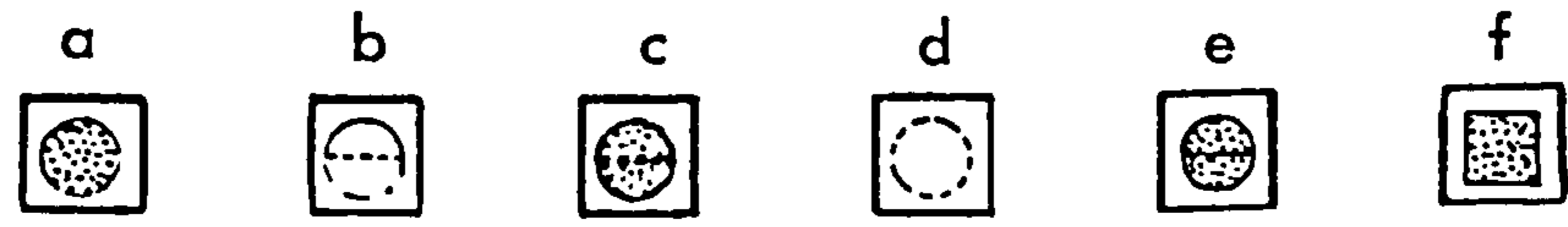
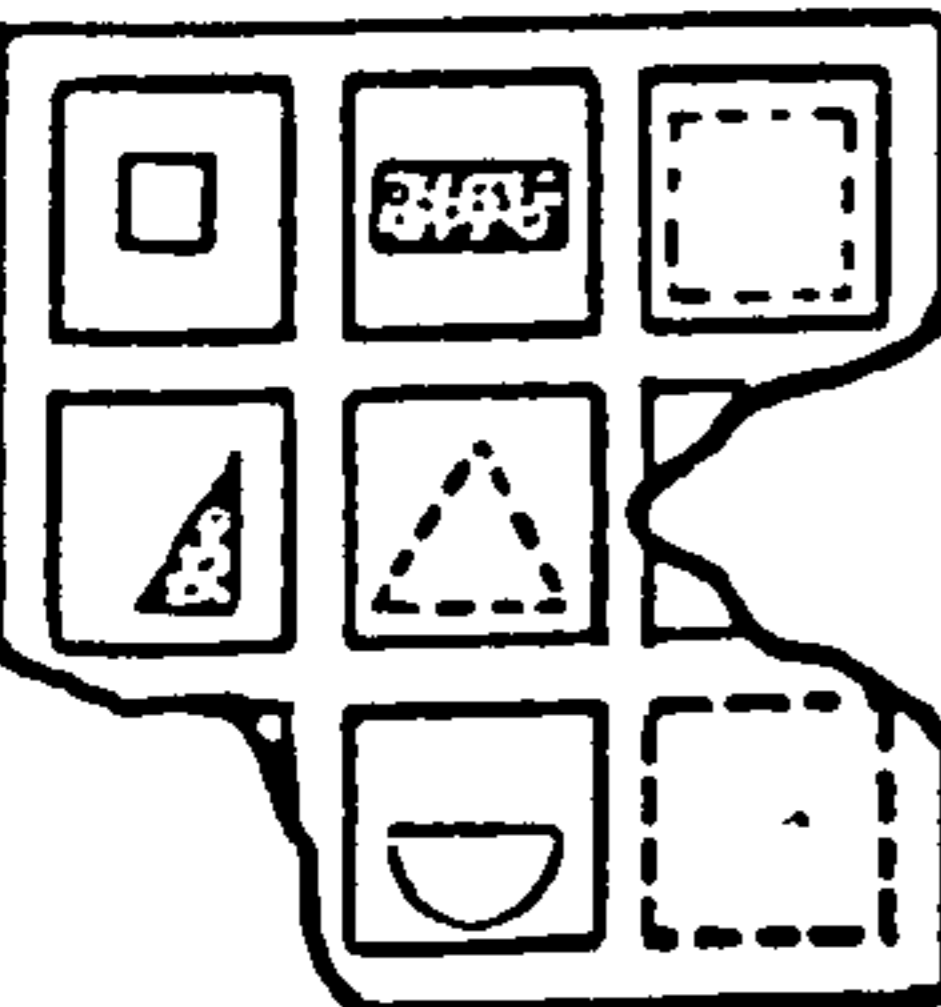
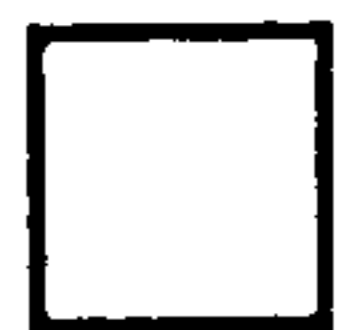
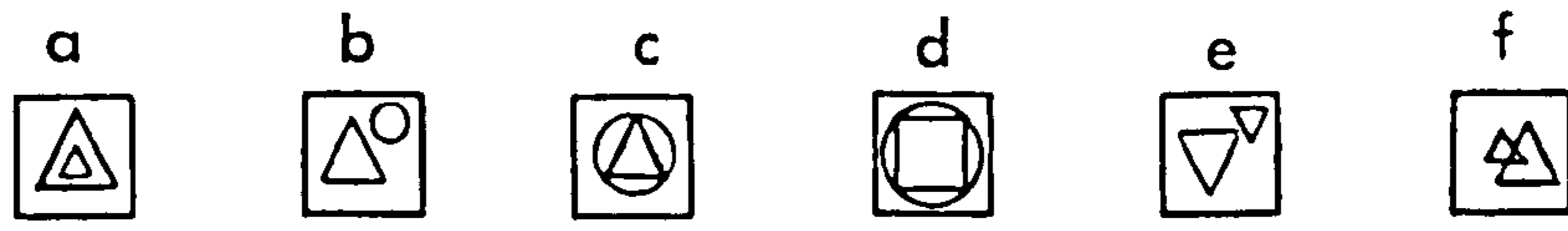
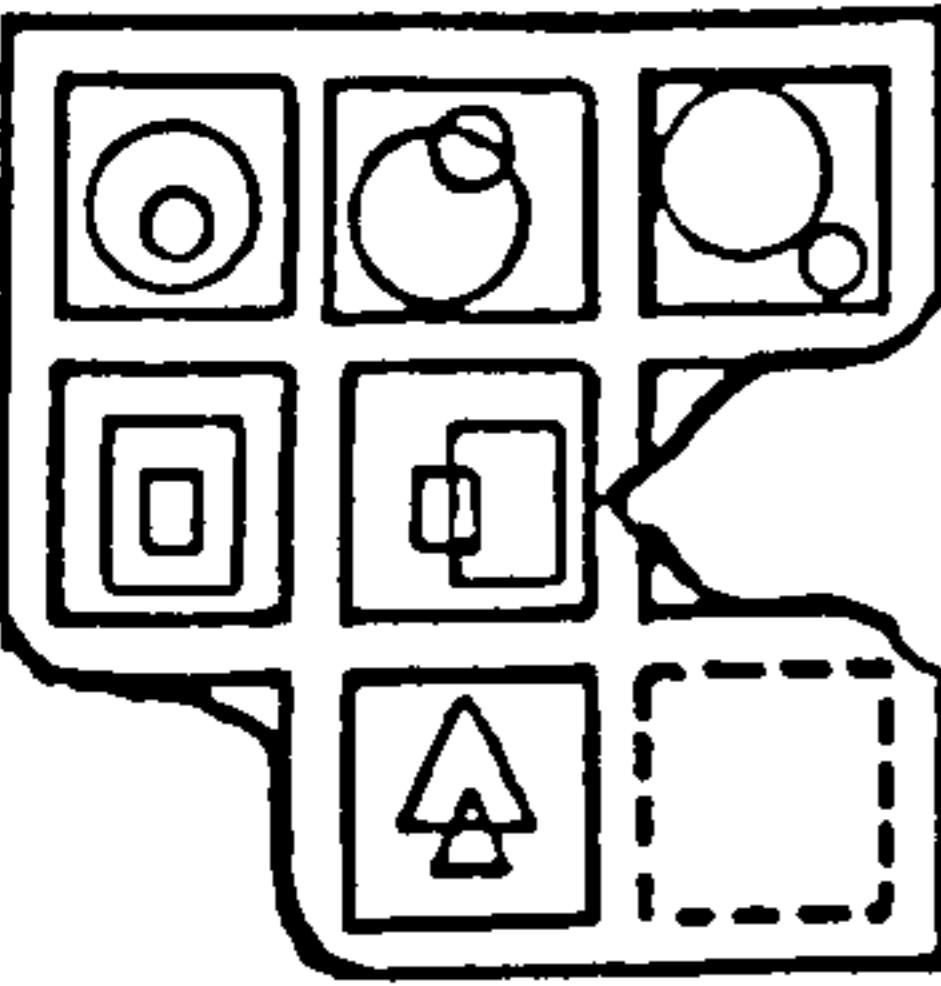
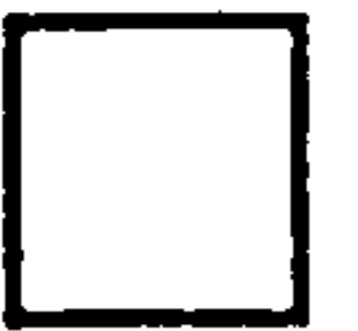
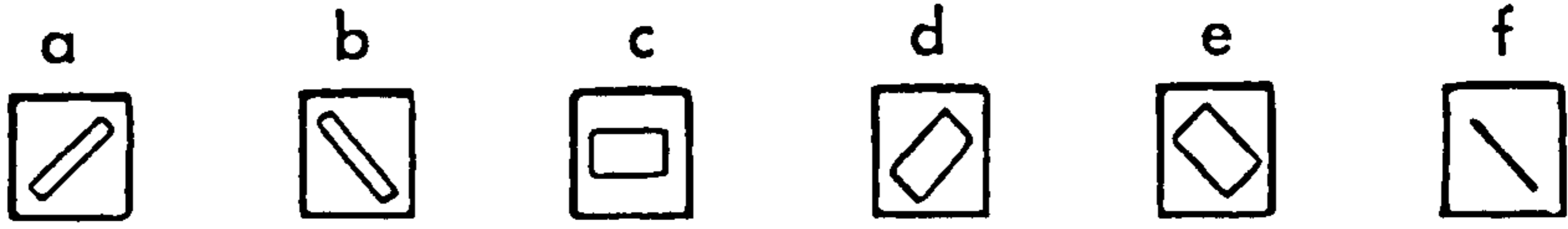
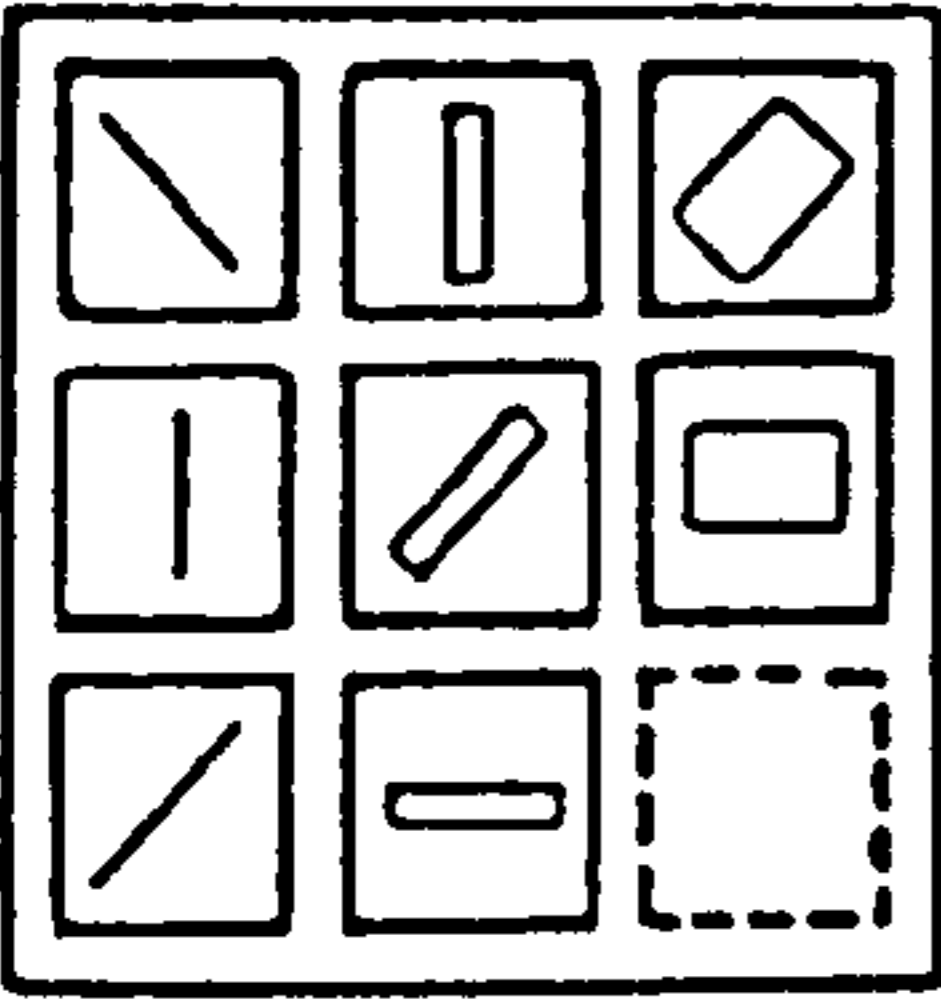
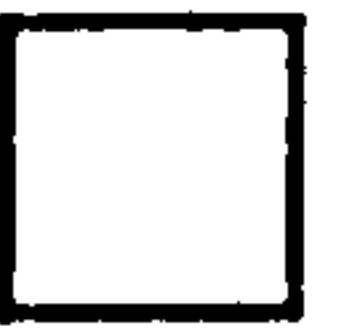
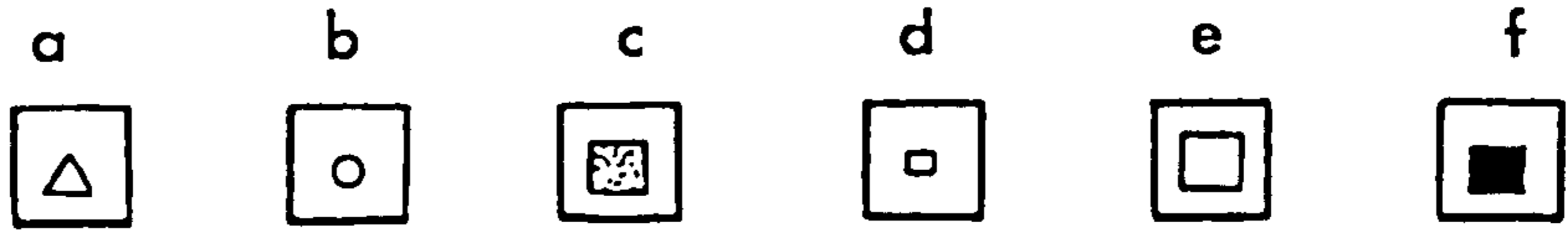
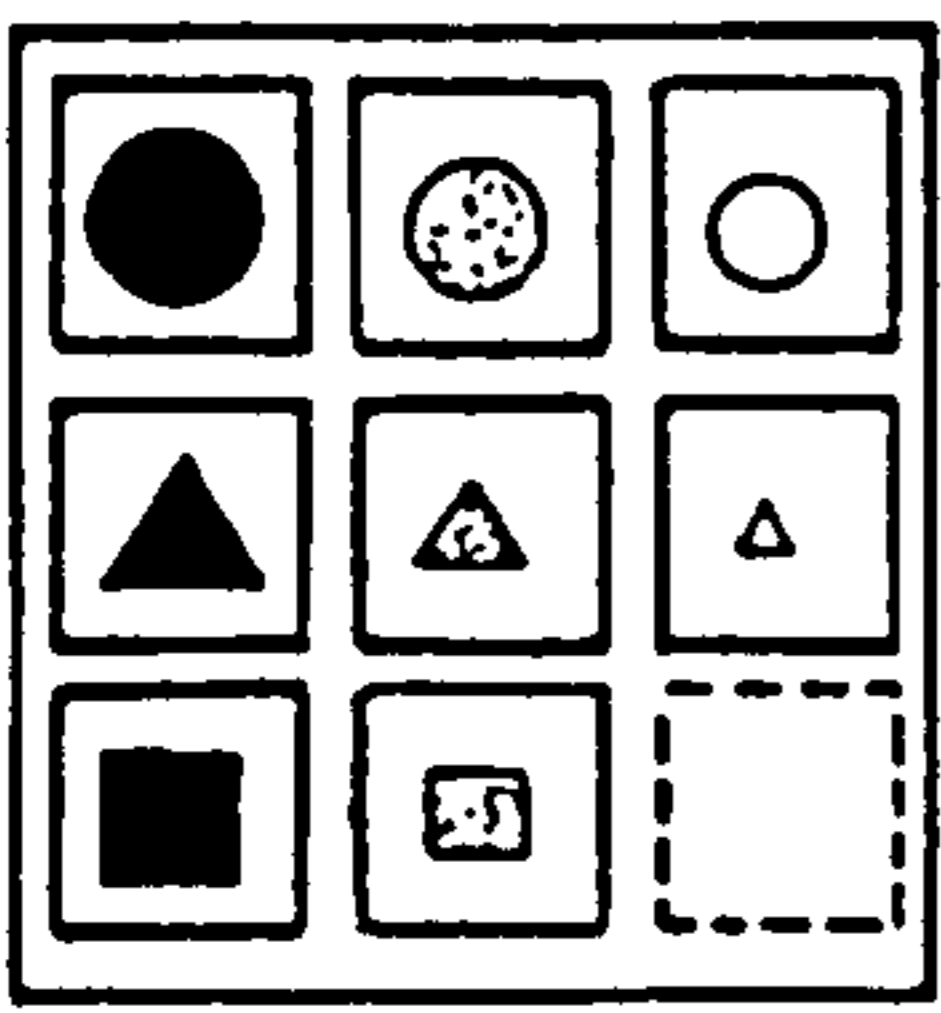
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Examples

TEST 3

Answers

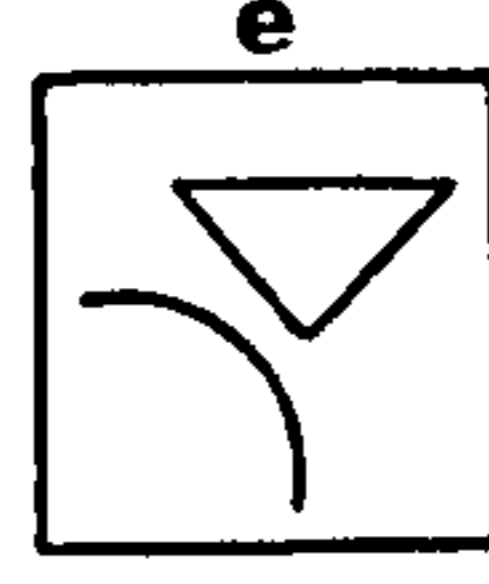
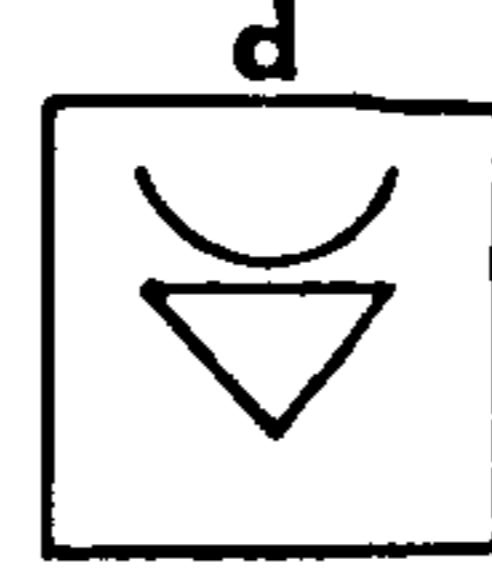
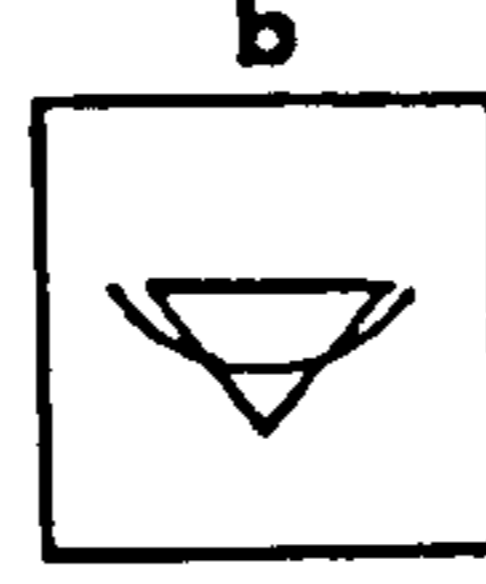
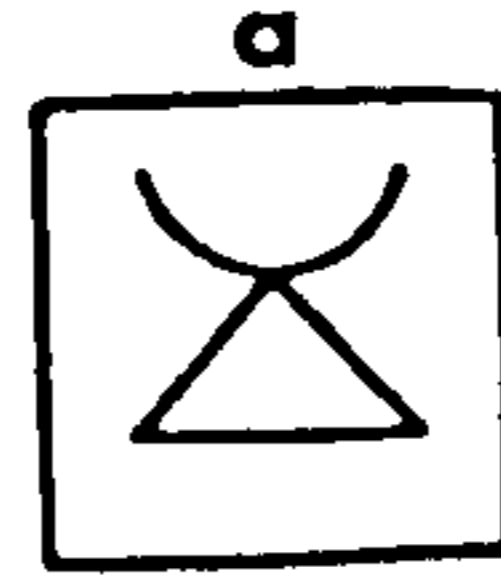
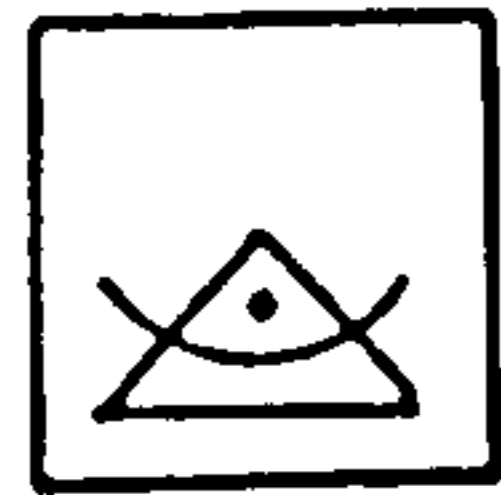
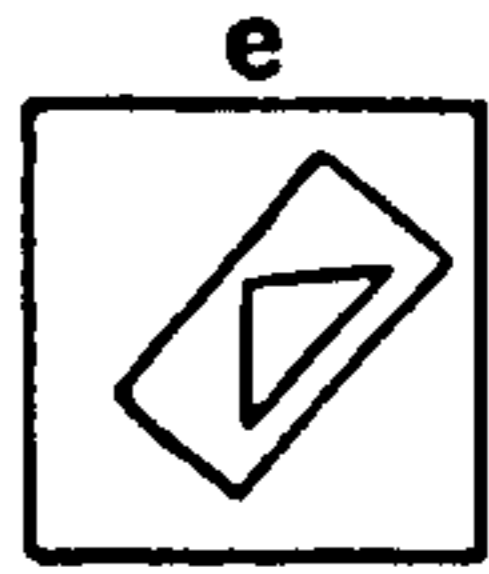
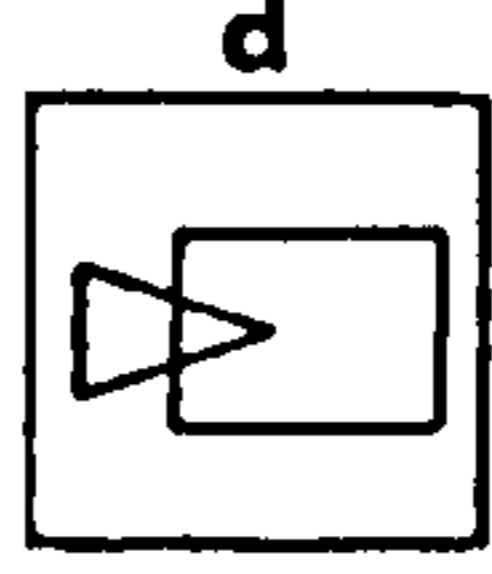
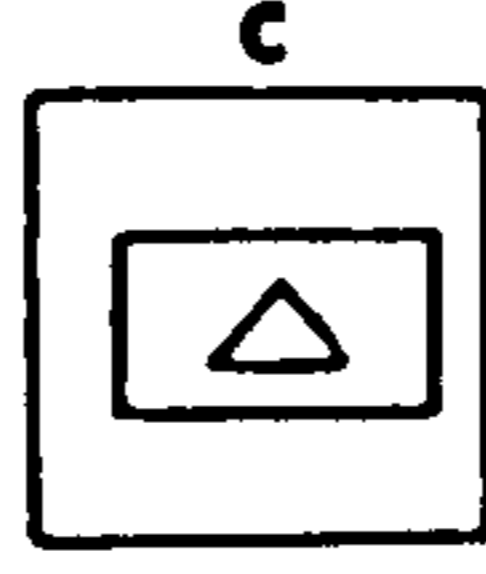
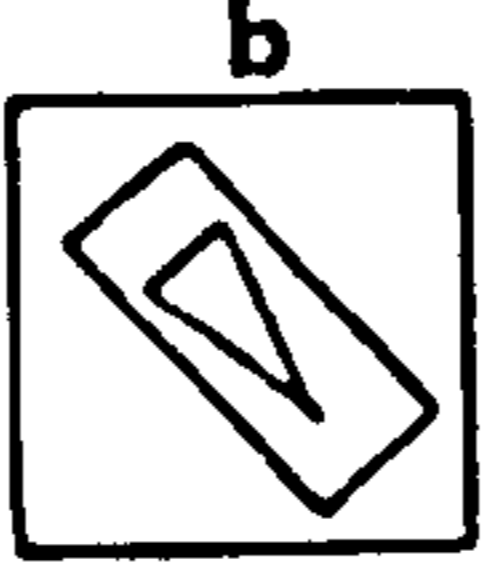
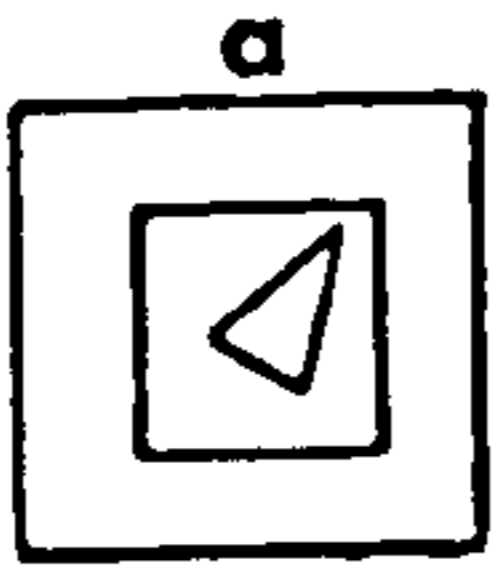
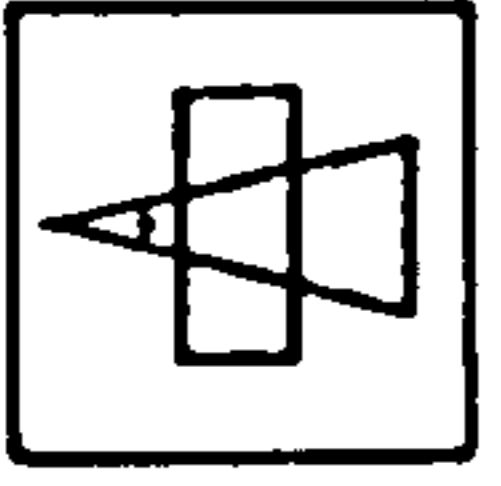
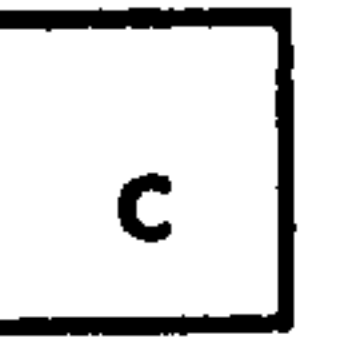
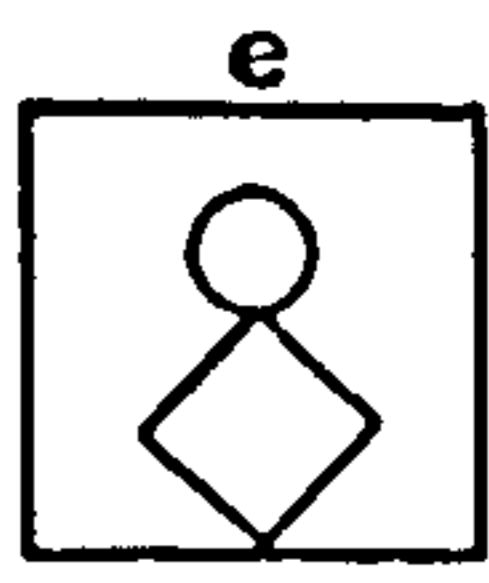
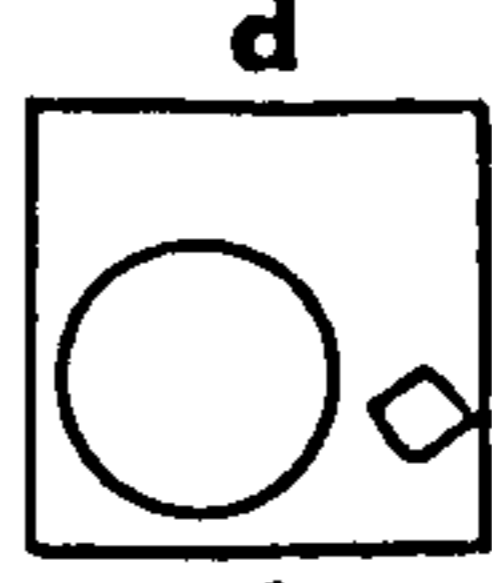
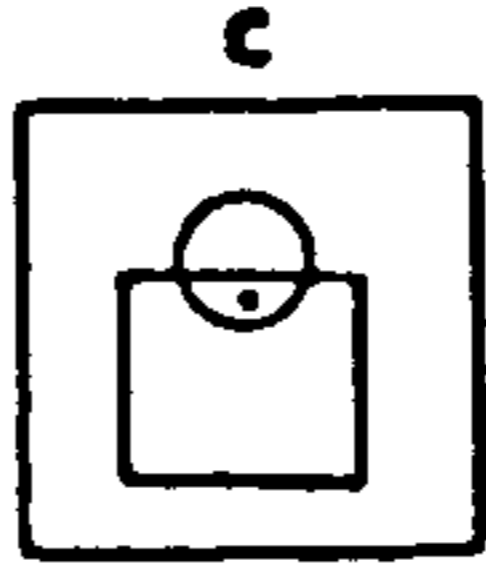
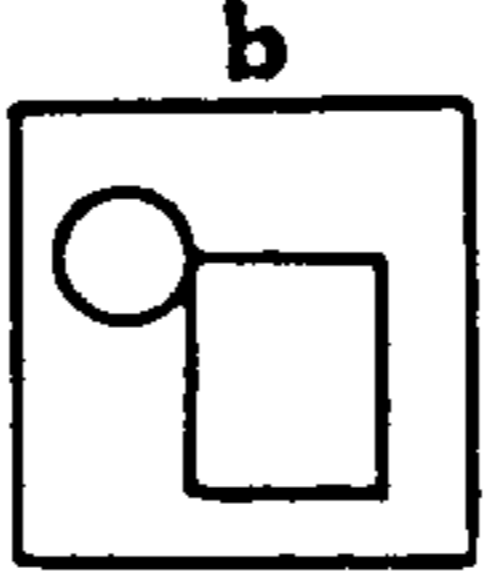
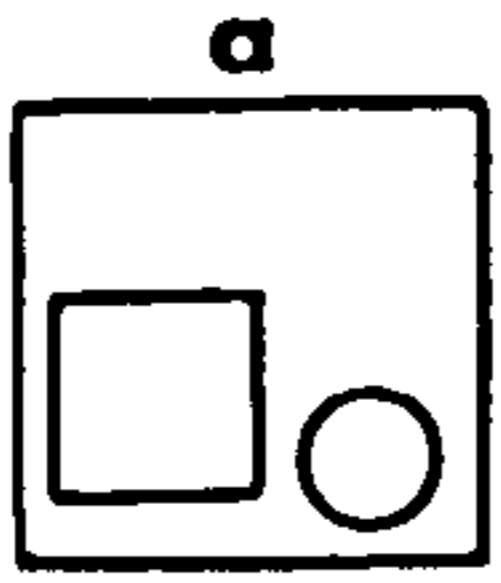
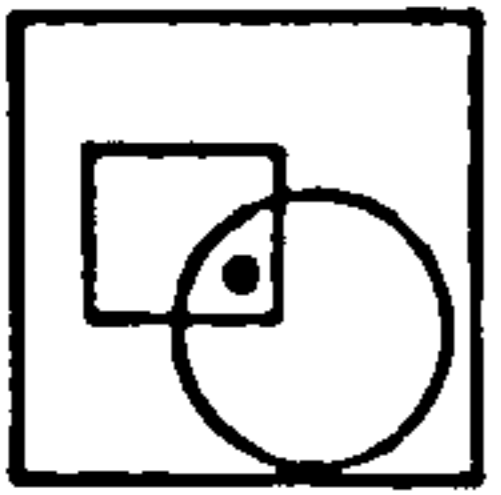




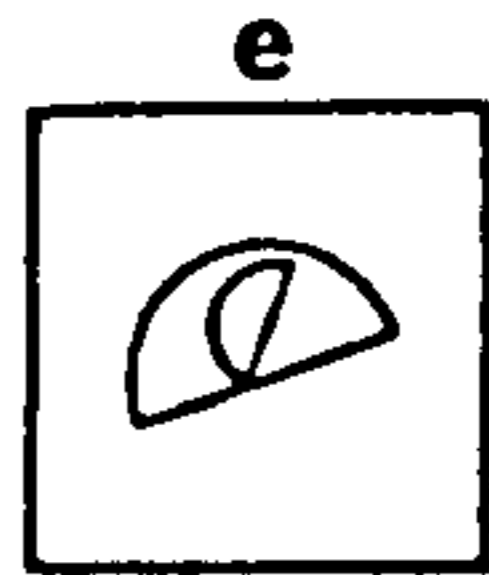
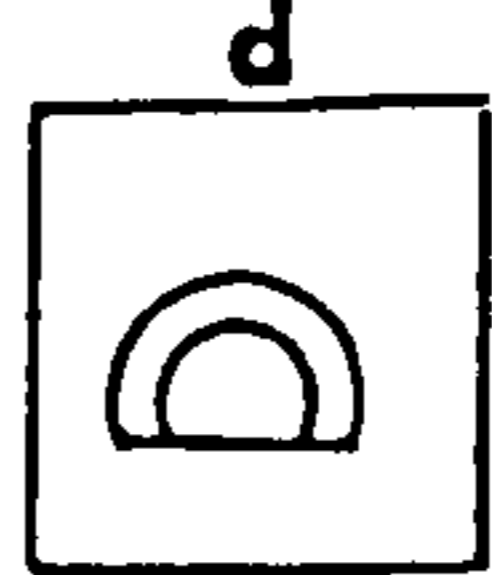
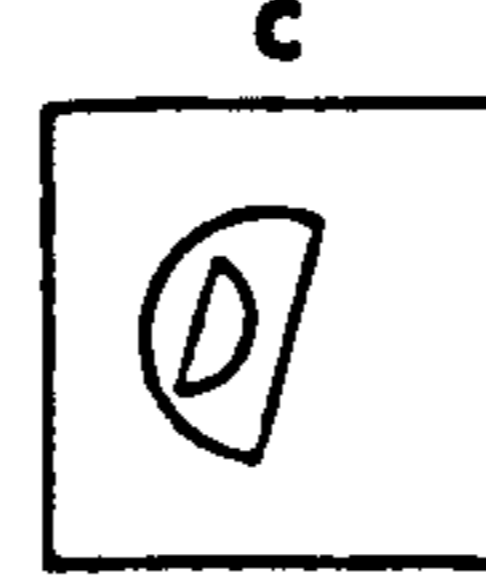
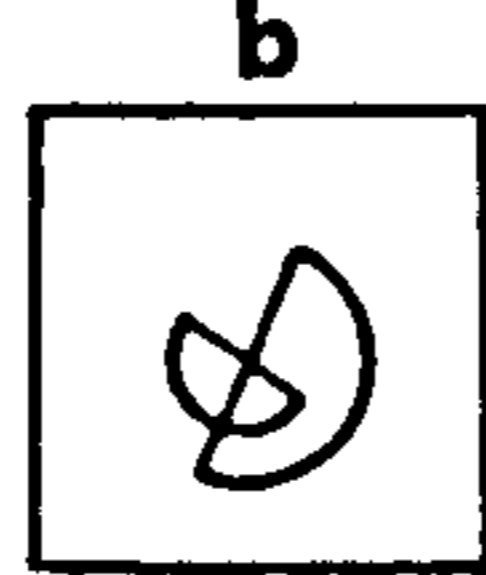
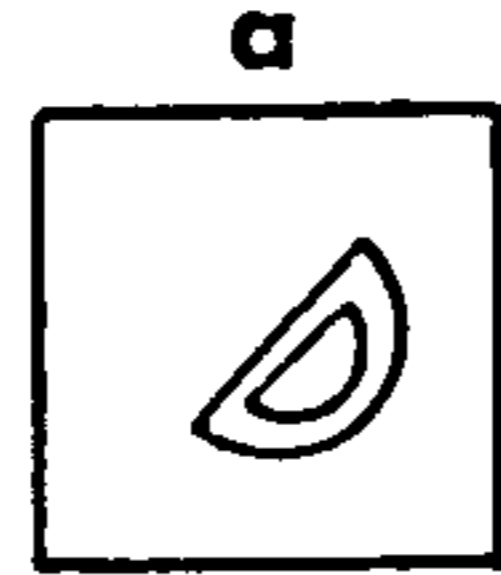
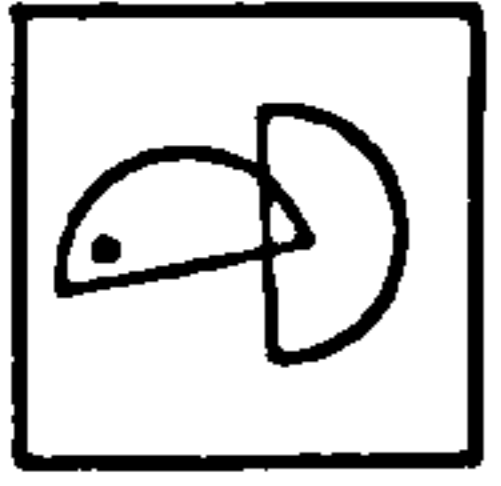
TEST 4

Examples

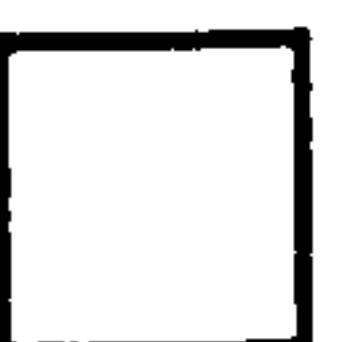
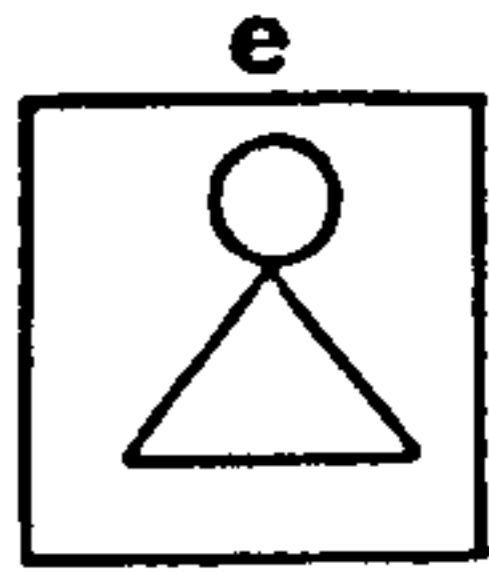
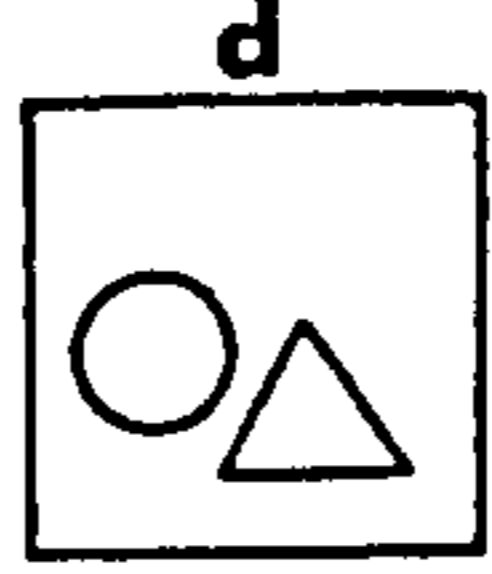
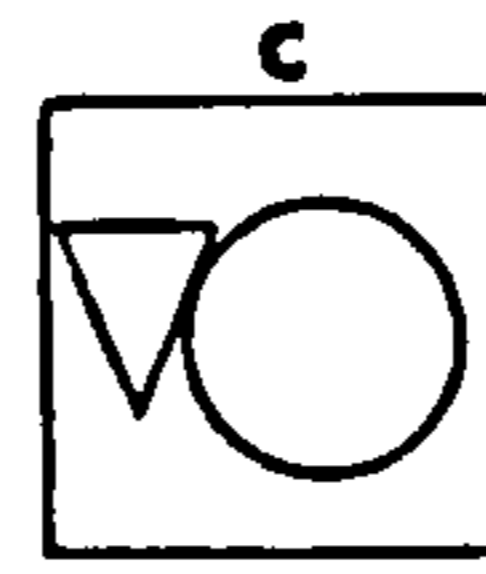
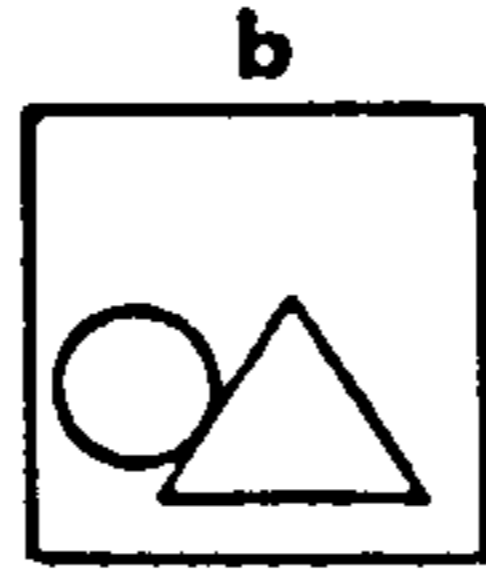
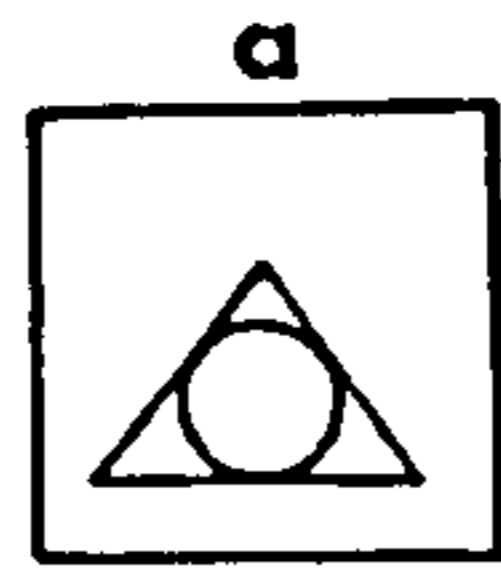
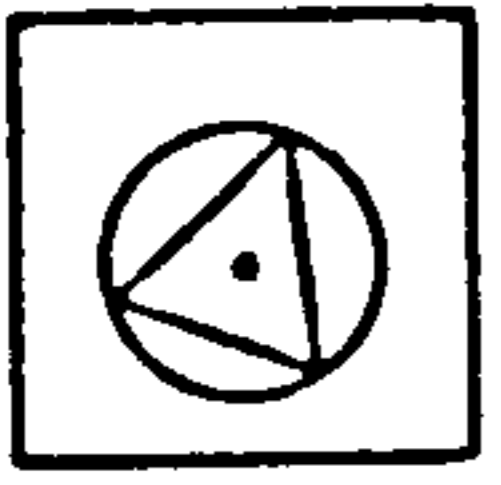
Answers



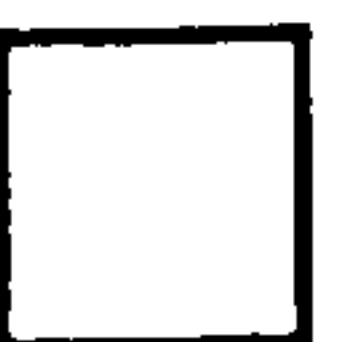
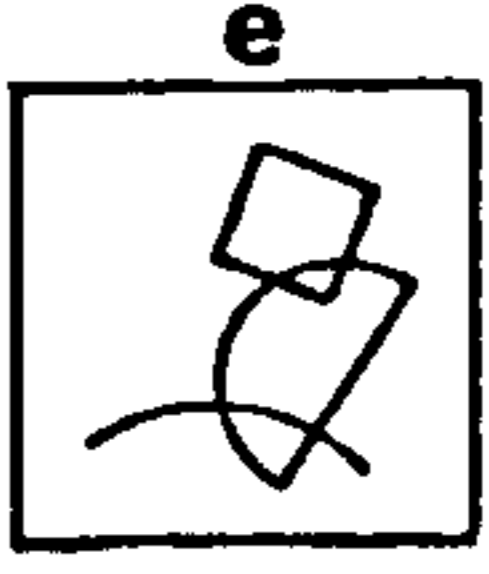
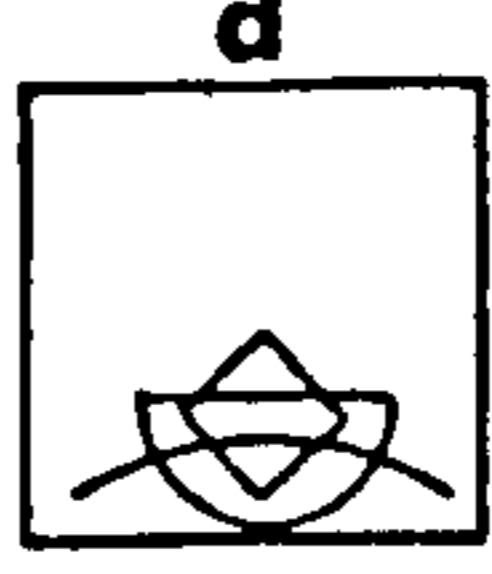
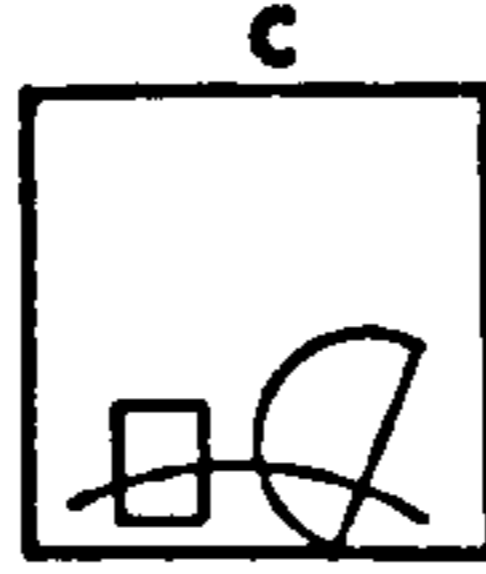
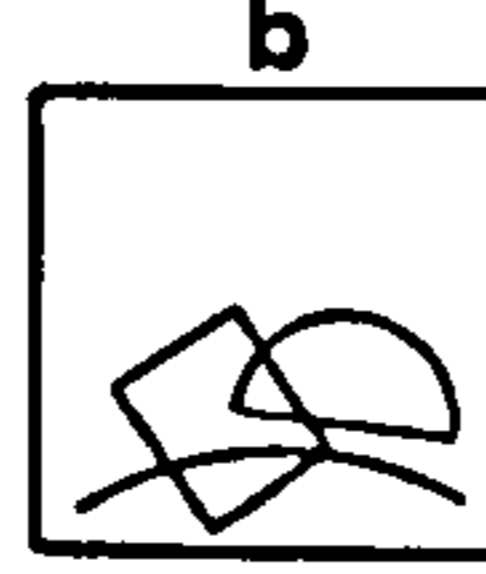
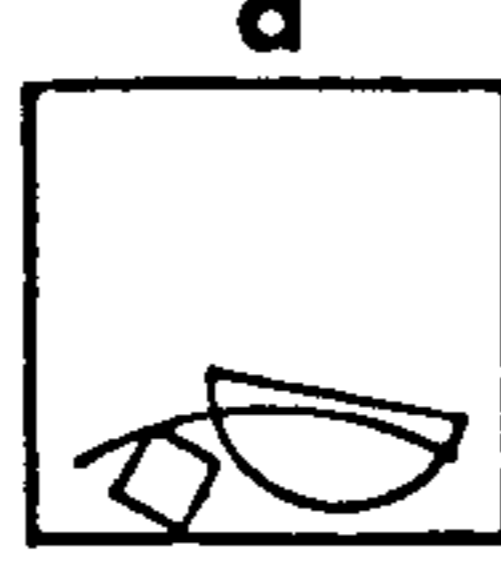
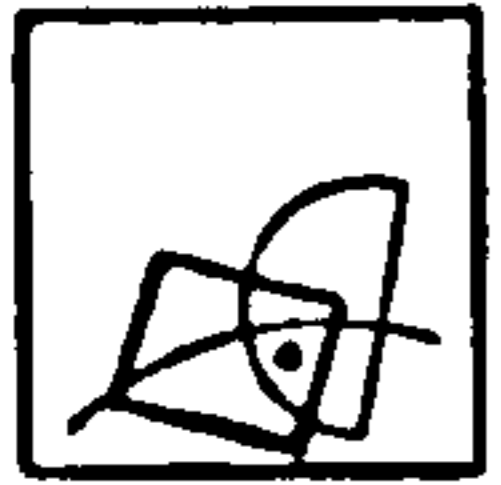
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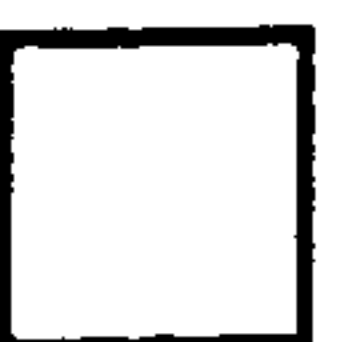
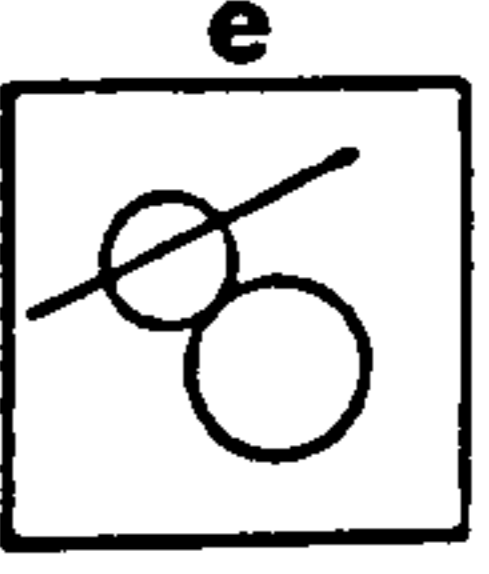
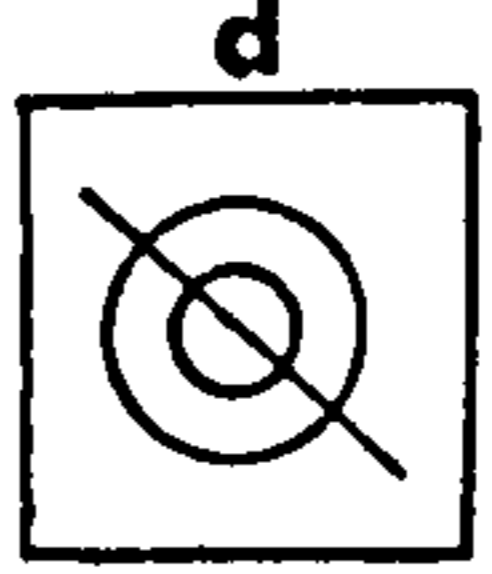
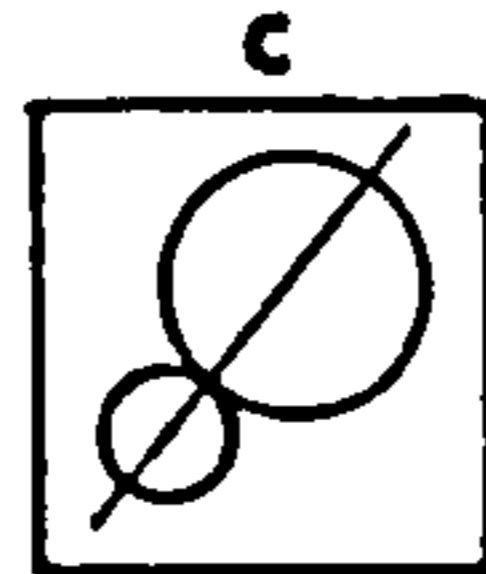
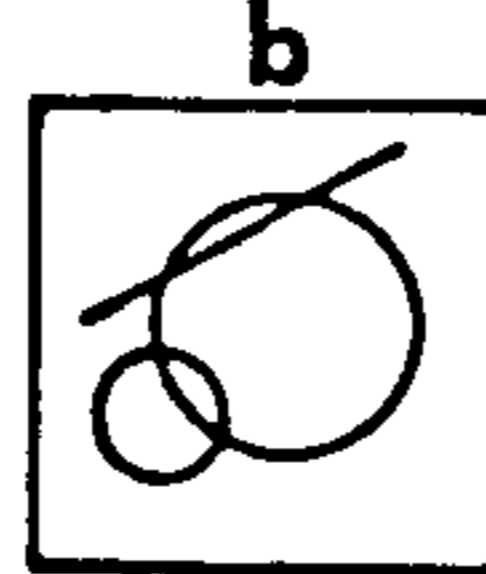
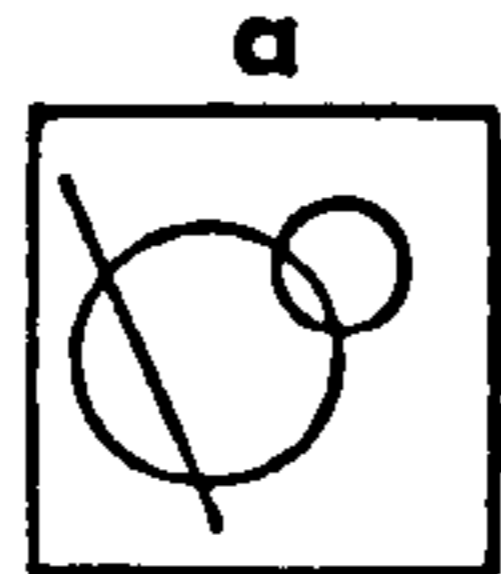
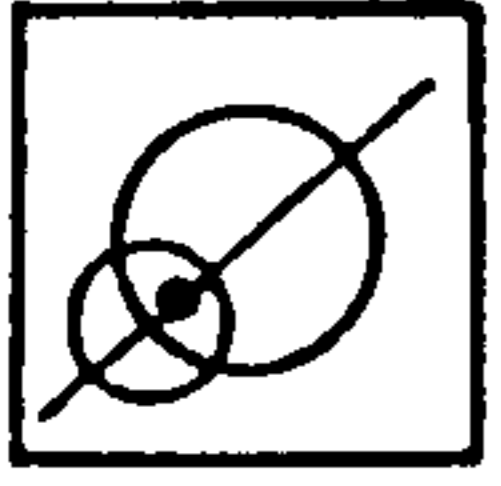
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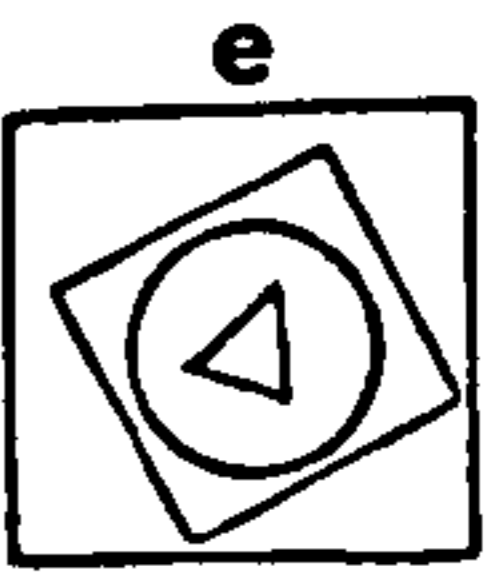
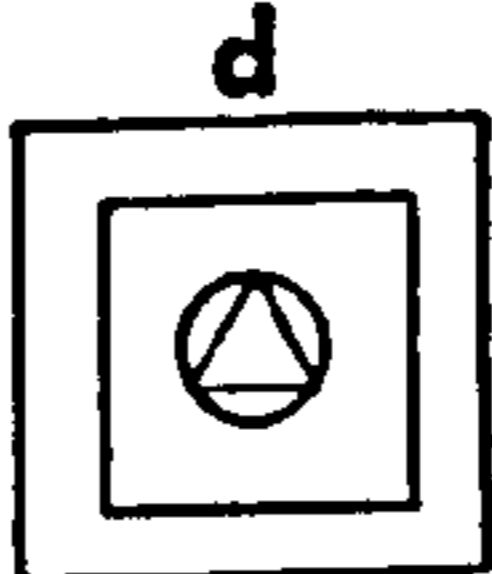
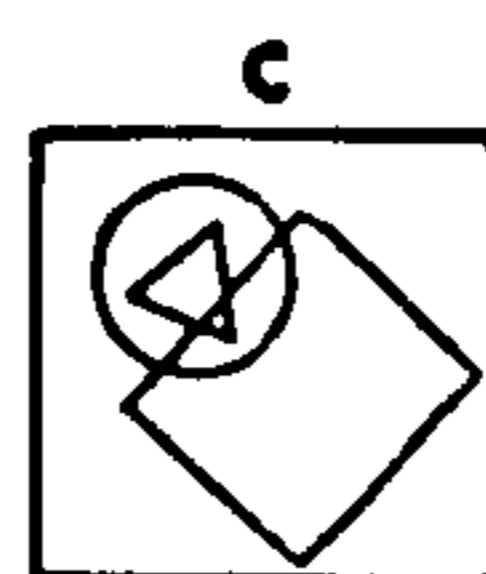
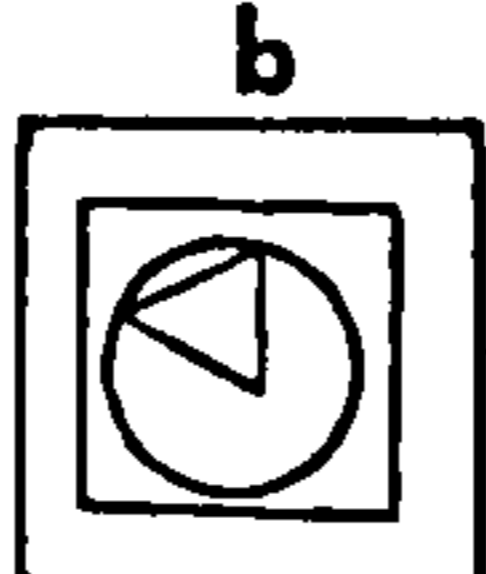
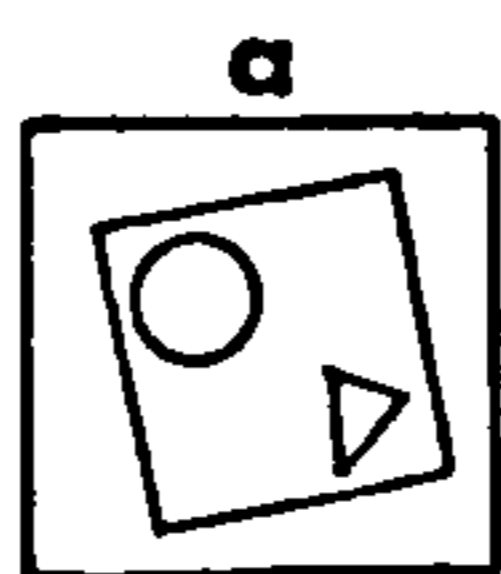
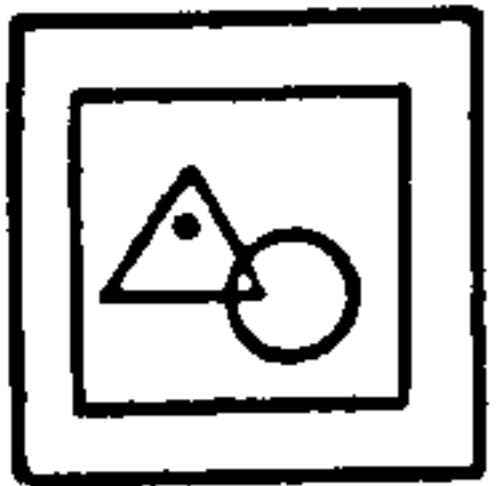
3.



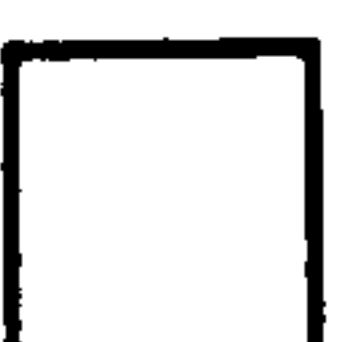
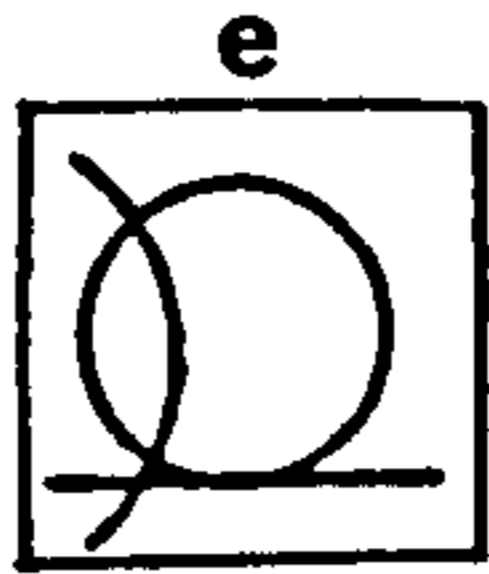
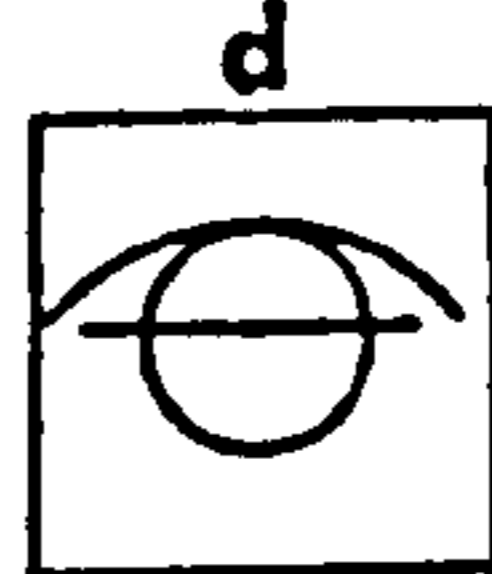
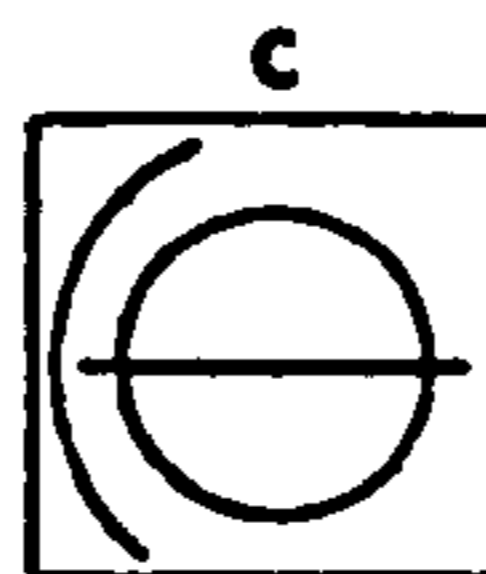
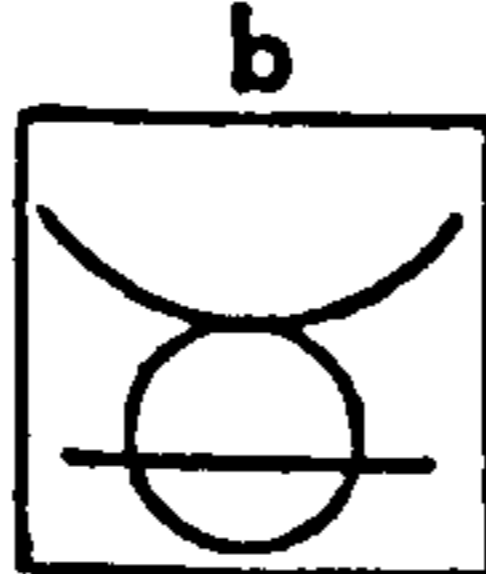
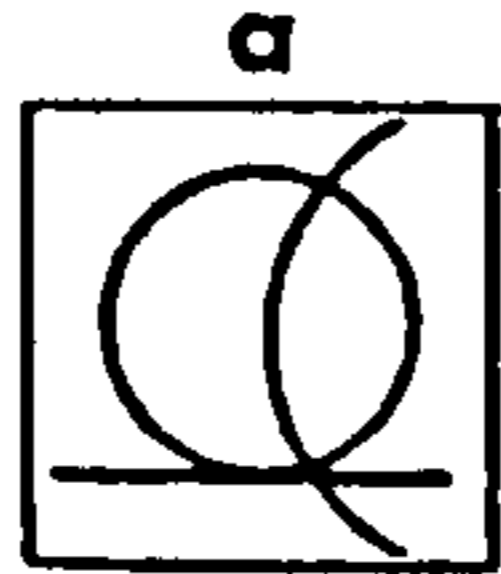
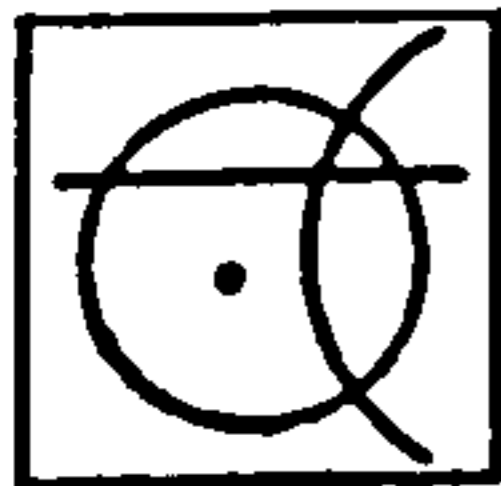
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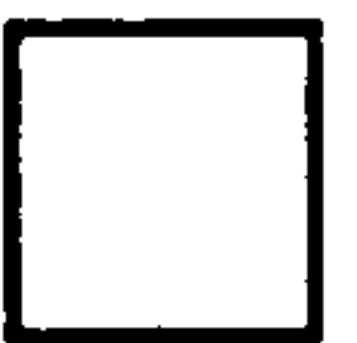
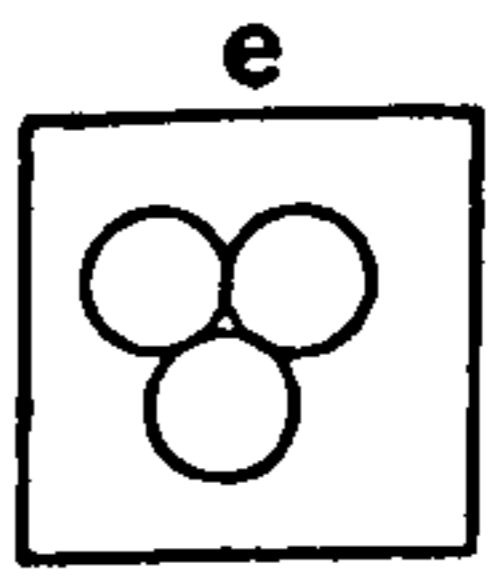
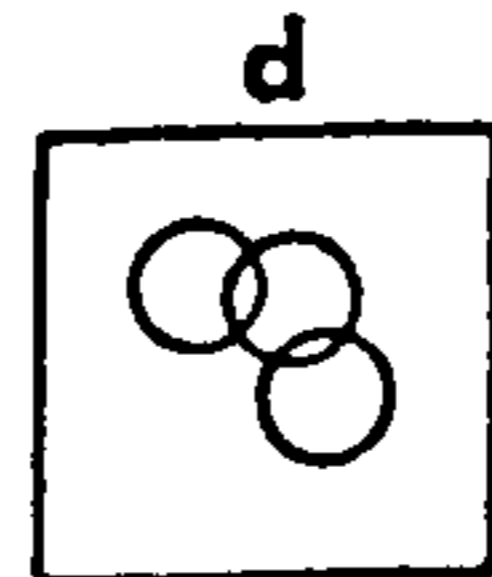
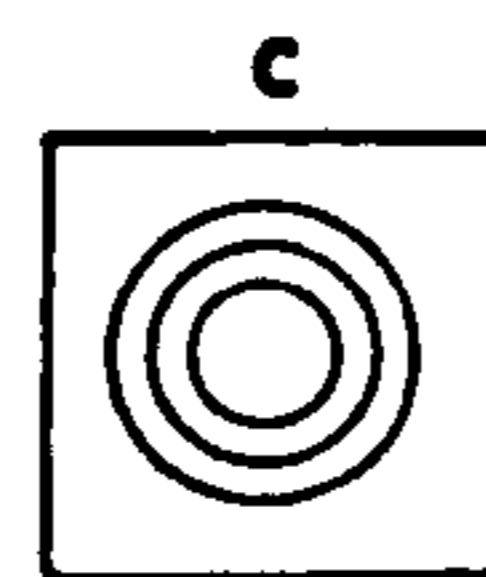
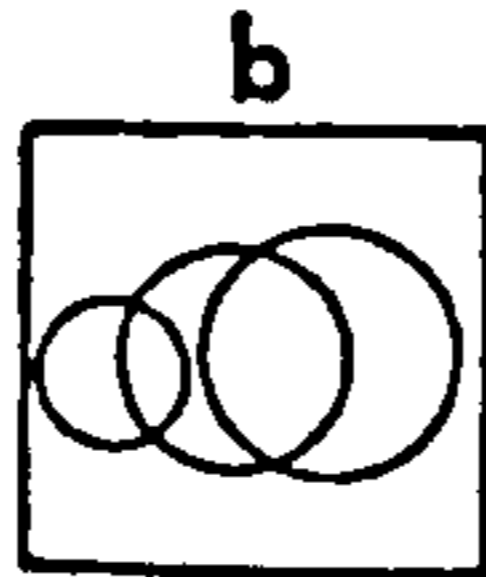
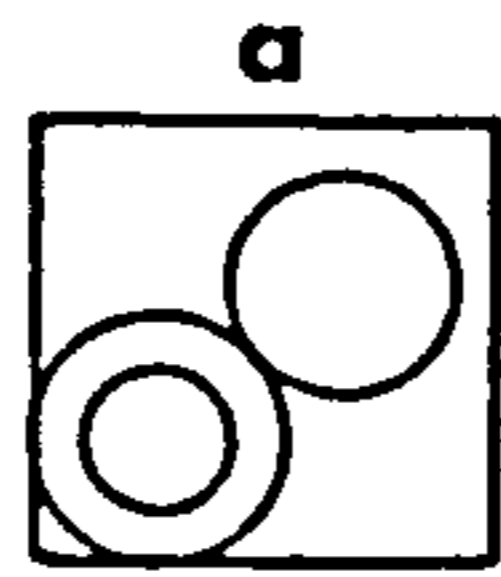
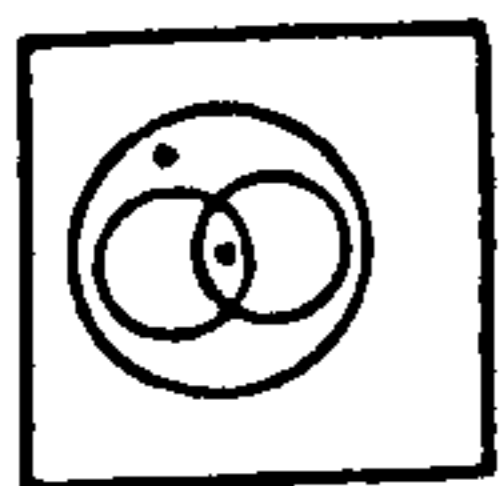
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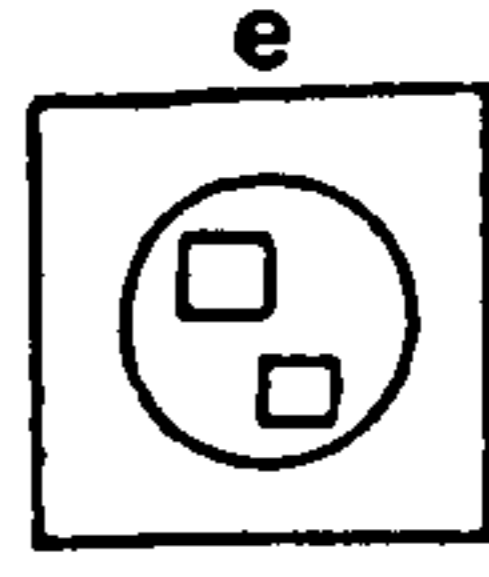
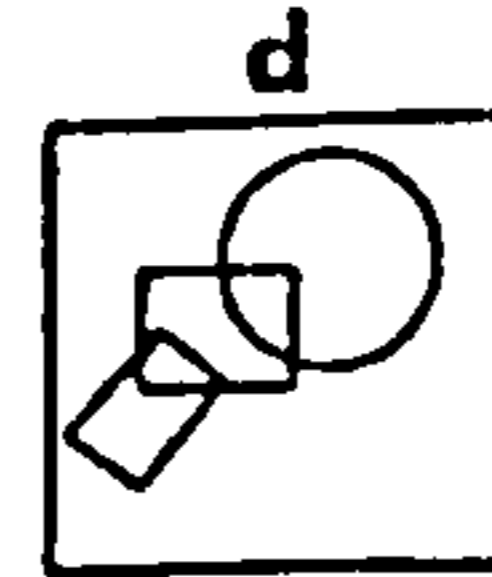
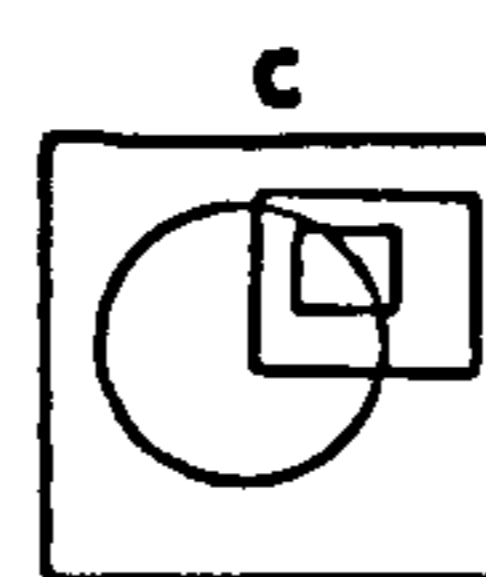
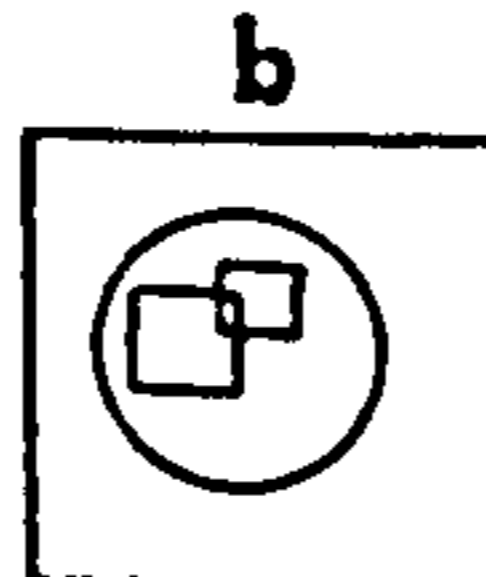
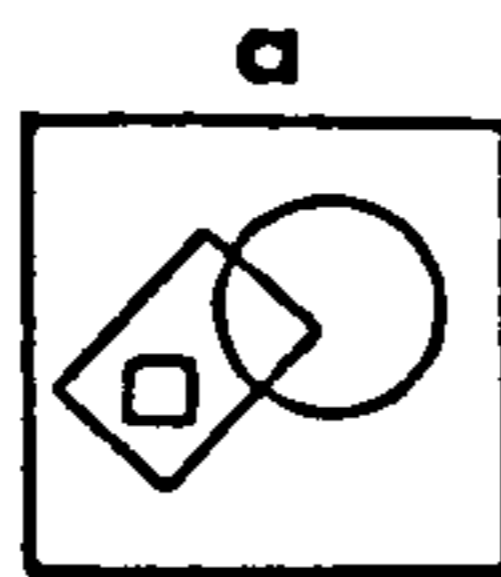
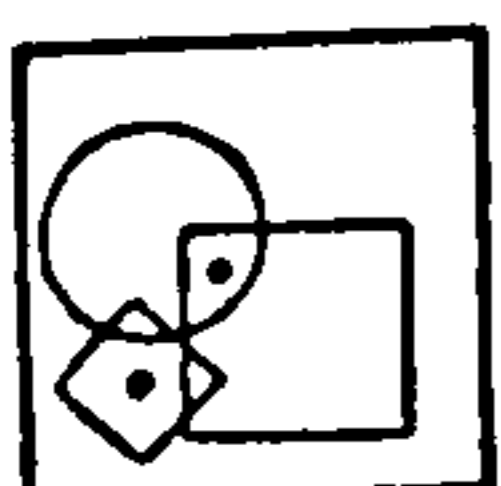
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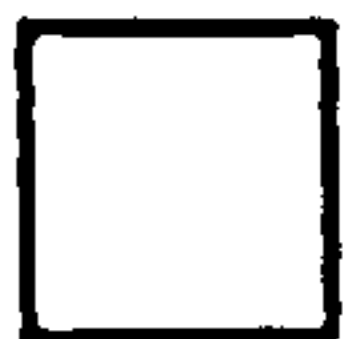
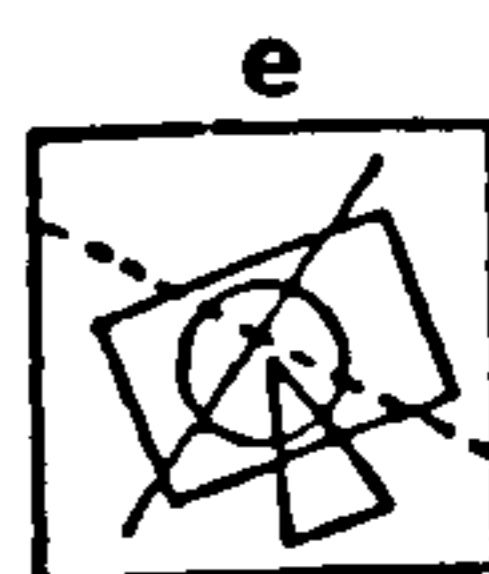
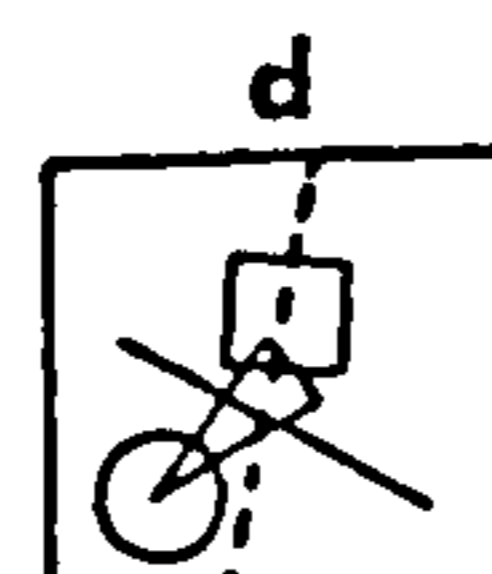
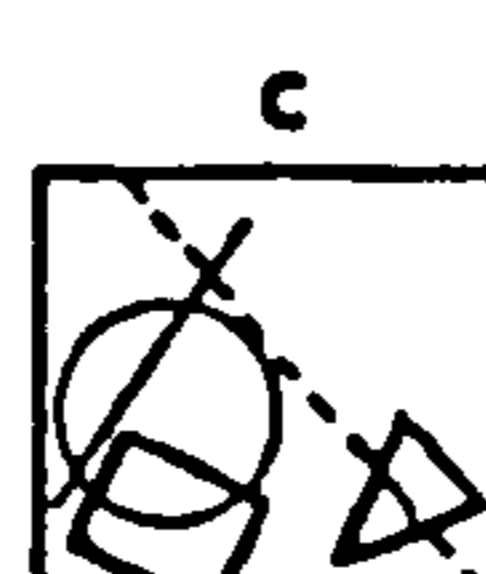
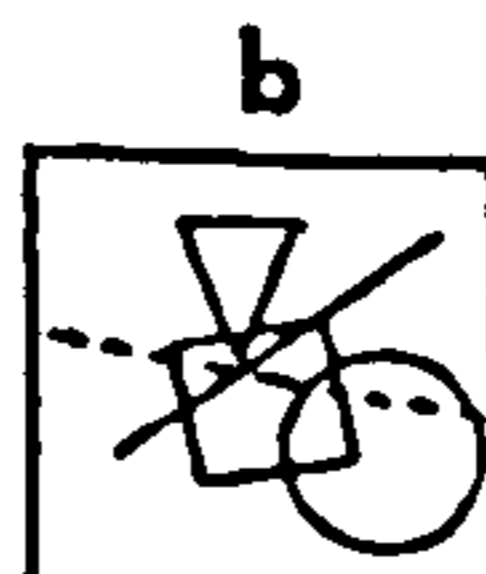
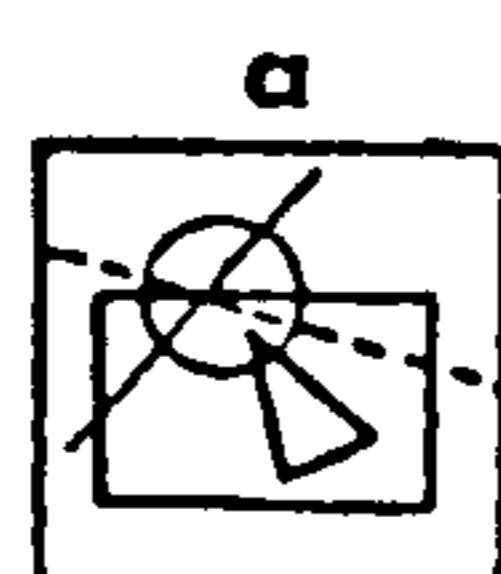
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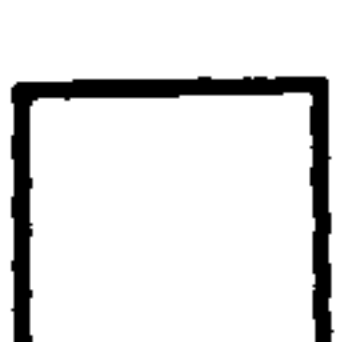
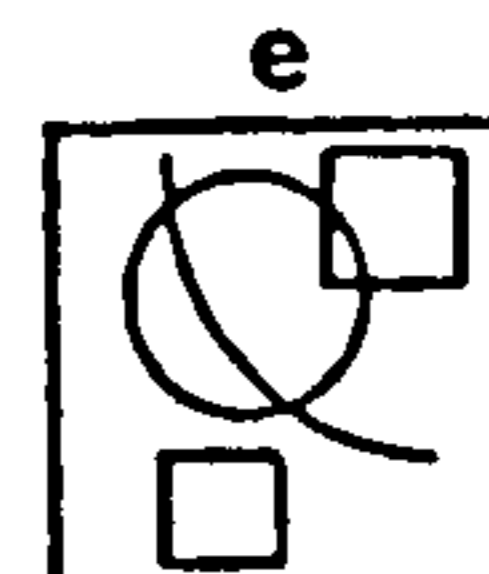
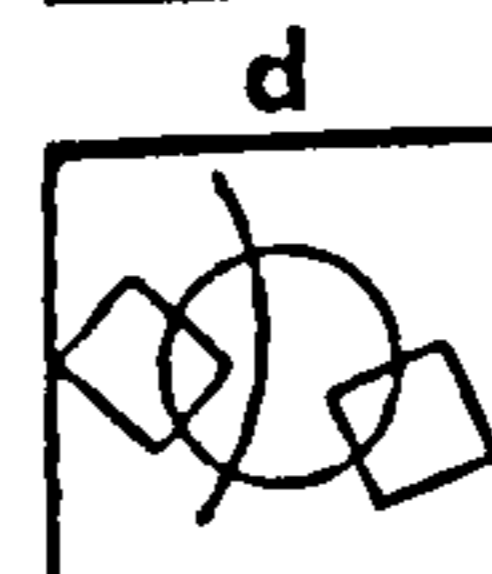
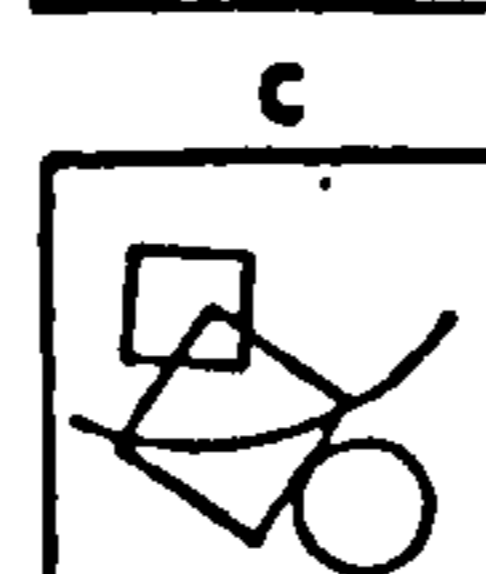
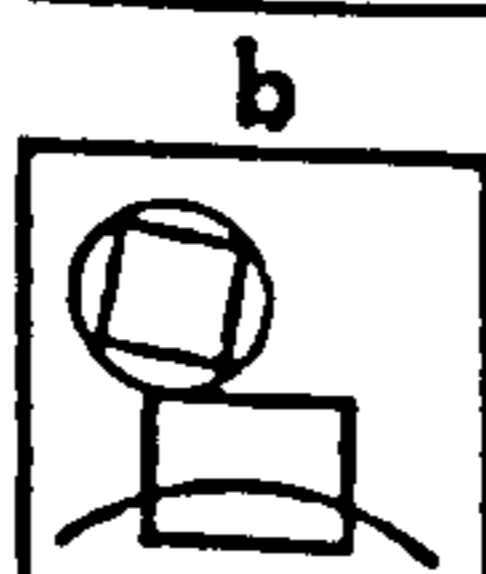
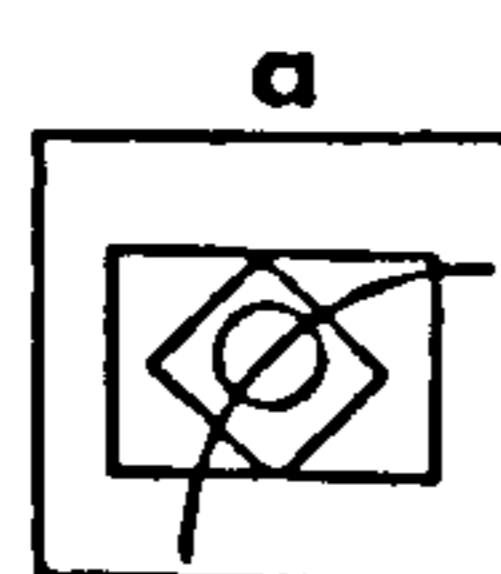
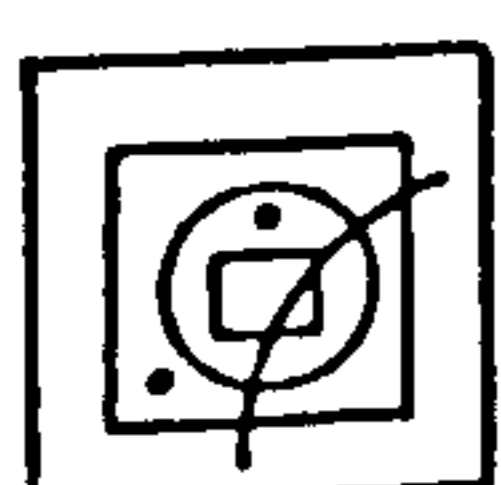
8.



9.



10.



Appendix III

Computer Printout of the results for the Original Age Range

For VM/CMS University of Warwick (Sky) License Number 60616
 This software is functional through July 31, 1991.

Try the new SPSS-X Release 3.1 features:

- * Interactive SPSS-X command execution
- * Online Help
- * Nonlinear Regression
- * Time Series and Forecasting (TRENDS)
- * Macro Facility
- * The new RANK procedure
- * Improvements in:
 - * REPORT and TABLES
 - * Simplified Syntax
 - * Matrix I/O

See SPSS-X User's Guide, Third Edition, for more information on these features.

```

1 0 title 'Science teaching project'
2 0 subtitle 'Test run to try out SPSSX'
3 0
4 0 data list file = schools
5 0
6 0 /
7 0 school 1 - 4 (A)
8 0 ttype 1 - 2
9 0 sex 6
10 0 iq 8
11 0 chem 9 - 11
12 0 biol
13 0 phys 13 - 15
14 0 intsci 17
15 0 singsex 19
16 0 selec 21
17 0 s23
18 0 s25 to s30
19 0 s32 23 - 30
20 0 pred 31
21 0 stotal 32
22 0 repld 34
23 0 r1 to r23 35 - 57
24 0 aslan 59
25 0
  
```

This command will read 1 records from SCHOOLS DATA A1

Variable	Rec	Start	End	Format
ID	1	1	4	A4
SCHOOL	1	1	2	F2.0
TTYPE	1	6	6	F1.0
SEX	1	8	8	F1.0
IQ	1	9	11	F3.0
CHEM	1	13	13	F1.0
BIOL	1	14	14	F1.0
PHYS	1	15	15	F1.0
INTSCI	1	17	17	F1.0
SINGSEX	1	19	19	F1.0

SELEC	1	21	21	F1.0
S23	1	23	23	F1.0
S25	1	24	24	F1.0
S26	1	25	25	F1.0
S27	1	26	26	F1.0
S28	1	27	27	F1.0
S29	1	28	28	F1.0
S30	1	29	29	F1.0
S32	1	30	30	F1.0
PRED	1	31	31	F1.0
STOTAL	1	32	32	F1.0
REPLIED	1	34	34	F1.0
R1	1	35	35	F1.0
R2	1	36	36	F1.0
R3	1	37	37	F1.0
R4	1	38	38	F1.0
R5	1	39	39	F1.0
R6	1	40	40	F1.0
R7	1	41	41	F1.0
R8	1	42	42	F1.0
R9	1	43	43	F1.0
R10	1	44	44	F1.0
R11	1	45	45	F1.0
R12	1	46	46	F1.0
R13	1	47	47	F1.0
R14	1	48	48	F1.0
R15	1	49	49	F1.0
R16	1	50	50	F1.0
R17	1	51	51	F1.0
R18	1	52	52	F1.0
R19	1	53	53	F1.0
R20	1	54	54	F1.0
R21	1	55	55	F1.0
R22	1	56	56	F1.0
R23	1	57	57	F1.0
ASIAN	1	59	59	F1.0

recode iq (0 thru 65 = 1) (65 thru 75 = 2) (75 thru 85 = 3)
 (85 thru 95 = 4) (95 thru 105 = 5) (105 thru 115 = 6)
 (115 thru 125 = 7) (125 thru 135 = 8) (135 thru h1 = 9)
 into gridq

variable labels
 school 'School Name'
 ttype 'Teaching method employed'
 iq 'Intelligence quotient'
 gridq 'Intelligence quotient (grouped)'
 sex 'Sex of child'
 chem 'Studies chemistry'
 phys 'Studies physics'
 Biol 'Studies biology'
 Intsc1 'Studies Integrated or combined science'
 slngsex 'Single-sex or co-educational school'
 selec 'Selects on Intelligence quotient'

43	0	s23	'Recognises anomalous result'
44	0	s25	'Recognises pattern in a set of results'
45	0	s26	'Draws valid conclusions from results'
46	0	s27	'Recognises an uncontrolled variable'
47	0	s28	'Devises method to control variable'
48	0	s29	'Forms hypothesis to explain results'
49	0	s30	'Forms 3 hypotheses for 1 set of results'
50	0	s32	'Devises experiment to test hypothesis'
51	0	pred	'Predicts based on previous results'
52	0	stotal	'Total no of skills'
53	0	repled	'Admitted existence of distraction'
54	0	r1	'Noise'
55	0	r2	'Fatigue'
56	0	r3	'Health'
57	0	r4	'Headache'
58	0	r5	'Teacher'
59	0	r6	'Nearness of nbrs'
60	0	r7	'Boredom'
61	0	r8	'Other pupils'
62	0	r9	'Feeling nervous'
63	0	r10	'Squeaky chairs'
64	0	r11	'Pressure of time'
65	0	r12	'Q,'n not u','stood'
66	0	r13	'Physical env','t'
67	0	r14	'Lack of comfort'
68	0	r15	'Content of work'
69	0	r16	'Mental block'
70	0	r17	'Hayfever'
71	0	r18	'Personal probs'
72	0	r19	'Hunger - thlrst'
73	0	r20	'Lack of knowl','ge'
74	0	r21	'Straying mind'
75	0	r22	'Cannot express'
76	0	r23	'Worry re outcome'
77	0	asian	'Of Asian family'
78	0	value labels	
79	0	school	
80	0	1	'Woodlands'
81	0	2	'Bablake'
82	0	3	'Cardinal Newman'
83	0	4	'K Henry VIII'
84	0	5	'Judge Meadow'
85	0	6	'Rufford'
86	0	7	'S Joseph Convent'
87	0	8	'Stoke Pk'
88	0	9	'Tille Hl Wood'
89	0	10	'Wreake Valley'
90	0	tttype	
91	0	1	'Trad'
92	0	2	'Process Science'
93	0	sex	
94	0	1	'Male'
95	0		
96	0		

```

97 0 0 / 2 'Female'
98 0 0 /
99 0 0 / chem phys b101 intsc1 selec
100 0 0 / s23 s25 s26 s27 s28
101 0 0 / s29 s30 s32 pred replled
102 0 0 / r21 to r23 aslan
103 0 0 / 1 'Yes'
104 0 0 / 2 'No'
105 0 0 /
106 0 0 / slingsex
107 0 0 / 1 'Single sex'
108 0 0 / 2 'Co-ed'
109 0 0 /
110 0 0 / gridq
111 0 0 / 1 'Under 65'
112 0 0 / 2 ' 75 - 85'
113 0 0 / 3 ' 85 - 95'
114 0 0 / 4 ' 95 - 105'
115 0 0 / 5 ' 105-115'
116 0 0 / 6 ' 115-125'
117 0 0 / 7 ' 125-135'
118 0 0 / 8 ' Over 135'
119 0 0 /
120 0 0 / frequencies variables = school to selec
121 0 0 / pred to replled
122 0 0 / aslan
123 0 0 / gridq
124 0 0 /
125 0 0 / format = onepage
126 0 0 / statistics
127 0 0 /
  
```

There are 2,014,360 bytes of memory available.
 The largest contiguous area has 2,014,360 bytes.

Memory allows a total of 32,767 values accumulated across all variables.
 There may be up to 8,192 value labels for each variable.

SCHOOL School Name

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Woodlands	1	18	7.3	7.3	7.3
Bablake	2	18	7.3	7.3	14.6
Cardinal Newman	3	22	8.9	8.9	23.5
K Henry VIII	4	49	19.8	19.8	43.3
Judge Meadow	5	24	9.7	9.7	53.0
Rufford	6	19	7.7	7.7	60.7
S Joseph Convent	7	38	15.4	15.4	76.1
Stoke Pk	8	24	9.7	9.7	85.8
Tile Hl Wood	9	20	8.1	8.1	93.9
Wreake Valley	10	15	6.1	6.1	100.0
Total		247	100.0	100.0	

Mean 5.417 Std dev 2.571 Minimum 1.000
 Maximum 10.000

Valid cases 247 Missing cases 0

TYPE Teaching method employed

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Trad	1	193	78.1	78.1	78.1
Process Science	2	54	21.9	21.9	100.0
Total		247	100.0	100.0	

Mean 1.219 Std dev .414 Minimum 1.000
 Maximum 2.000

Valid cases 247 Missing cases 0

SEX Sex of child

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Male	1	101	40.9	40.9	40.9
Female	2	146	59.1	59.1	100.0
Total		247	100.0	100.0	

Mean 1.591 Std dev .493 Minimum 1.000
Maximum 2.000

Valid cases 247 Missing cases 0

IQ Intelligence quotient

Value	Freq	Pct	Cum Pct	Value	Freq	Pct	Cum Pct	Value	Freq	Pct	Cum Pct
57	2	1	1	101	1	0	43	123	3	1	83
76	1	0	1	102	20	8	51	124	1	0	83
79	1	0	2	104	3	1	52	125	1	0	84
81	3	1	3	105	10	4	56	126	5	2	86
83	3	1	4	106	2	1	57	127	6	2	88
84	2	1	5	108	2	1	57	128	1	0	89
86	6	2	7	109	16	6	64	129	1	0	89
87	9	4	11	111	4	2	66	131	1	1	90
89	3	1	12	113	10	4	70	133	2	3	93
91	7	3	15	114	6	2	72	134	5	2	95
92	13	5	20	116	2	1	73	137	1	0	96
94	15	6	26	117	3	1	74	139	7	3	98
96	9	4	30	118	6	2	77	140	1	0	99
97	17	7	37	119	6	2	79	144	1	0	99
98	1	0	37	121	2	1	80	154	1	0	100
99	12	5	42	122	5	2	82	158	1	0	100

Mean 106.462 Std dev 16.455 Minimum 57.000
Maximum 158.000

Valid cases 247 Missing cases 0

CHEM Studies chemistry

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	86	34.8	34.8	34.8
No	2	161	65.2	65.2	100.0
Total		247	100.0	100.0	
Mean		1.652			
Maximum		2.000			
Std dev		.477			
Minimum					1.000

Valid cases 247 Missing cases 0

BIOL Studies biology

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	143	57.9	57.9	57.9
No	2	104	42.1	42.1	100.0
Total		247	100.0	100.0	
Mean		1.421			
Maximum		2.000			
Std dev		.495			
Minimum					1.000

Valid cases 247 Missing cases 0

PHYS Studies physics

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	84	34.0	34.0	34.0
No	2	163	66.0	66.0	100.0
Total		247	100.0	100.0	
Mean		1.660			
Maximum		2.000			
Std dev		.475			
Minimum					1.000

Valid cases 247 Missing cases 0

INTSCI Studies Integrated or combined science

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	114	46.2	46.2	46.2
No	2	133	53.8	53.8	100.0
Total		247	100.0	100.0	

Mean 1.538 Std dev .500 Minimum 1.000
 Maximum 2.000

Valid cases 247 Missing cases 0

 SINGSEX Single-sex or co-educational school

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Single sex	1	76	30.8	30.8	30.8
Co-ed	2	171	69.2	69.2	100.0
Total		247	100.0	100.0	

Mean 1.692 Std dev .462 Minimum 1.000
 Maximum 2.000

Valid cases 247 Missing cases 0

SELEC selects on intelligence quotient

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	67	27.1	27.1	27.1
No	2	142	57.5	57.5	84.6
	3	38	15.4	15.4	100.0
Total		247	100.0	100.0	

Mean 1.883 Std dev .643 Minimum 1.000
 Maximum 3.000

Valid cases 247 Missing cases 0

 PRED Predicts based on previous results

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	66	26.7	26.7	26.7
No	2	181	73.3	73.3	100.0
Total		247	100.0	100.0	

Mean 1.733 Std dev .443 Minimum 1.000
 Maximum 2.000

Valid cases 247 Missing cases 0

STOTAL Total no of skills

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
0	3	3	1.2	1.2	1.2
1	14	14	5.7	5.7	6.9
2	26	26	10.5	10.5	17.4
3	55	55	22.3	22.3	39.7
4	44	44	17.8	17.8	57.5
5	44	44	17.8	17.8	75.3
6	24	24	9.7	9.7	85.0
7	26	26	10.5	10.5	95.5
8	7	7	2.8	2.8	98.4
9	4	4	1.6	1.6	100.0
Total	247	247	100.0	100.0	

Mean 4.231 Std dev 1.919 Minimum .000
 Maximum 9.000

Valid cases 247 Missing cases 0

REPLIED Admitted existence of distraction

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	171	69.2	69.2	69.2
No	2	76	30.8	30.8	100.0
Total		247	100.0	100.0	

Mean 1.308 Std dev .462 Minimum 1.000
 Maximum 2.000

Valid cases 247 Missing cases 0

ASIAN Of Asian family

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	39	15.8	15.8	15.8
No	2	208	84.2	84.2	100.0
Total		247	100.0	100.0	

Mean 1.842 Std dev .365 Minimum 1.000
 Maximum 2.000

Valid cases 247 Missing cases 0

GRIQ Intelligence quotient (grouped)

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Under 65	1.00	2	.8	.8	.8
75 - 85	3.00	10	4.0	4.0	4.9
95 - 105	4.00	53	21.5	21.5	26.3
115-125	5.00	73	29.6	29.6	55.9
125-135	6.00	40	16.2	16.2	72.1
Over 135	7.00	29	11.7	11.7	83.8
	8.00	28	11.3	11.3	95.1
	9.00	12	4.9	4.9	100.0
Total		247	100.0	100.0	

Mean 5.603 Std dev 1.607 Minimum 1.000
 Maximum 9.000

Valid cases 247 Missing cases 0

21-Nov-90 Science teaching project
15:57:02 Test run to try out SPSSx

preceding task required .67 seconds CPU time; 7.51 seconds elapsed.

128 0 means iq by s23 to s32
129 0

There are 2,015,592 bytes of memory available.
The largest contiguous area has 2,015,592 bytes.

Given workspace allows for 32,767 cells of 1 dimensions for BREAKDOWN

21-Nov-90 Science teaching project
15:57:08 Test run to try out SPSSx

D E S C R I P T I O N O F S U B P O P U L A T I O N S

Criterion Variable IQ Intelligence quotient
Broken Down by S23 Recognises anomalous result

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population					
S23	1	Yes	106.4615	16.4546	247
S23	2	No	114.0933	16.2491	75
			103.1337	15.4454	172
Total Cases = 247					

D E S C R I P T I O N O F S U B P O P U L A T I O N S

Criterion Variable IQ Intelligence quotient
Broken Down by S25 Recognises pattern in a set of results

Variable	Value Label	Mean	Std Dev	Cases
For Entire Population				
S25	1 Yes	106.4615	16.4546	247
S25	2 No	109.7453	16.3804	161
		100.3140	14.8278	86

Total Cases = 247

DESCRIPTION OF SUBPOPULATIONS

Criterion Variable IQ Intelligence quotient
 Broken Down by S26 Draws valid conclusions from results

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population					
S26	1	Yes	106.4615	16.4546	247
S26	2	No	109.4733	16.1181	150
			101.8041	15.9528	97

Total Cases = 247

21-Nov-90 Science teaching project
15:57:08 Test run to try out SPSSX

DESCRIPTION OF SUBPOPULATIONS

Criterion Variable IQ Intelligence quotient
Broken Down by S27 Recognises an uncontrolled variable

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population					
S27	1	Yes	106.4615	16.4546	247
S27	2	No	107.2785	16.3233	219
			100.0714	16.3638	28
Total Cases = 247					

DESCRIPTION OF SUBPOPULATIONS

Criterion Variable IQ Intelligence quotient
Broken Down by S28 Devises method to control variable

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population					
			106.4615	16.4546	247
S28	1	Yes	107.4104	15.7930	173
S28	2	No	104.2432	17.8217	74
Total Cases = 247					

DESCRIPTION OF SUBPOPULATIONS

Criterion Variable IQ Intelligence quotient
Broken Down by S29 Forms hypothesis to explain results

Variable	Value Label	Mean	Std Dev	Cases
For Entire Population				
S29	1 Yes	109.3741	16.1700	139
S29	2 No	102.7130	16.1263	108

Total Cases = 247

DESCRIPTION OF SUBPOPULATIONS

Criterion Variable IQ Intelligence quotient
Broken Down by S30 Forms 3 hypotheses for 1 set of results

Variable	Value Label	Mean	Std Dev	Cases
For Entire Population				
S30	1 Yes	106.4615	16.4546	247
S30	2 No	123.9583	13.4212	24
		104.5785	15.6430	223

Total Cases = 247

D E S C R I P T I O N O F S U B P O P U L A T I O N S

Criterion Variable IQ Intelligence quotient
Broken Down by S32 Devices experiment to test hypotheses

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population					
S32	1	Yes	111.7105	16.5968	38
S32	2	No	105.5072	16.2871	209
Total Cases = 247					

Preceding task required .38 seconds CPU time; 6.38 seconds elapsed.

```
130 0 mult response
131 0 groups = skills 'Skills passed' (s23 to s32 pred (1))
132 0 repltes 'Distractions admitted' (r1 to r23 (1))
133 0 / variables = sex(1,2)
134 0 aslan(1,2)
135 0 chem(1,2)
136 0 btol(1,2)
137 0 phys(1,2)
138 0 intsc1(1,2)
139 0 ttype(1,2)
140 0 slngsex(1,2)
141 0 school(1,10)
142 0 gr1q(1,9)
143 0
144 0 / frequencles = skills repltes
145 0 / tables = skills repltes by sex aslan chem btol phys
146 0 intsc1 ttype slngsex school
147 0 gr1q
```

MULT RESPONSE requires 13472 bytes of workspace for execution.

Group SKILLS Skills passed
 (Value tabulated = 1)

Dichotomy label	Name	Count	Pct of Responses	Pct of Cases
Recognises anomalous result	S23	75	7.2	30.7
Recognises pattern in a set of results	S25	161	15.4	66.0
Draws valid conclusions from results	S26	150	14.4	61.5
Recognises an uncontrolled variable	S27	219	21.0	89.8
Devises method to control variable	S28	173	16.6	70.9
Forms hypotheses to explain results	S29	139	13.3	57.0
Forms 3 hypotheses for 1 set of results	S30	24	2.3	9.8
Devises experiment to test hypothesis	S32	38	3.6	15.6
Predicts based on previous results	PRED	66	6.3	27.0
Total responses		1045	100.0	428.3

3 missing cases; 244 valid cases

Group REPLIES Distractions admitted
 (Value tabulated = 1)

Dichotomy Label	Name	Count	Pct of Responses	Pct of Cases
Noise	R1	20	5.6	11.8
Fatigue	R2	30	8.5	17.6
Health	R3	12	3.4	7.1
Headache	R4	8	2.3	4.7
Teacher	R5	2	.6	1.2
Nearness of nbhrs	R6	3	.8	1.8
Boredom	R7	7	2.0	4.1
Other pupils	R8	32	9.0	18.8
Feelling nervous	R9	51	14.4	30.0
Squeaky chairs	R10	18	5.1	10.6
Pressure of time	R11	27	7.6	15.9
O'n not u'stood	R12	21	5.9	12.4
Physical env't	R13	15	4.2	8.8
Lack of comfort	R14	7	2.0	4.1
Content of work	R15	2	.6	1.2
Mental block	R16	19	5.4	11.2
Hayfever	R17	3	.8	1.8
Personal probs	R18	3	.8	1.8
Hunger - thirst	R19	15	4.2	8.8
Lack of knowl'ge	R20	12	3.4	7.1
Straying mind	R21	25	7.1	14.7
Cannot express	R22	5	1.4	2.9
Worry re outcome	R23	17	4.8	10.0
Total responses		354	100.0	208.2

77 missing cases; 170 valid cases

*** C R O S S T A B U L A T I O N ***

SKILLS (tabulating 1) Skills passed
 by SEX Sex of child

SKILLS	SEX		Row Total
	Male	Female	
S23 Recognises anomalous	1	2	75 30.7
S25 Recognises pattern 1	63	98	161 66.0
S26 Draws valid conclusions	62	88	150 61.5
S27 Recognises an uncount	84	135	219 89.8
S28 Devises method to count	71	102	173 70.9
S29 Forms hypothesis to test	60	79	139 57.0
S30 Forms 3 hypotheses to test	11	13	24 9.8
S32 Devises experiment to test	13	25	38 15.6
PRED Predicts based on previous	31	35	66 27.0
Column Total	99 40.6	145 59.4	244 100.0

Percents and totals based on respondents

244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***

SKILLS (tabulating 1) Skills passed
 by ASIAN Of Asian family

SKILLS	Count		Row Total
	Yes	No	
S23	1	2	3
Recognises anomalous	10	65	75
S25	20	141	161
Recognises pattern 1	21	129	150
S26	30	189	219
Draws valid conclusions	27	146	173
S27	19	120	139
Recognises an uncount	4	20	24
S28	6	32	38
Devises method to compare	7	59	66
S29	7	59	66
Forms hypothesis to test	6	32	38
S30	6	32	38
Forms 3 hypotheses for experiment	7	59	66
S32	7	59	66
Devises experiment to predict based on previous	7	59	66
PRED	7	59	66
Predicts based on previous	7	59	66
Column Total	38	206	244
Total	15.6	84.4	100.0

Percents and totals based on respondents

244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***
 SKILLS (tabulating 1) SKILLS passed
 by CHEM Studies chemistry

SKILLS	Count		ROW Total
	Yes	No	
S23	1	2	75
Recognises anomalous	38	37	30.7
S25	68	93	161
Recognises pattern 1	60	90	66.0
S26	60	90	150
Draws valid conclusi	79	140	61.5
S27	79	140	219
Recognises an uncount	70	103	89.8
S28	70	103	173
Devises method to co	63	76	70.9
S29	63	76	139
Forms hypothesis to	21	3	57.0
S30	21	3	24
Forms 3 hypotheses f	23	15	9.8
S32	23	15	38
Devises experiment t	30	36	15.6
PRED	30	36	66
Predicts based on pr	85	159	27.0
Column	34.8	65.2	244
Total	34.8	65.2	100.0

Percents and totals based on respondents
 244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***
 SKILLS (tabulating 1) Skills passed
 by BIOL Studies biology

SKILLS	Count		Row Total
	Yes	No	
S23	1	2	75
Recognises anomalous	55	20	30.7
S25	104	57	161
Recognises pattern 1	97	53	66.0
S26	128	91	150
Draws validd conclust	102	71	61.5
S27	92	47	219
Recognises an uncount	22	2	89.8
S28	26	12	173
Devises method to co	48	18	70.9
S29	141	103	139
Forms hypothesists to	57.8	42.2	57.0
S30			24
Forms 3 hypotheses f			9.8
S32			38
Devises experiment t			15.6
PRED			66
Predicts based on pr			27.0
Column Total	141	103	244
Total	57.8	42.2	100.0

Percents and totals based on respondents
 244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***
 SKILLS (tabulating 1) Skills passed
 by PHYS studies physics

SKILLS	PHYS		Row Total
	Count Yes	No	
S23 Recognises anomalous	33	42	75 30.7
S25 Recognises pattern 1	66	95	161 66.0
S26 Draws validd conclusi	60	90	150 61.5
S27 Recognises an uncount	76	143	219 89.8
S28 Devlases method to co	68	105	173 70.9
S29 Forms hypothesists to	62	77	139 57.0
S30 Forms 3 hypothesises f	20	4	24 9.8
S32 Devlases experiment t	20	18	38 15.6
PRED Predicts based on pr	30	36	66 27.0
Column Total	82 33.6	162 66.4	244 100.0

Percents and totals based on respondents

244 validd cases; 3 missing cases

* * * C R O S S T A B U L A T I O N * * *

SKILLS (tabulating 1) Skills passed
 by INTSCI Studies Integrated or combined science

SKILLS	Count		ROW Total
	Yes	No	
S23	1	2	75
Recognises anomalous	27	48	30.7
S25	64	97	161
Recognises pattern 1	59	91	66.0
S26	59	91	150
Draws valid conclus1	101	118	61.5
S27	101	118	219
Recognises an uncont	80	93	89.8
S28	80	93	173
Devises method to co	52	87	70.9
S29	52	87	139
Forms hypothesis to	4	20	57.0
S30	4	20	24
Forms 3 hypotheses f	12	26	9.8
S32	12	26	38
Devises experiment t	22	44	15.6
PRED	22	44	66
Predicts based on pr			27.0
Column	113	131	244
Total	46.3	53.7	100.0

Percents and totals based on respondents

244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***
 SKILLS (tabulating 1) SKILLS passed
 by TYPE Teaching method employed

SKILLS	Count	TYPE	Trad	Process Science	Row Total
S23	67	1	2	8	75
Recognises anomalous					30.7
S25	133		28	28	161
Recognises pattern 1					66.0
S26	122		28	28	150
Draws valid conclusi					61.5
S27	177		42	42	219
Recognises an uncont					89.8
S28	140		33	33	173
Devises method to co					70.9
S29	113		26	26	139
Forms hypothesis to					57.0
S30	23		1	1	24
Forms 3 hypotheses f					9.8
S32	31		7	7	38
Devises experiment t					15.6
PRED	59		7	7	66
Predicts based on pr					27.0
Column Total	191		53	53	244
Total	78.3		21.7	21.7	100.0

Percents and totals based on respondents
 244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***

SKILLS (tabulating 1) SKILLS passed
 by SINGSEX Single-sex or co-educational school

SKILLS	Count		Row Total
	Single sex	Co-ed	
S23 Recognises anomalous	24	51	75 30.7
S25 Recognises pattern 1	48	113	161 66.0
S26 Draws valid conclusi	45	105	150 61.5
S27 Recognises an uncount	71	148	219 89.8
S28 Devises method to co	61	112	173 70.9
S29 Forms hypothesis to	36	103	139 57.0
S30 Forms 3 hypotheses f	3	21	24 9.8
S32 Devises experiment t	9	29	38 15.6
PRED Predicts based on pr	13	53	66 27.0
Column Total	74 30.3	170 69.7	244 100.0

Percents and totals based on respondents

244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***
 SKILLS (tabulating 1) Skills passed
 by SCHOOL School Name

SKILLS	SCHOOL										Row Total
	Count	Woodland Bablake	Cardinal Newman	K Henry VIII	Judge Meadow	Ruford	S Joseph Convent	Stoke PK Wood	Tile Hill	Wreake Valley	
S23 Recognises anomalous	1	2	3	4	5	6	7	8	9	10	75
S25 Recognises pattern 1	9	16	16	42	14	9	32	9	7	7	161
S26 Draws valid conclusions	8	16	7	38	11	8	25	13	12	12	150
S27 Recognises an uncount	14	18	22	46	20	15	37	17	20	10	219
S28 Devises method to compare	14	17	15	33	17	8	30	11	17	11	173
S29 Forms hypothesis to test	7	13	12	37	16	7	25	14	4	4	139
S30 Forms 3 hypotheses to test	0	2	1	17	0	1	3	0	0	0	24
S32 Devises experiment to test	0	0	5	14	6	1	9	3	0	0	38
PRED Predicts based on previous	2	8	9	25	4	3	10	4	1	0	66
Column Total	17	18	22	49	24	19	37	24	20	14	244
	7.0	7.4	9.0	20.1	9.8	7.8	15.2	9.8	8.2	5.7	100.0

Percents and totals based on respondents

244 valid cases; 3 missing cases

*** C R O S S T A B U L A T I O N ***

SKILLS (tabulating 1) Skills passed
 by GRIQ Intelligence quotient (grouped)

SKILLS	GRIQ									Row Total
	Under 65	65 - 75	75 - 85	85 - 95	95 - 105	105-115	115-125	125-135	Over 135	
S23 Recognises anomalous	1	3	4	5	6	7	8	9		75
S25 Recognises pattern 1	0	1	7	20	13	15	11	8		30.7
S26 Draws valid conclusi	1	3	27	42	33	24	20	11		161
S27 Recognises an uncount	0	4	30	37	28	21	19	11		66.0
S28 Devises method to co	2	8	41	67	37	26	28	10		150
S29 Forms hypothesis to	1	7	31	54	29	21	23	7		219
S30 Forms 3 hypotheses f	1	2	24	41	21	22	20	8		89.8
S32 Devises experiment t	0	0	1	2	3	5	9	4		173
PRED Predicts based on pr	0	2	4	11	4	9	5	3		70.9
Column Total	0	1	7	20	11	10	10	7		139
	2	9	51	73	40	29	28	12		57.0
	.8	3.7	20.9	29.9	16.4	11.9	11.5	4.9		244

Percents and totals based on respondents

244 valid cases; 3 missing cases

Appendix IV

Statistical Analysis of the Results - Pages 1-14
Graphical Displays of the Results - 15-40

APPENDIX IV

Statistical Analysis of the data

The data was analysed to establish the level of statistical significance using the Chi squared test with the Yates correction. The correction was necessary because two random binomial samples are involved each divided into two classes. (Langley, R. 1968) Statistical Tables (Fisher and Yates 1970).

Example, To evaluate the difference in performance of boys and girls within the IQ range 115 to 125 with regards to the 9 skills tested.

The Null hypothesis, (tentative negative assumption) is that the difference in results in the skills tested between boys and girls is not due to their sex but due to chance.

The mean percentage success rate for the nine skills was compared.

	% Success	% Failure	R
Girls	63	57	100
Boys	58	42	100
C	121	79	N=200

Where

R=Row Total

O=Observed Frequency

C=Column Total

$\frac{E=R \times C}{N}$ Expected Frequency

N=Total Number

D=O-E Frequency Difference

df=Degrees of freedom

Y=Difference with Yates correction

O	$\frac{R \times C}{N} = E$	O-E=D	D-0.5=Y	Y ²	$\frac{Y^2}{E}$
63	$\frac{100 \times 121}{200} = 60.5$	63 - 60.5 = 2.5	2.5-0.5 = 2.0	4	$\frac{4}{60.5} = 0.066$
37	$\frac{100 \times 79}{200} = 39.5$	37 - 39.5 = -2.5	2.5-0.5 = 2.0	4	$\frac{4}{39.5} = 0.101$
58	$\frac{100 \times 121}{200} = 60.5$	58-60.5 = -2.5	2.5-0.5 = 2.0	4	$\frac{4}{60.5} = 0.066$
42	$\frac{100 \times 79}{200} = 39.5$	42-39.5 = 2.5	2.5-0.5 = 2.0	4	$\frac{4}{39.5} = 0.101$
		Total Y ² /E = Chi ²			

Therefore the probability that the result is due to chance 0.5 to .07. The null hypothesis is highly probably.

Degrees of freedom df=1

Asian / Non Asian Origin

Null Hypothesis:- that the difference in success in the skills tested in the two samples is due to chance and not significant

	Mean % Success	Mean % Failure	R
Asian Origin	47.4	52.6	100
Non Asian	44.3	55.7	100
C	91.7	108.3	N=200

	O	E	D	Y	Y ²	Y ² /E
Asian	47.4	45.85	1.55	1.05	1.102	0.024
	52.6	54.15	1.55	1.05	1.102	0.023
Non Asian	44.3	45.85	1.55	1.05	1.102	0.024
	55.7	54.15	1.55	1.05	1.102	0.023
df=1			Chi Squared			=0.094

Degrees of Freedom df = 1 Probability that the difference in result is due to chance = 0.7 to 0.8 highly probable.

Comparison of teaching by Process Science rationale as opposed to traditional Science teaching for succes in the skills tested.

Null Hypothesis, the difference in teaching method is not significant, any difference is likely to be due to chance.

O	Mean % Pass	Mean % Failure	R
Traditional	38.1	61.9	100
Process	37.5	62.5	100
C	75.6	124.4	N=200

	O	E	D	Y	Y ²	Y ² /E
Trad.	38.1	37.8	0.3	0.2	0.04	.00105
	61.9	62.2	0.3	0.2	0.04	.00064
Proc.	37.5	37.8	0.3	0.2	0.04	.00105
	62.5	62.2	0.3	0.2	0.04	.00064
df=1	Chi Squared = .00338					

Probability that the difference is due to chance 0.90-0.95

Extremely probable.

Non-selective compared to selective crossmatched for IQ for success in the skills tested.

	Mean % Success	Mean % Failure	R
Non Select	41.1	58.9	100
Select	62.8	37.2	100
C	103.9	96.1	N=200

	O	E	D	Y	Y ²	Y ² /E
Non-Select	41.1	51.95	10.85	10.35	107.12	2.06
	58.9	48.05	10.85	10.35	107.12	2.06
Select	62.8	51.95	10.85	10.35	107.12	2.06
	37.2	48.05	10.85	10.35	107.12	2.23
df=1	Chi squared = 10.25					

Probability that the result is due to chance .01 - .001

The null hypothesis is very improbable, ie., selective education as opposed to non-selective is very significant as a causative factor in the difference in the results.

Non-selective compared to selective the probability of gaining grade A, B or C

	ABC Grade	not ABC Grade	R
Non Select	15	10	25
Select	25	0	25
C	40	10	N=50

Ideally for these numbers, Fisher's Test should have been used, however, the value 0 made it unworkable.

	O	E	D	Y	Y ²	Y ² /E
Non-Select	15	20	5	4.5	20.25	1.01
	10	5	5	4.5	20.25	4.05
Select	25	20	5	4.5	20.25	1.01
	0	5	5	4.5	20.25	4.05

Probability that this result is due to chance .01-.001. The selective Education seems to be very significant in obtaining grades A,B or C

Single Sexed Education as opposed to Co-education for boys for success in the skills tested.

Null hypothesis, that the difference in results is due to chance.

	Mean % Success	Mean % Failure	R
Single Sex	34.5	65.5	100
Co-ed	35.5	64.5	100
C	70.0	130	N=200

	O	E	D	D ²	D ² /E
Single Sex	34.5	35	0.5	0.25	.007
	65.5	65	0.5	0.25	.0038
Co-ed	35.5	35	0.5	0.25	.007
	64.5	65	0.5	0.25	.0038
df=1	Chi squared = .0216				

Yates correction cannot be applied the difference is too small

Probability that the difference is due to chance .80-.90. Highly probable

Girls in a single sex comprehensive as compared to girls in a co-educational comprehensive cross matched for IQ for success in the skills tested.

O	Mean % Success	Mean % Failure	R
Single Sex	35.7	64.3	100
Co-ed	40.3	59.7	100
C	76.0	124.0	N=200

	O	E	D	Y	Y ²	Y ² /E
Single Sex	35.7	38	2.3	1.8	3.24	0.085
	64.3	62	23.	1.8	3.24	0.052
Co-ed	40.3	38	2.3	1.8	3.24	0.085
	59.7	62	2.3	1.8	3.24	0.053
df=1	Chi Squared = 0.274					

The probability that the difference in the result is due to chance is 0.5 to 0.7, highly probable.

Girls in a single sexed semi-selective school as compared to girls in a co-educational comprehensive school cross matched for IQ for the success in the skills tested.

O	Mean % Success	Mean % Failure	R
Single Sex	64.2	35.8	100
Co-ed	53.9	46.1	100
C	118.1	81.9	N=200

	O	E	D	Y	Y ²	Y ² /E
Single Sex	64.2	59.05	5.15	4.65	21.62	0.37
	35.8	40.95	5.15	4.65	21.62	0.53
Co-Ed	53.9	59.05	5.15	4.65	21.62	0.37
	46.1	40.95	5.15	4.65	21.62	0.37
df=1	Chi Squared				1.8	

The probability that this result is due to chance 0.1 to 0.2 a lower level of probability but the probability of single sex education being the cause of the difference is still not significant.

The effect of the study of three Sciences in a non-selective school as opposed to studying integrated science, the candidates are Cross matched for IQ on the success in the skills tested.

Null hypothesis that the differences in result is not significant but due to chance.

	Mean % Success	Mean % Failure	R
3 Science	37	63	100
Integrated Science	42	58	100
C	79	121	200

	O	E	D	Y	Y ²	Y ² /E
3 Science	37	39.5	2.5	2	4	0.101
	63	60.5	2.5	2	4	0.066
Integrated	42	39.5	2.5	2	4	0.101
	58	60.5	2.5	2	4	0.066
df=1	Chi Squared =				0.334	

Probability that the result is due to chance 0.5 to 0.7

The effect of studying three sciences in a semi selective school as opposed to not studying three sciences on success in the skills tested.

Null hypothesis that the difference is due to chance.

	Mean % Success	Mean % Failure	R
3 Sciences	58.3	41.7	100
Integrated Science	57.6	41.4	100
C	115.9	84.1	200

	O	E	D	Y	Y ²	Y ² /E
3 Sciences	58.3	57.95	0.35	0.3	0.09	.0015
	41.7	42.05	0.35	0.3	0.09	.0021
Not 3 Sciences	57.6	57.95	0.35	0.3	0.09	.0015
	42.4	42.05	0.35	0.3	0.09	.0021
df=1	Chi Squared = .0072					

The probability that this difference is due to chance is 0.90 to 0.95. Highly probable.

The effect of studying three sciences in a selective school as opposed to not studying three sciences on success in the skills tested.

Null hypothesis that the difference is due to chance.

Sample A (The original sample)

	Mean % Success	Mean % Failure	R
Studies 3 Sciences	71.4	28.6	100
Does not study 3 Sciences	49.0	51.0	100
C	120.4	79.6	N=200
df = 1	Chi Squared = .01 to .001		

	O	E	D	Y	Y ²	Y ² /E
3 Sciences	71.4	60.2	11.2	10.7	114.49	1.90
	28.6	39.8	11.2	10.7	114.49	2.87
Not 3 Sciences	49.0	60.2	11.2	10.7	114.49	1.90
	51.0	39.8	11.2	10.7	114.49	2.87

The probability that this result is done is due to chance is .01 to .001. It is unlikely to be due to chance.

Sample B the test was repeated in 1993 using two groups taught by the same teacher under very similar conditions.

	Mean % Success	Mean % Failure	R
Studies 3 Sciences	62.9	37.1	100
Does not study 3 Sciences	59.4	40.6	100
C	122.3	77.7	N=200

	O	E	D	Y	Y ²	Y ² /E
3 Sciences	62.9	61.15	1.75	1.25	1.56	.025
	37.1	38.85	1.75	1.25	1.56	.040
Not 3 Sciences	59.4	61.16	1.75	1.25	1.56	.025
	40.6	38.85	1.75	1.25	1.56	.040
df=1	Chi Squared =					.130

The probability that this result is caused by chance is 0.7 to 0.8 highly probable.

Neither sample was cross matched for IQ although both were taken from the same selective school and therefore in the same restricted IQ range.

**The effect of the results of studying 3 Sciences for the whole original sample
Cross matched for IQ for success in the skills tested.**

	Mean % Success	Mean % Failure	R
Studies 3 Sciences	62.7	37.3	100
Does not study 3 Sciences	53.0	47	100
C	115.7	84.3	N=200

	O	E	D	Y	Y ²	Y ² /E
3 Sciences	62.7	57.85	4.85	4.8	23.04	0.398
	37.3	42.15	4.85	4.8	23.04	0.547
Not 3 Sciences	53.0	57.85	4.85	4.8	23.04	0.398
	47.0	42.15	4.85	4.8	23.04	0.547

Probability that the difference is due to chance 0.10 to 0.20

**To find the effect of studying three sciences on obtaining an A Grade GCSE
using the above sample.**

	Grade A	Not Grade A	R
Studies 3 Sciences	19	26	45
Does not study 3 Sciences	5	40	45
C	24	66	90=N

	O	E	D	Y	Y ²	Y ² /E
3 Sciences	19	12	7	6.5	42.25	3.52
	26	33	7	6.5	42.25	1.28
Not 3 Sciences	5	12	7	6.5	42.25	3.52
	40	33	7	6.5	42.25	1.22
1df	Chi Squared = 9.60					

The probability that this result is due to chance is .01 to .001.

ie.,the study of three sciences is highly significant in obtaining a Grade A at GCSE.

The correlation of passing skill 30 with obtaining a GCSE Grade A

Null hypothesis that there is no correlation between these criteria.

	Passed 30	Failed 30	N
Obtained Grade A	62.6	37.4	100
Did not obtain Grade A	18.7	81.3	100
C	81.3	118.7	N=200

	O	E	D	Y	Y ²	Y ² /E
Grade A	62.6	40.65	21.95	21.9	479.61	11.80
	37.4	59.35	21.95	21.9	479.61	8.80
Not Grade A	18.7	40.65	21.95	21.9	479.61	11.80
	81.3	59.65	21.95	21.9	479.61	8.80
df=1	Chi Squared = 39.76					

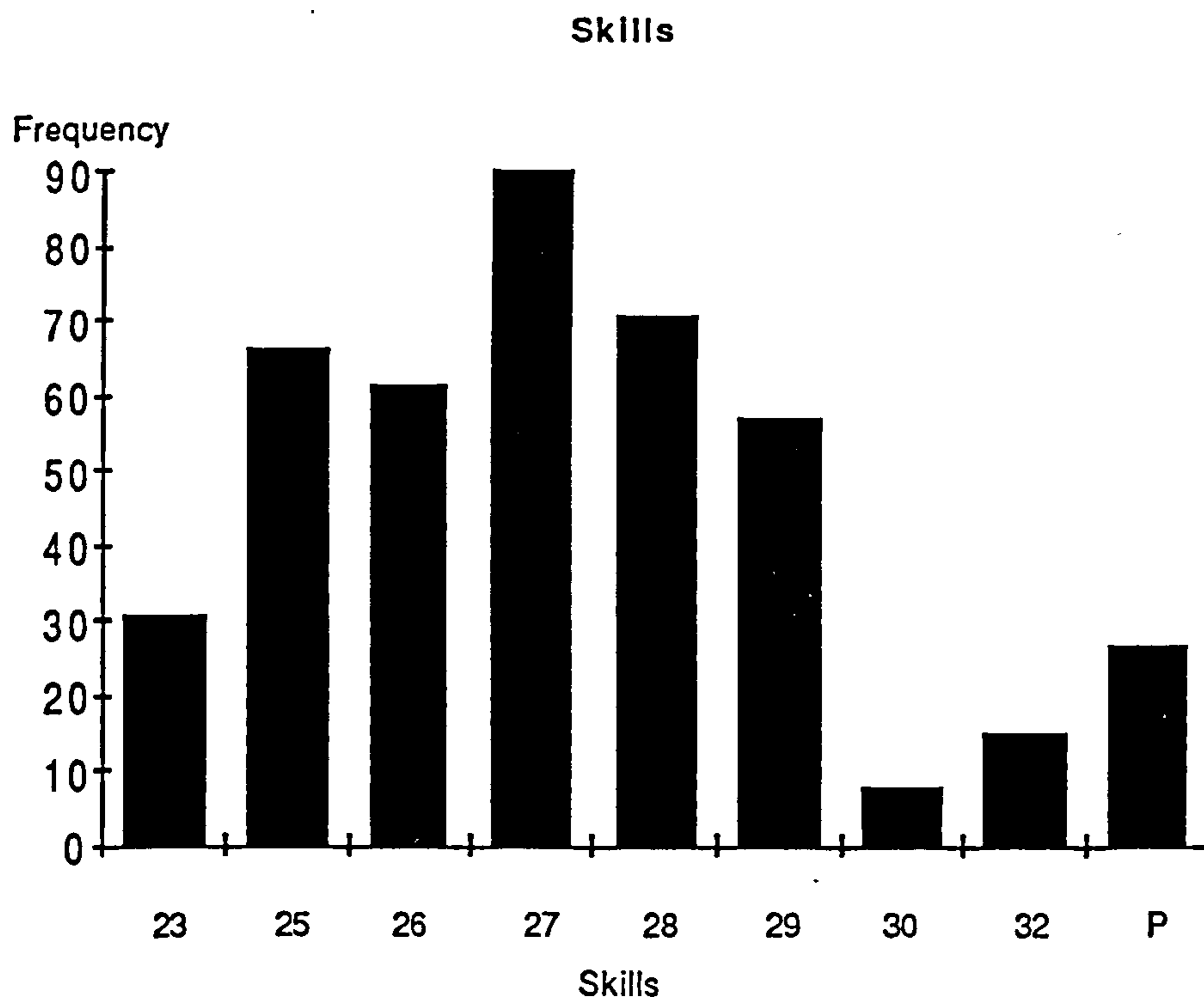
The probability that there is no correlation between the ability to obtain a Grade A at GCSE and pass 30 skill is less than 0.001. The correlation is therefore very significant.

Graphical Displays

Pages 15 - 40

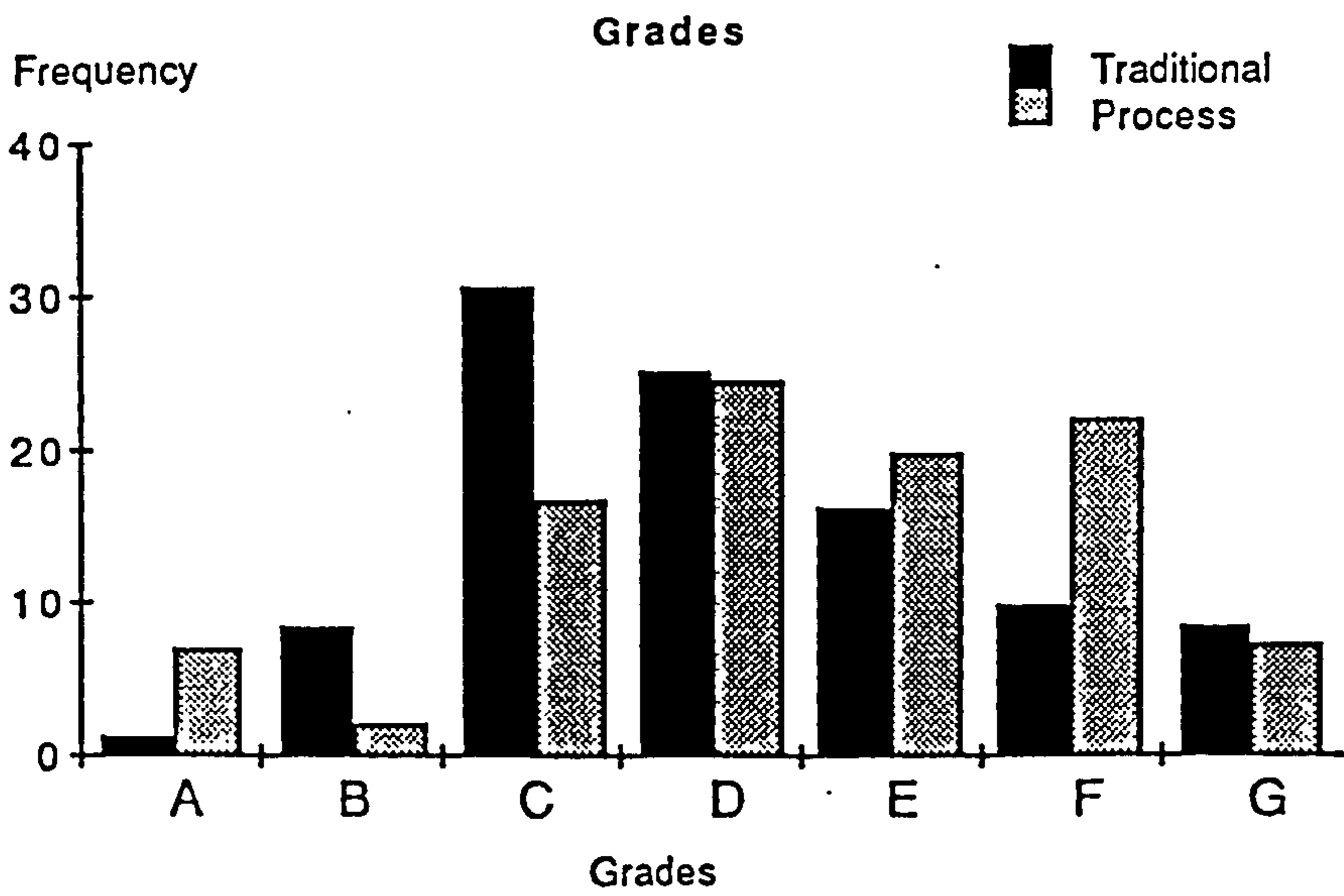
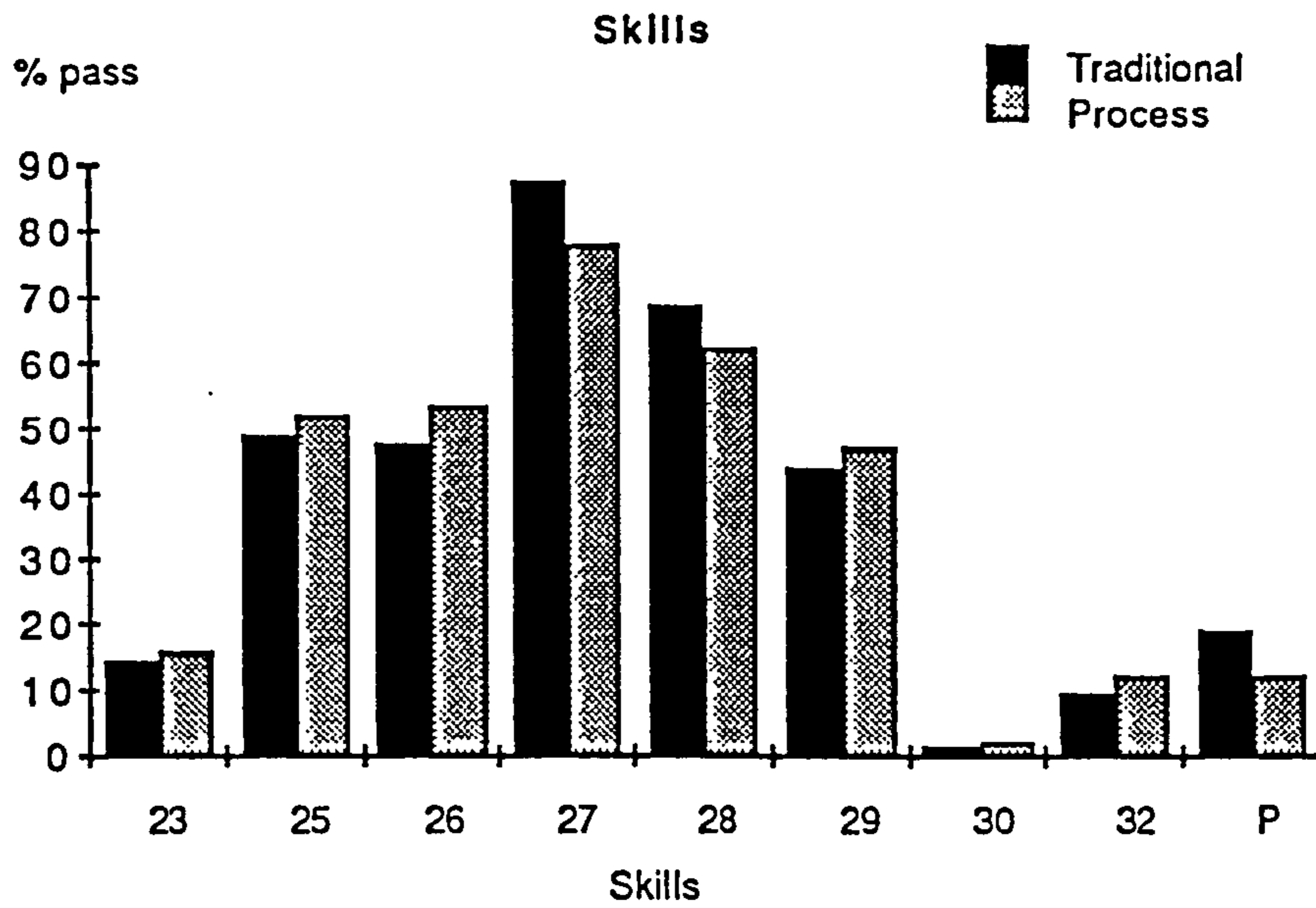
Graph 3.1

% Success Rate in the Nine Skills for the Entire sample



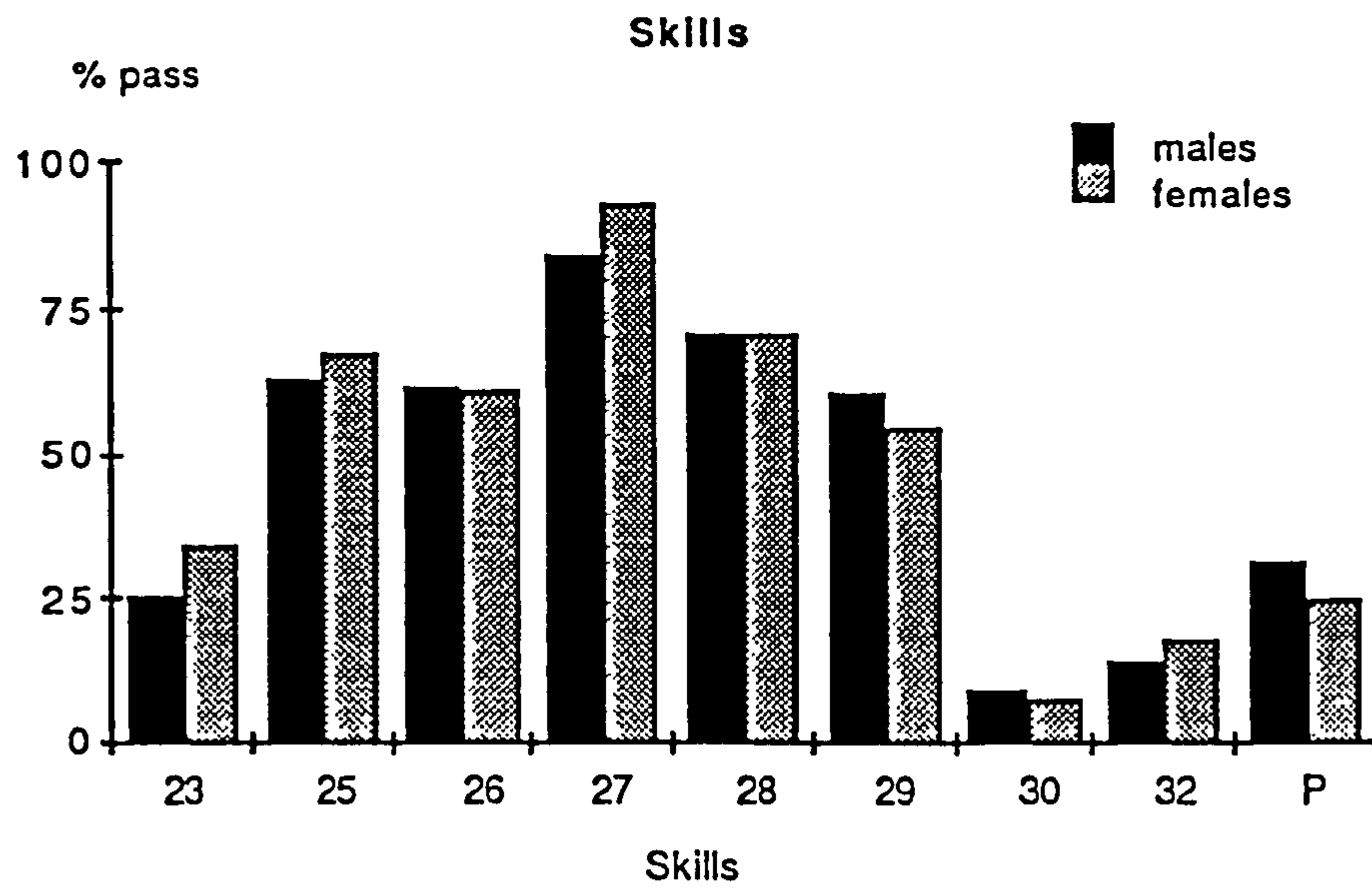
Graph 3.2

% pass rate in the selected skills and the grades achieved by all the candidates in comprehensive schools using traditional science compared to those studying process science.



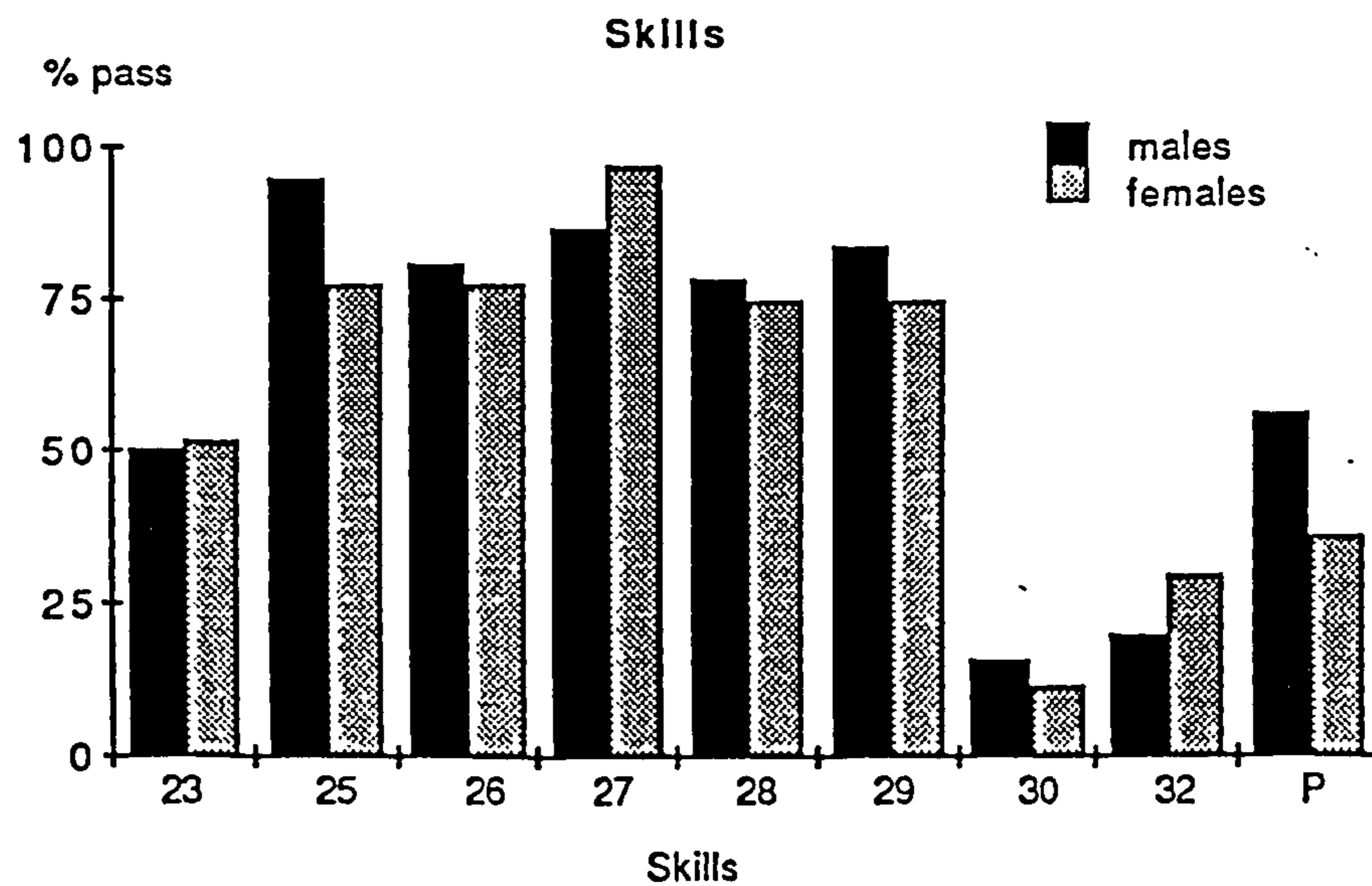
Graph 3.3

% pass rate for the selected skills of the total sample, males and females compared.



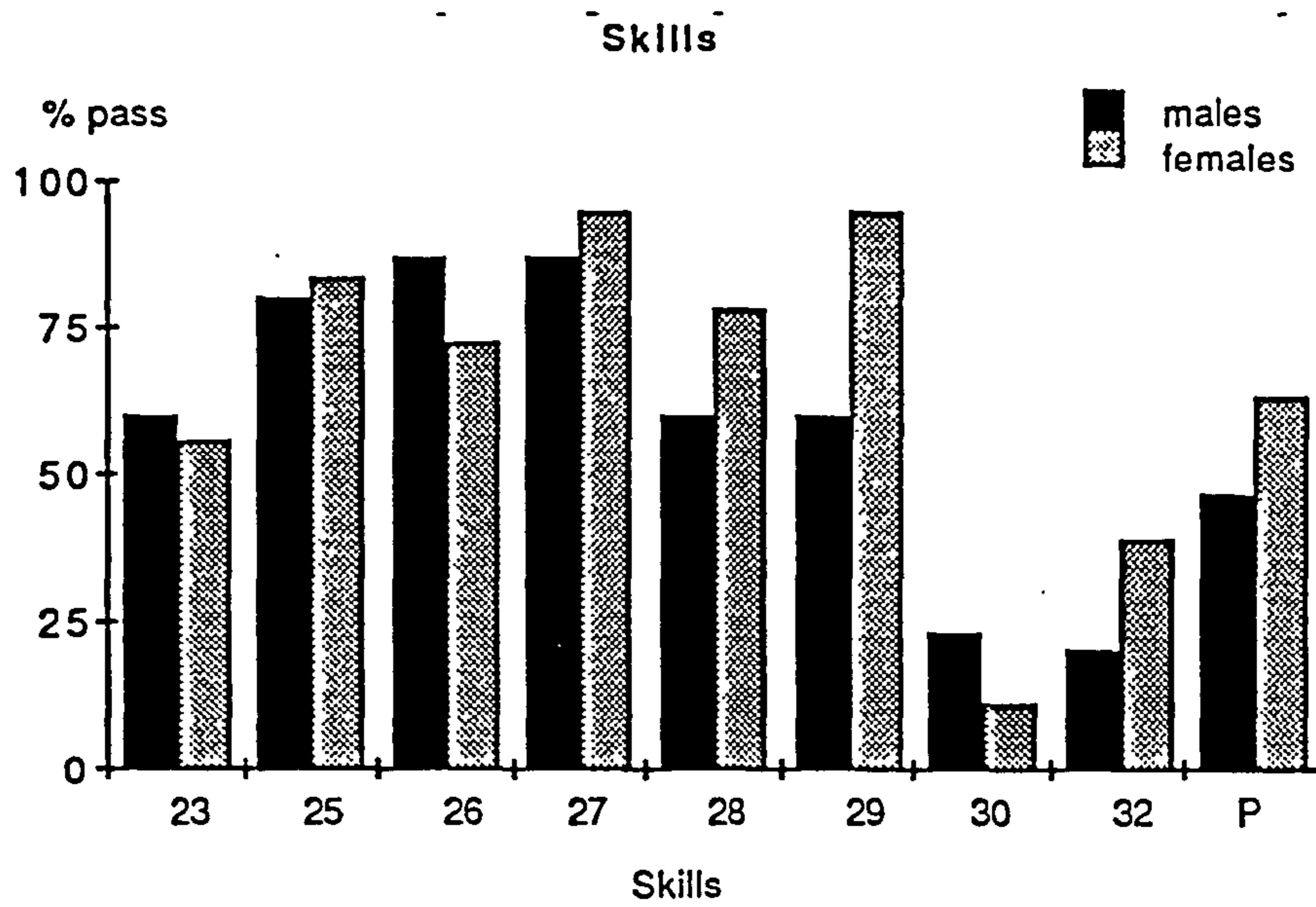
Graph 3.4

% pass rate for the selected skills in selective schools, males and females compared.

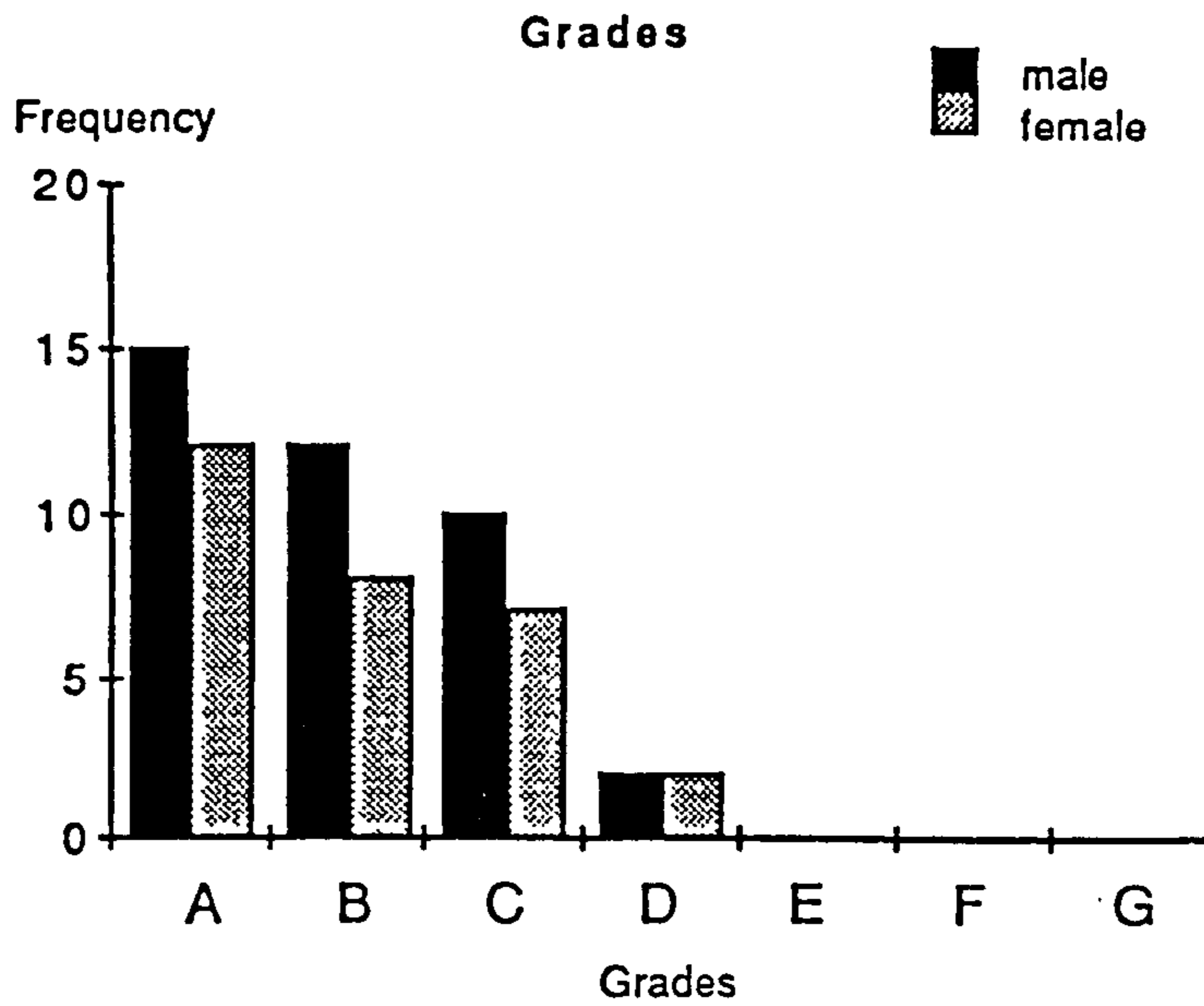


Graph 3.5

% pass rate for the selected skills by students of IQ range 115 to 125, males and females compared.

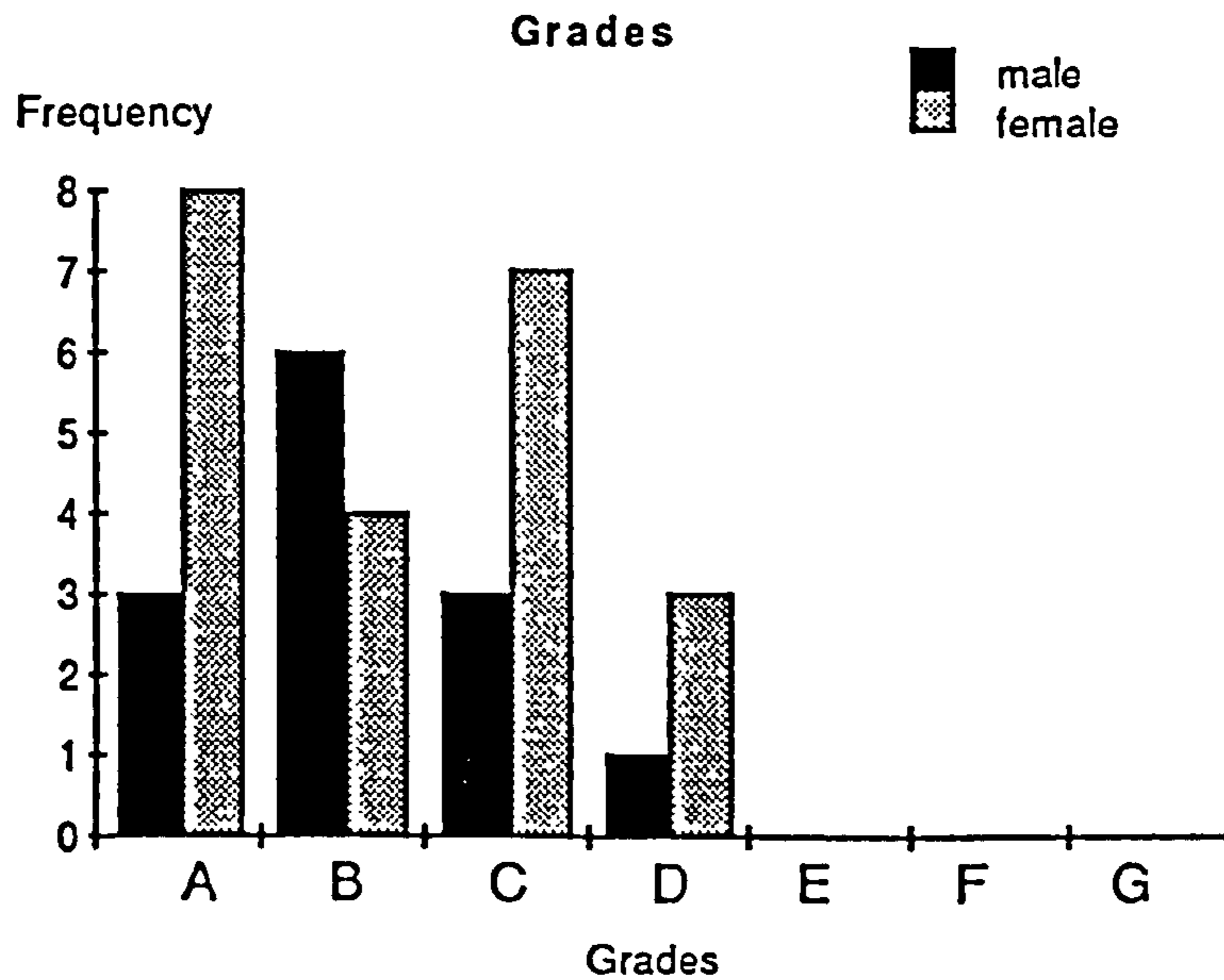


Grades achieved by selective school pupils,
males and females compared.



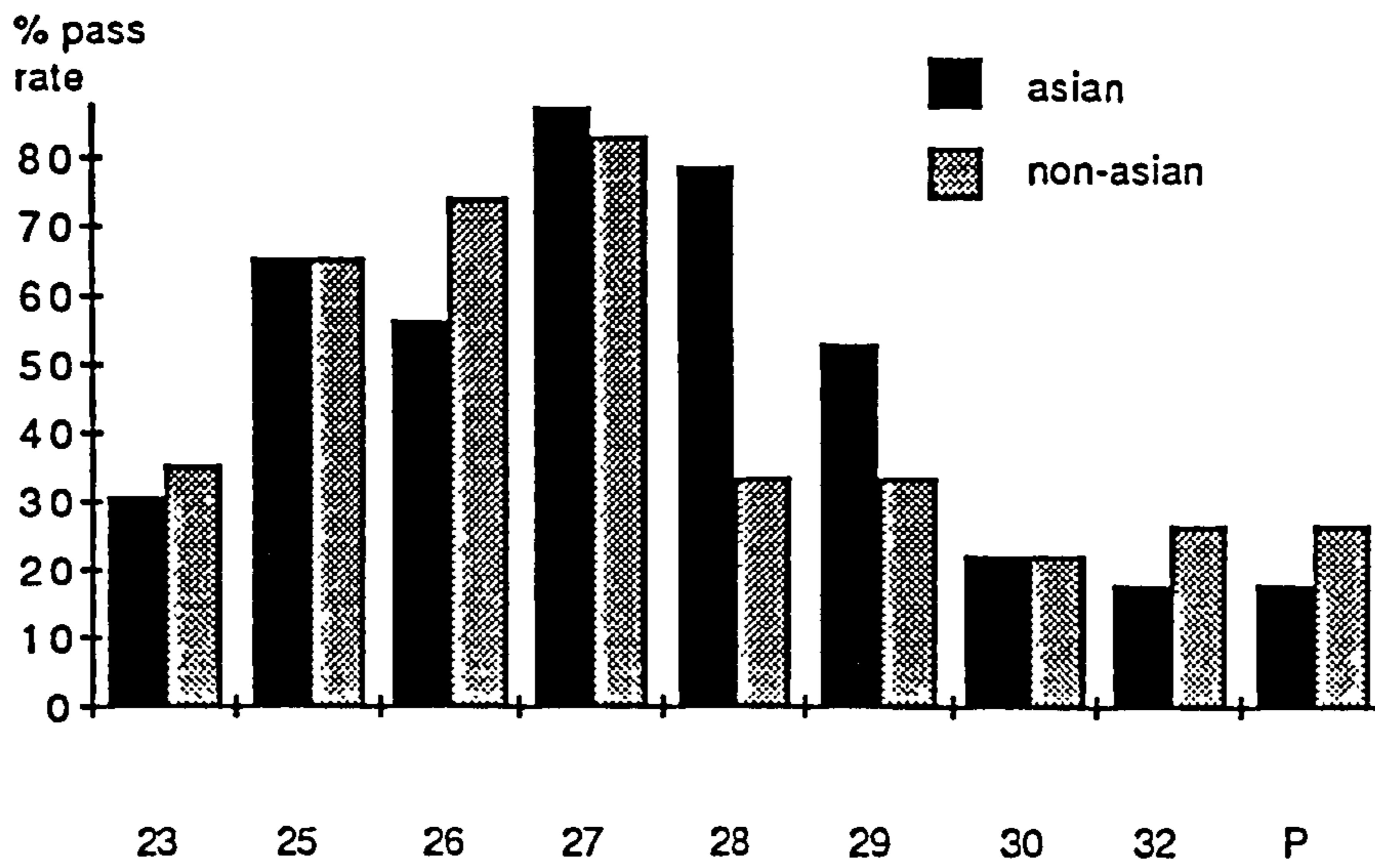
Graph 3.7

Grades achieved by pupils of IQ range 115 - 125,
males and females compared.



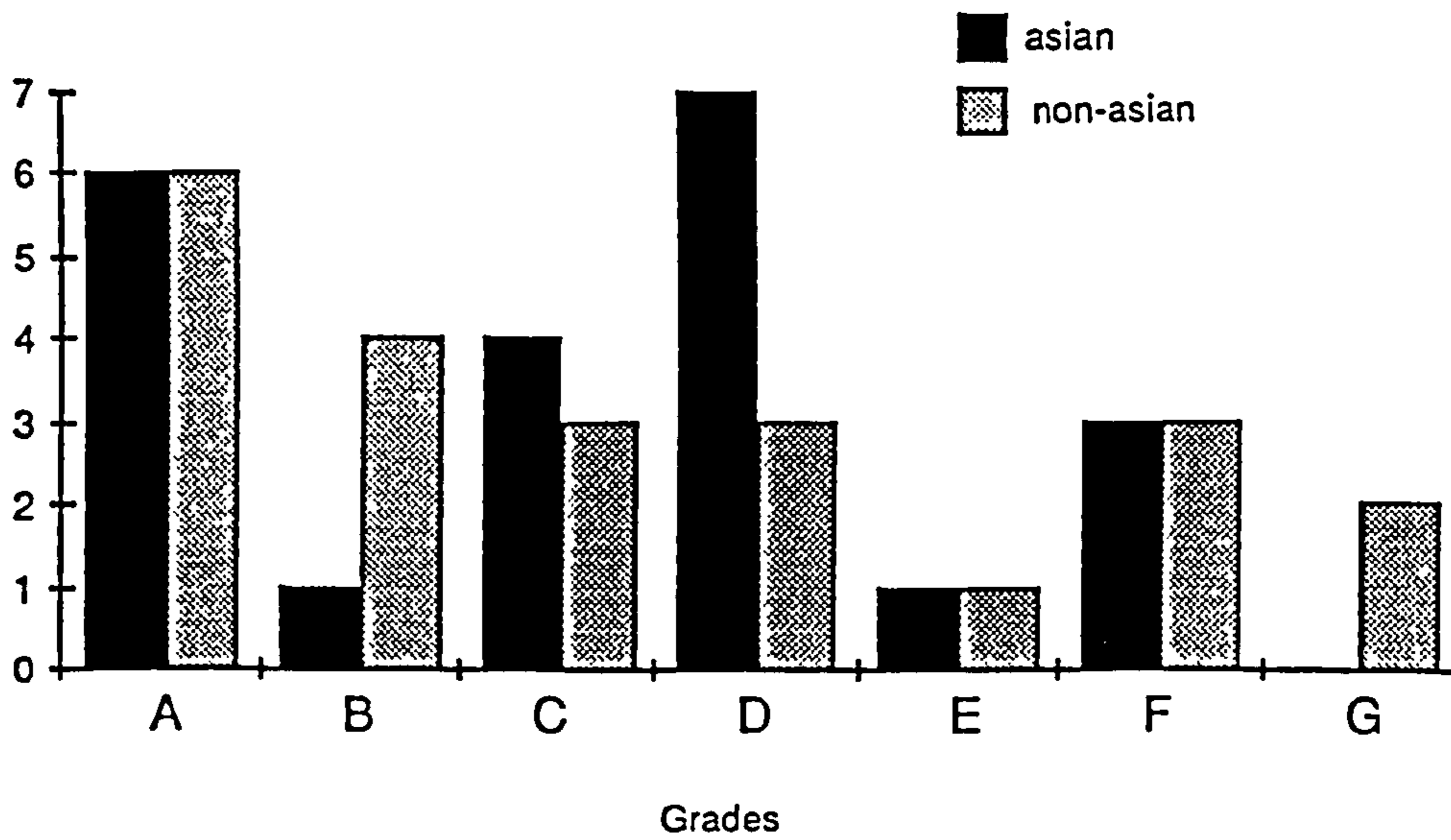
Graph 3.8

Pass Rate of Skills Asian and Non-Asian Candidates cross matched for IQ

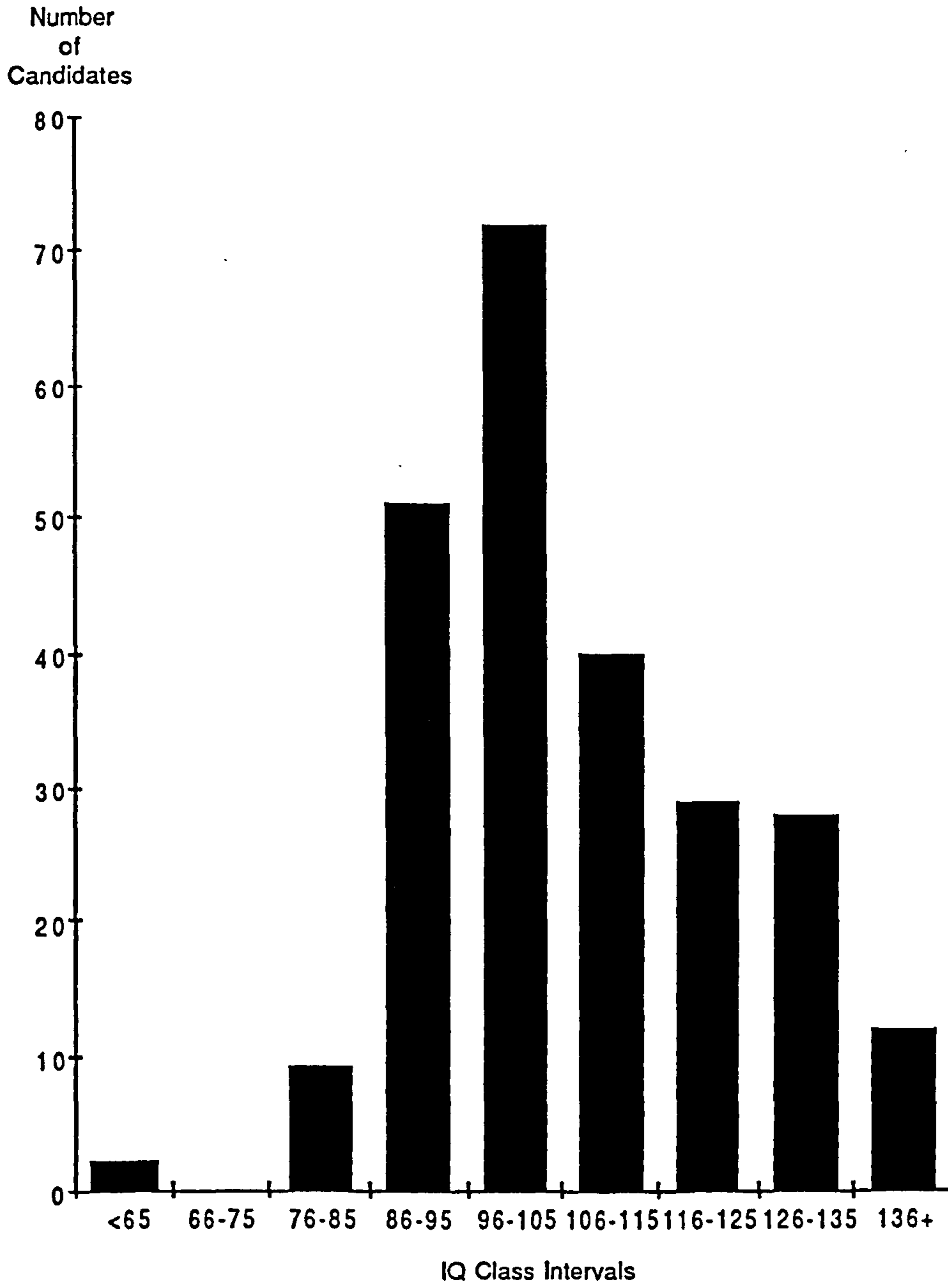


Graph 3.9

Grade Distribution for Asian and Non-Asian candidates cross matched for IQ

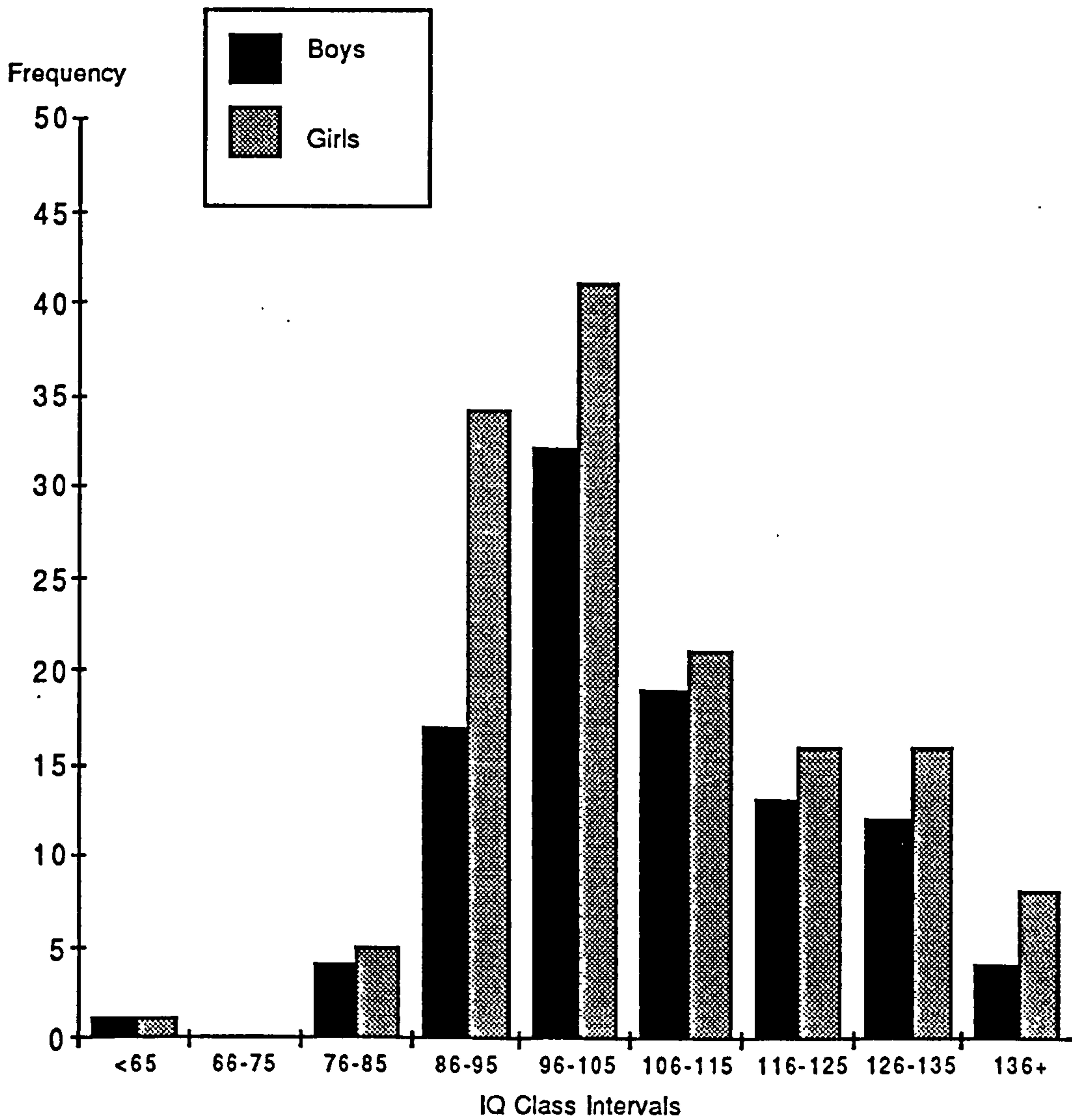


Distribution of IQ within the Population tested



Total tested 244
Mean 106.5
Range 57-158
Mode 96-105
Median 102.

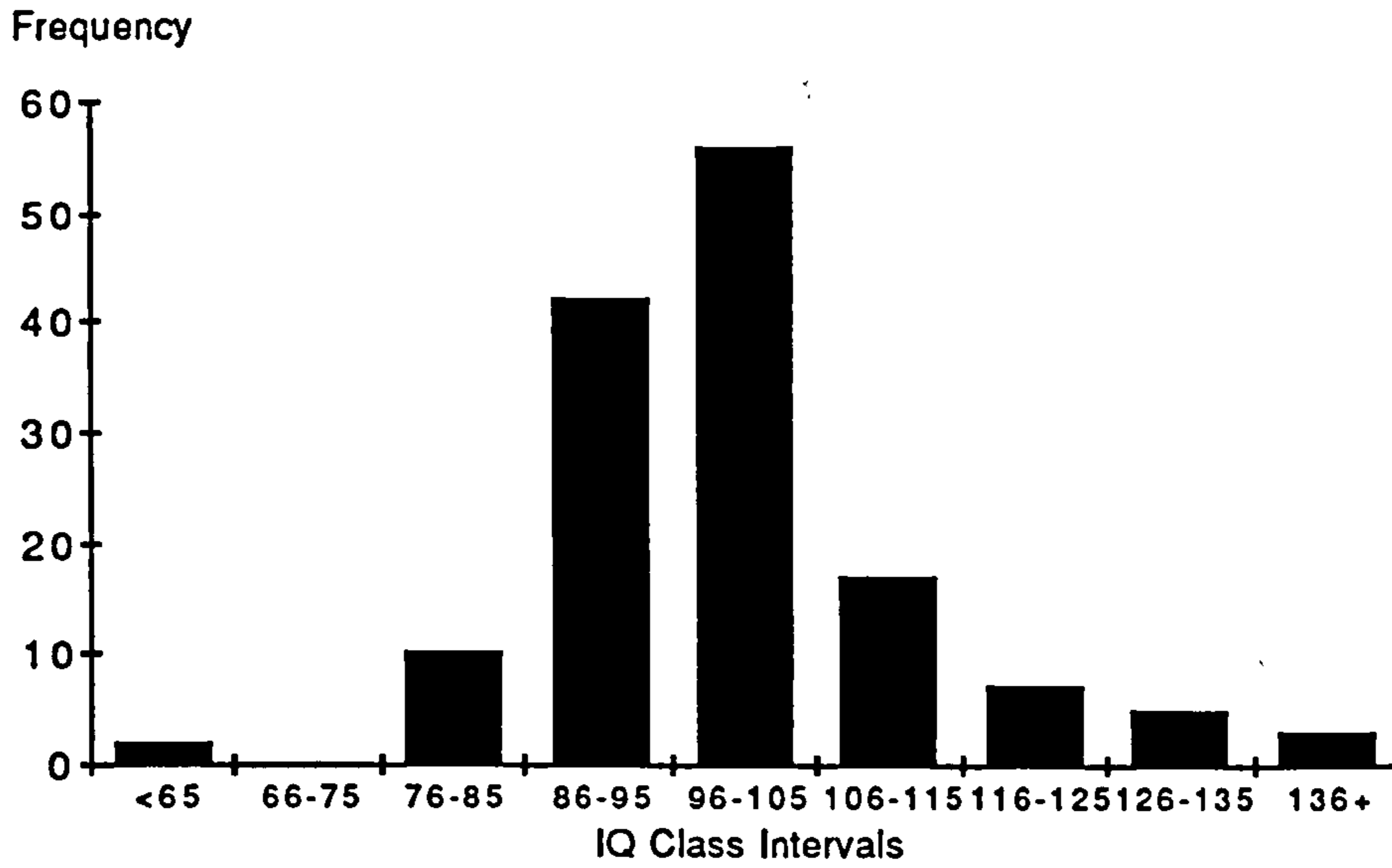
Distribution of IQ for boys and girls separately



	Boys	Girls
Total	102	142
Mode Interval	96-105	96-105
Range	57-139	57-158
% Below mode	21.8%	29.5%
% Above mode	47.5%	43.2%
Number above mode	22	40
Number above mode	48	61

Graph 3.12

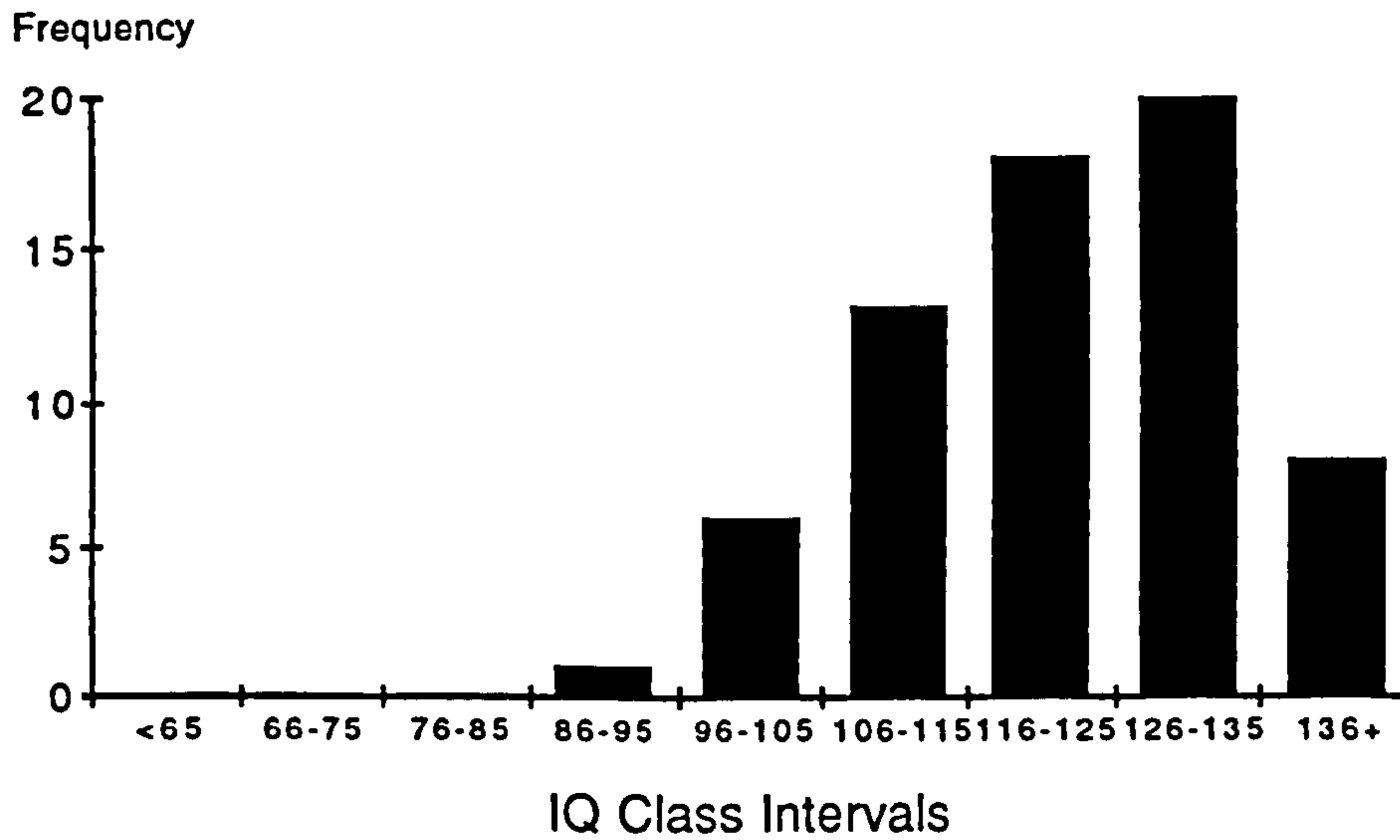
All Comprehensive Schools Sampled



Mean	101.8
Range	57-158
Median	96-105
Mode	96-105

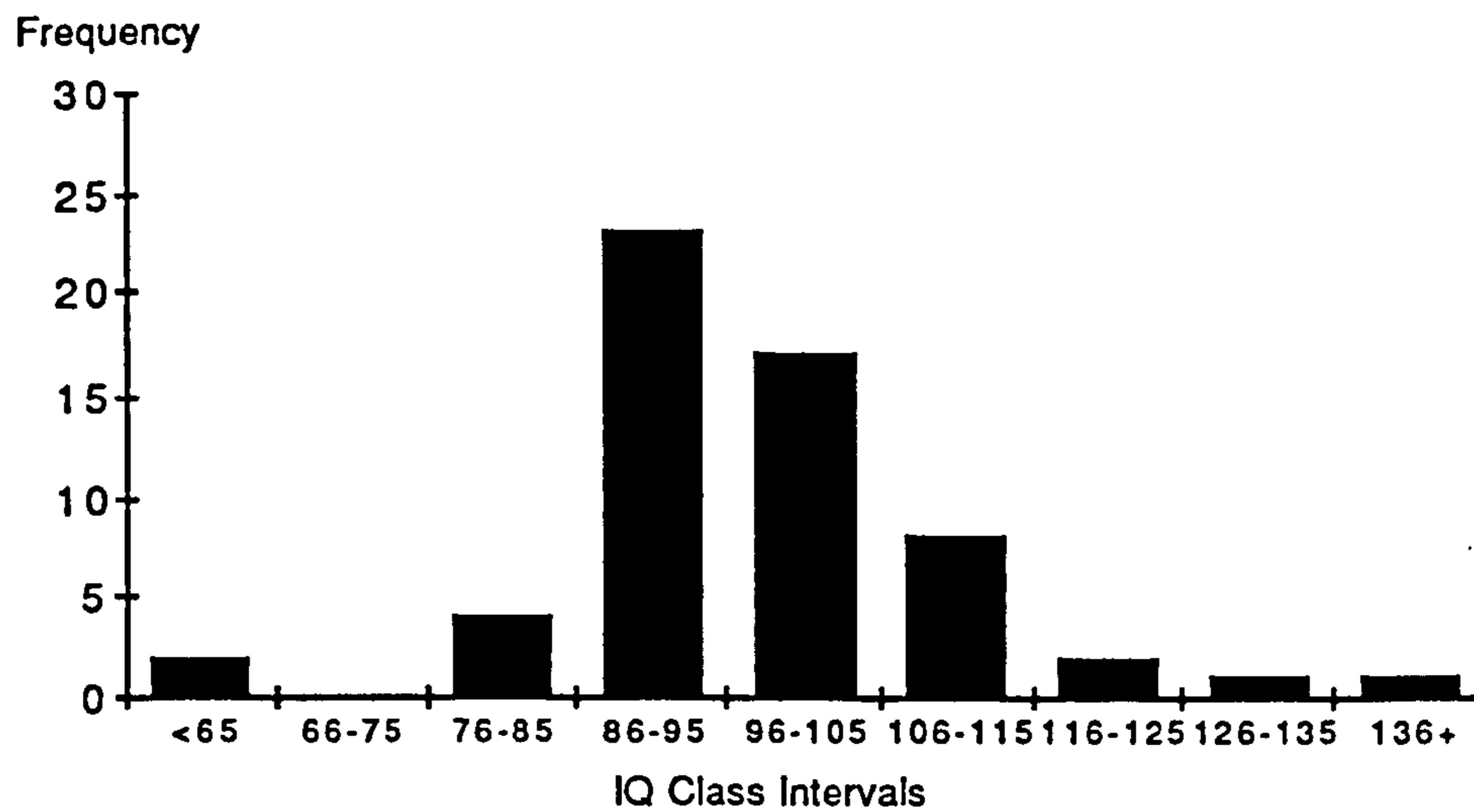
Graph 3.13

Selective Schools



Mean	
Range	
Median	116-125
Mode	125-135

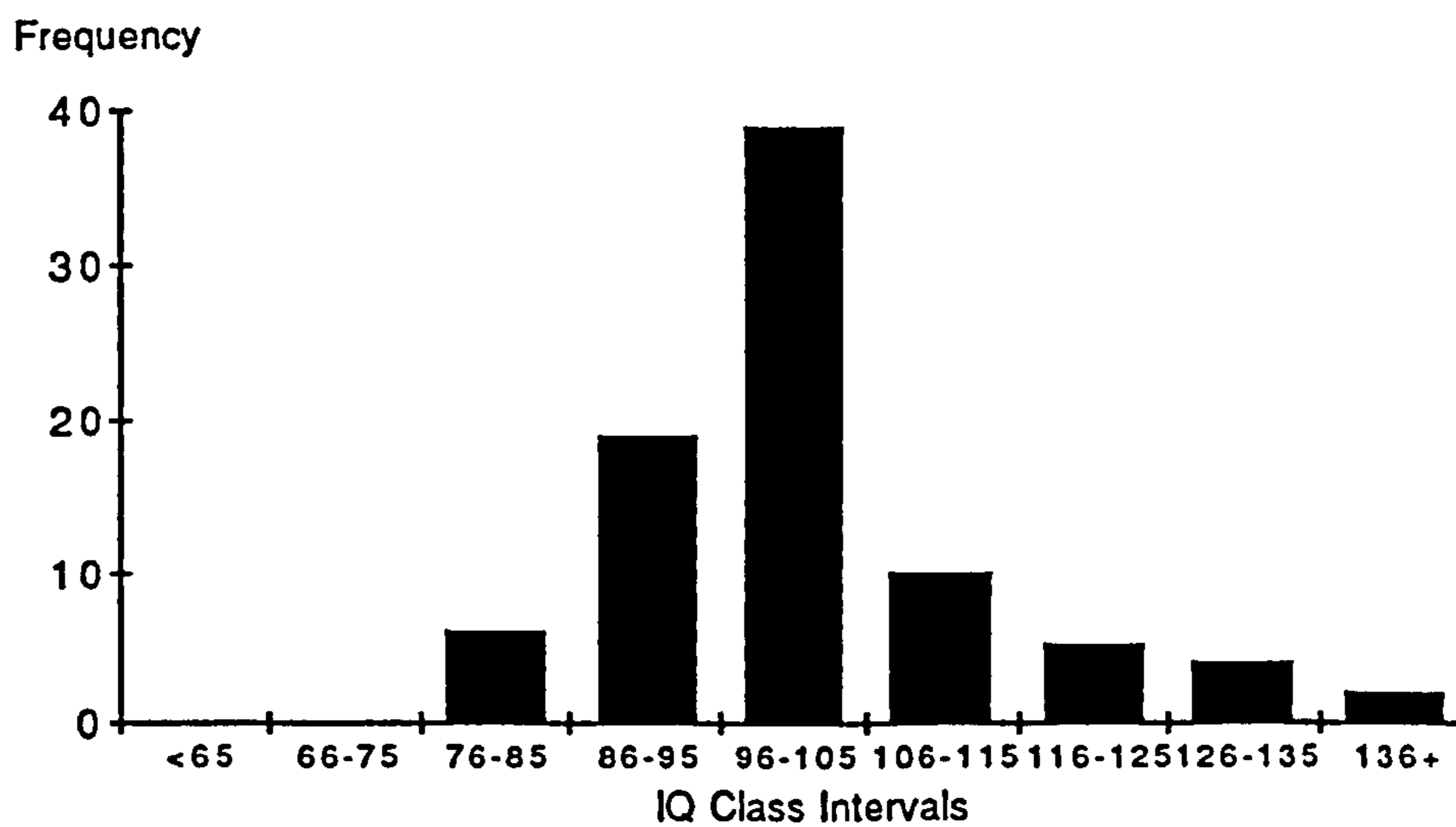
Process Science Comprehensive Schools



Mean	107.9
Range	57-158
Median	96-105
Mode	86-95

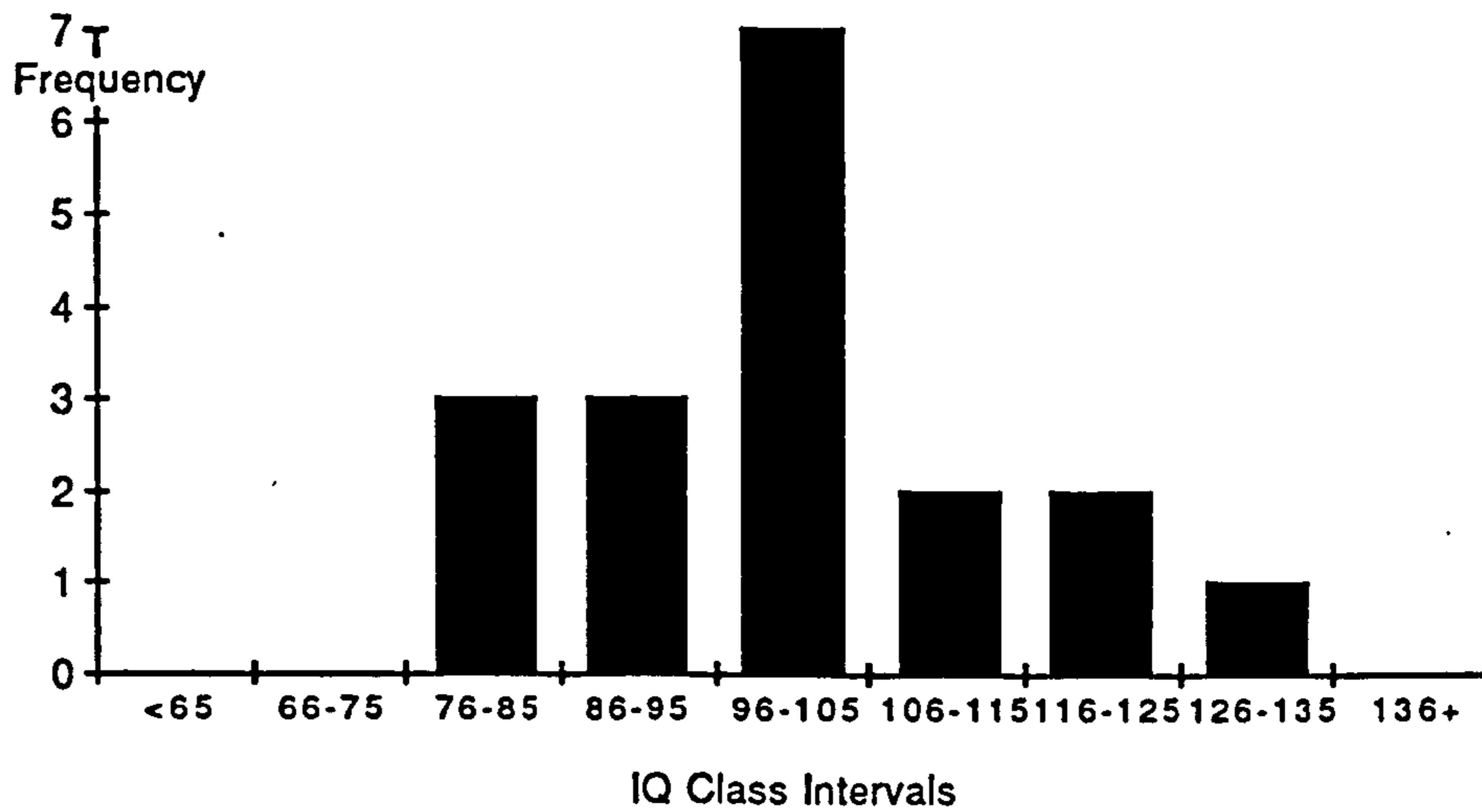
Graph 3.15

Traditional Science Comprehensive Schools



Mean	102.4
Range	83-139
Median	96-105
Mode	96-105

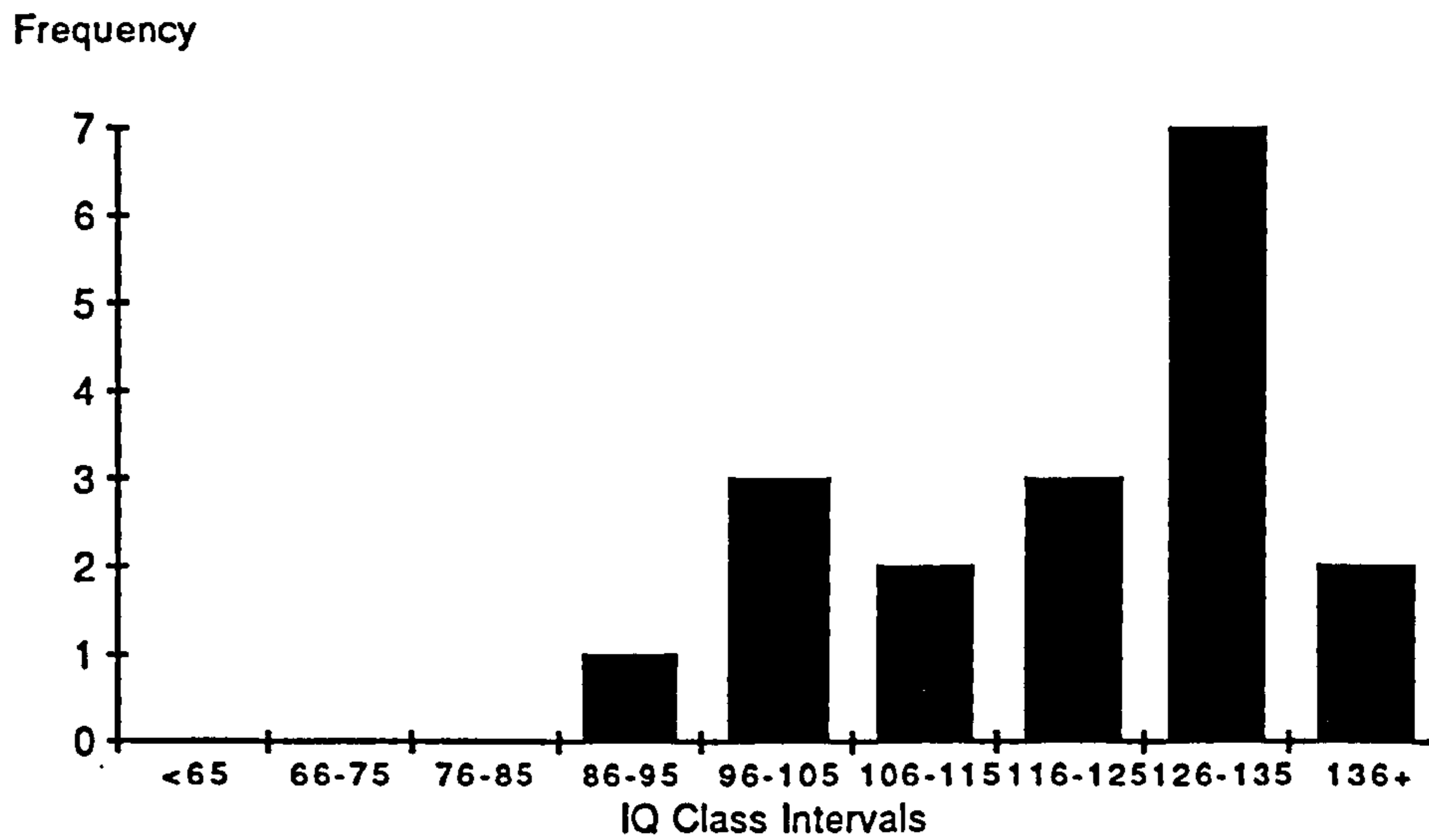
School 1



Mean IQ	99
Range	76-127
Median	96-105
Mode	96-105

Graph 3.17

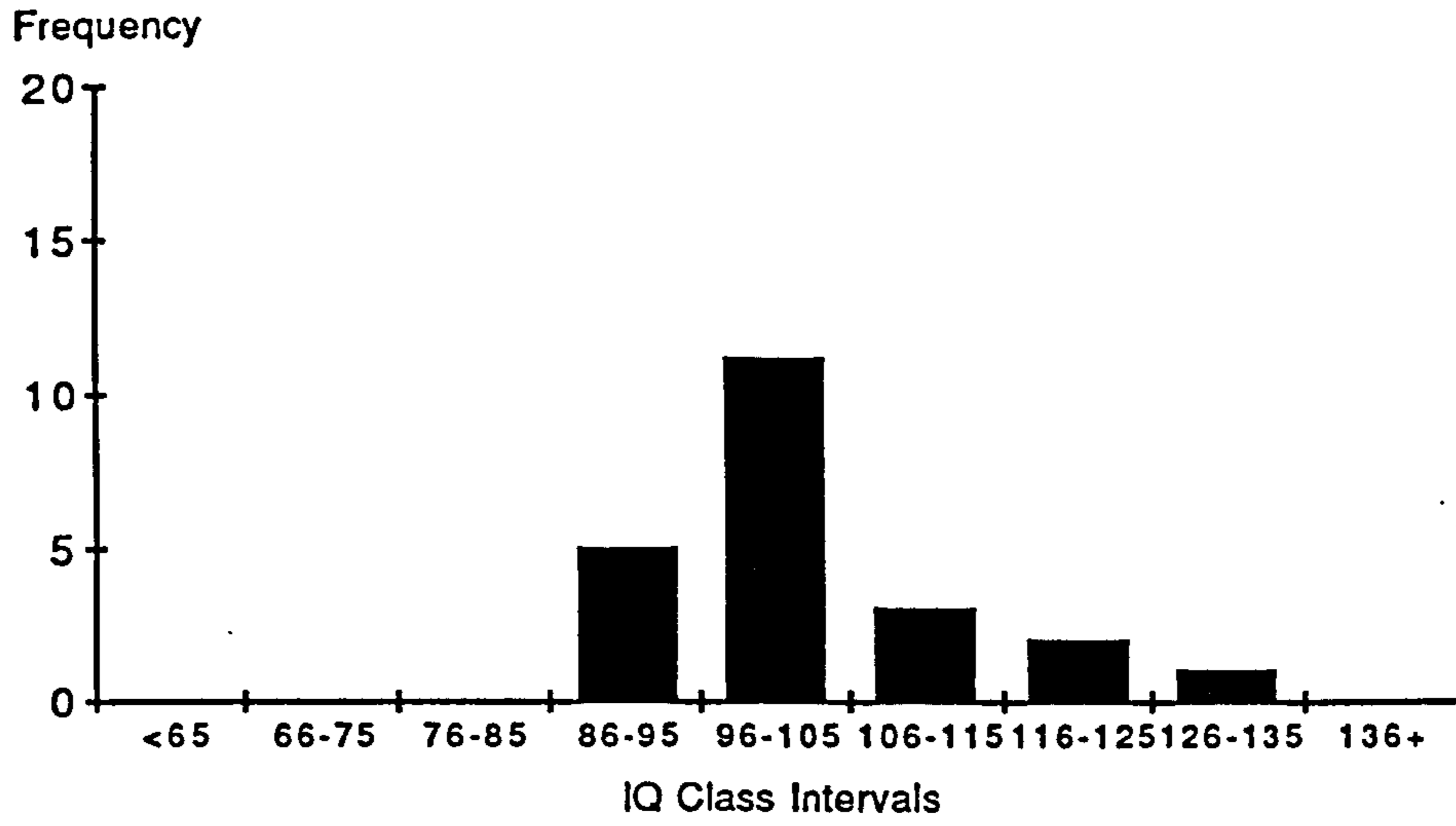
School 2



Mean IQ	120.3
Range	86-154
Median	125
Mode	126-135

Graph 3.18

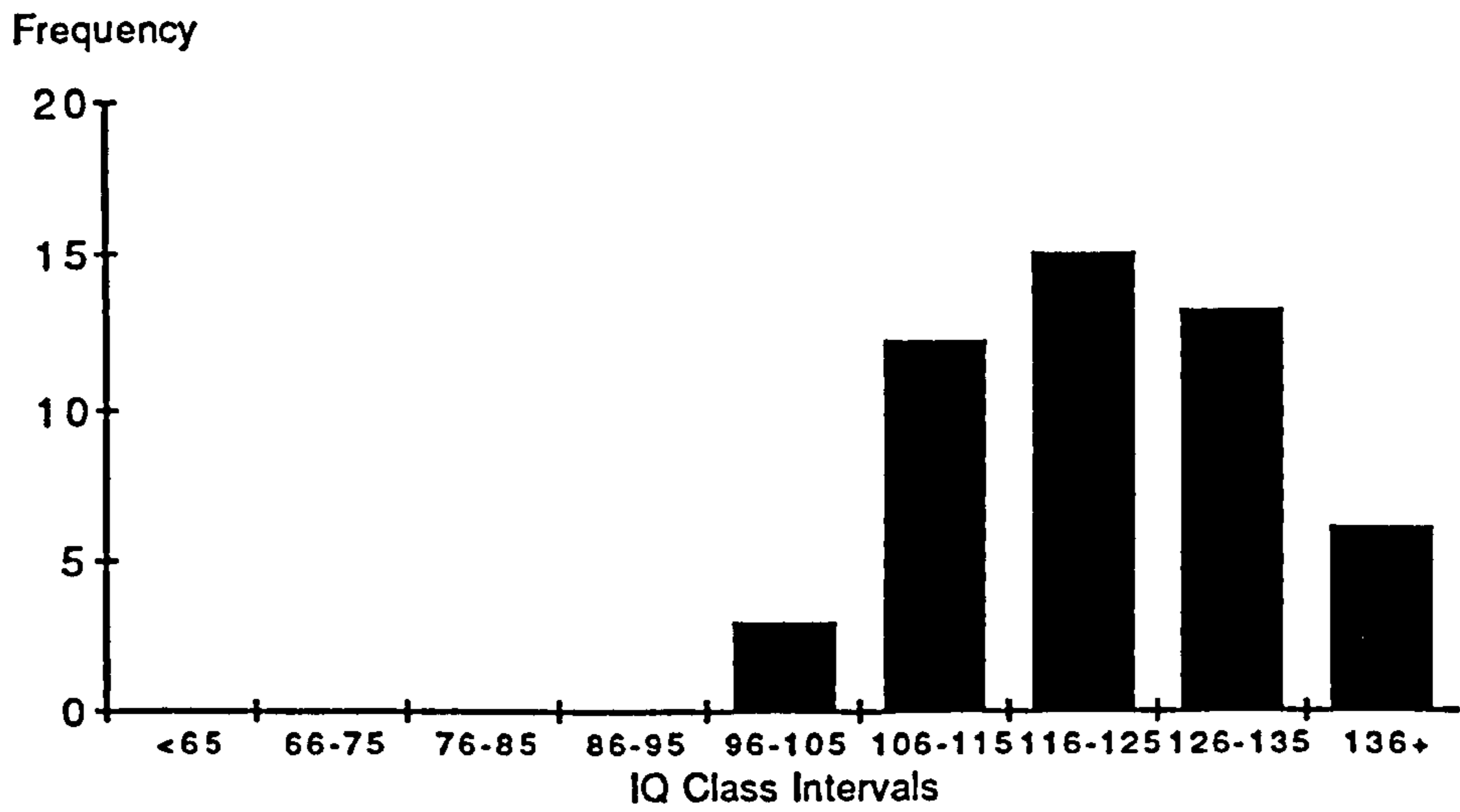
School 3



Mean	108.4
Range	86-127
Median	96-105
Mode	96-105

Graph 3.19

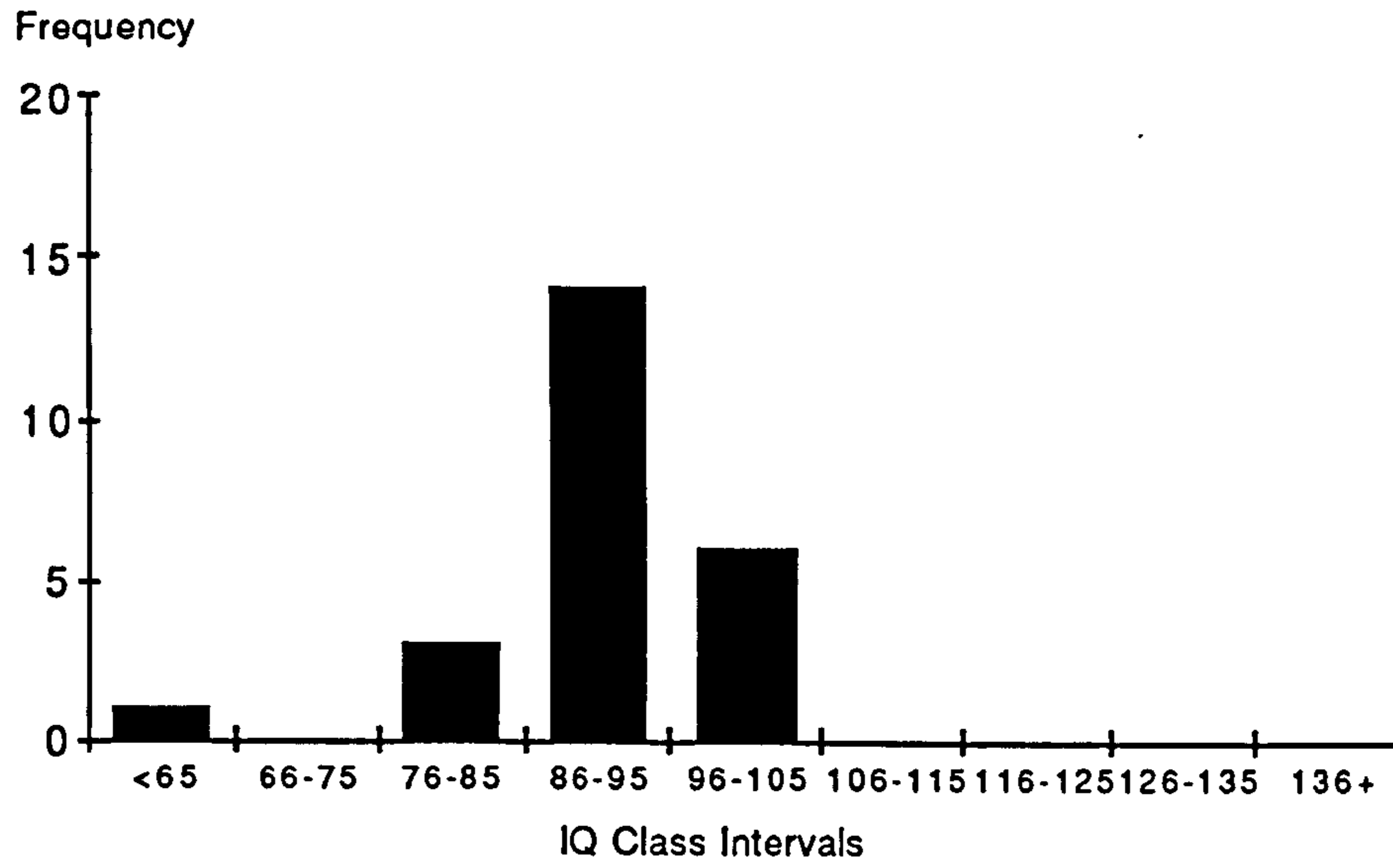
School 4



Mean IQ	121.8
Range	101-144
Median	116-125
Mode	116-125

Graph 3.20

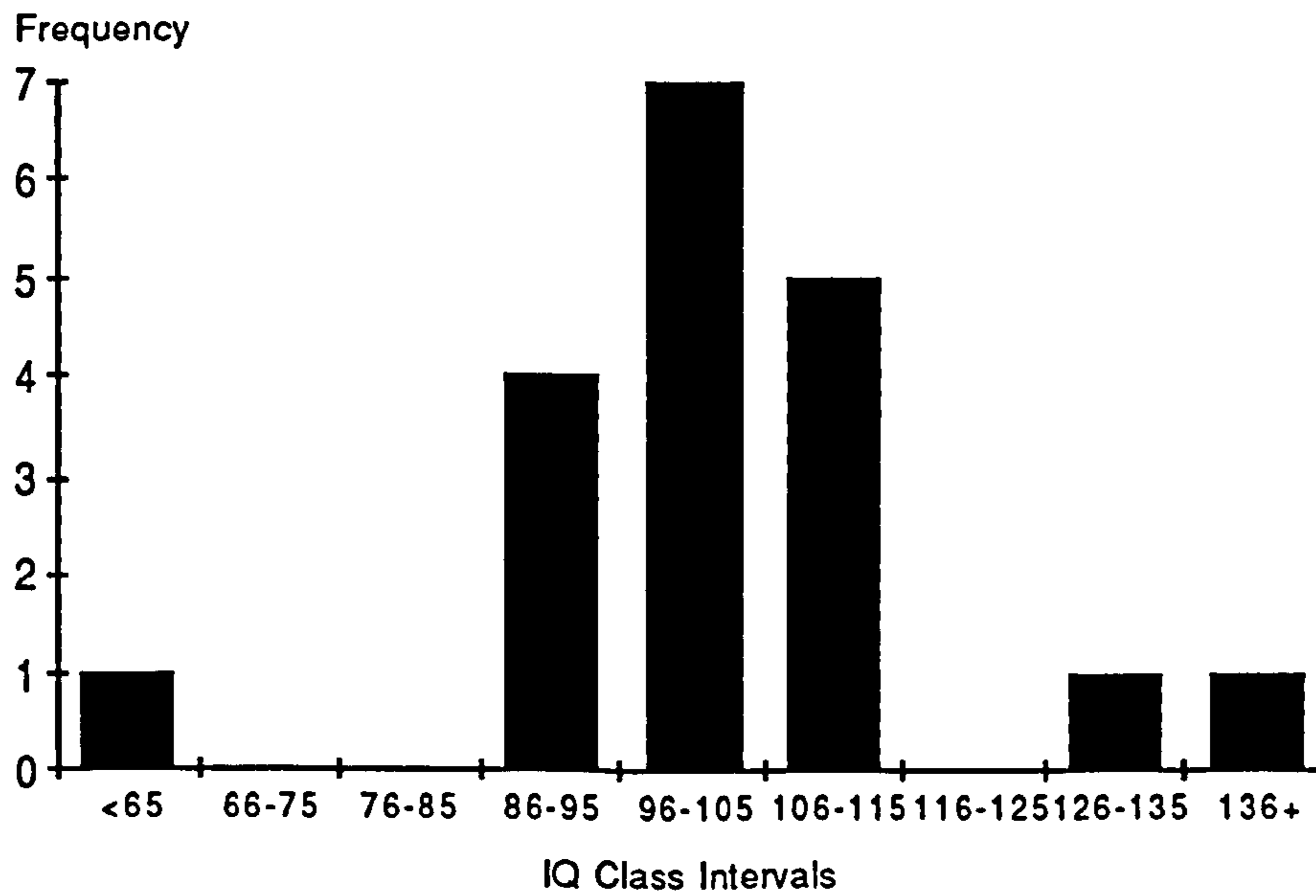
School 5



Mean 89.8
Range 57--102
Median 90
Mode 86-95

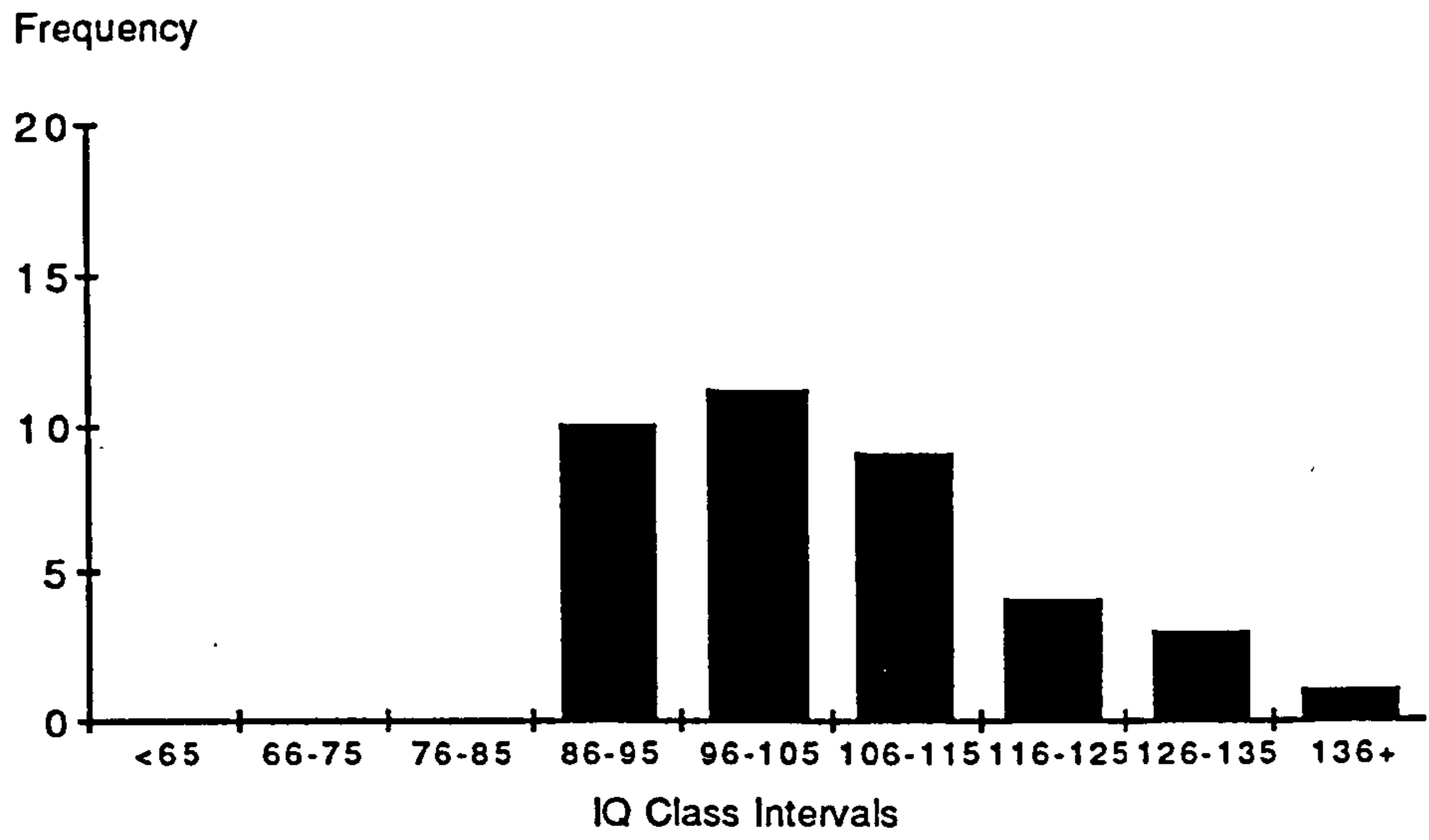
Graph 3.21

School 6



Mean 108.1
Range 57-158
Median 103
Mode 96-105

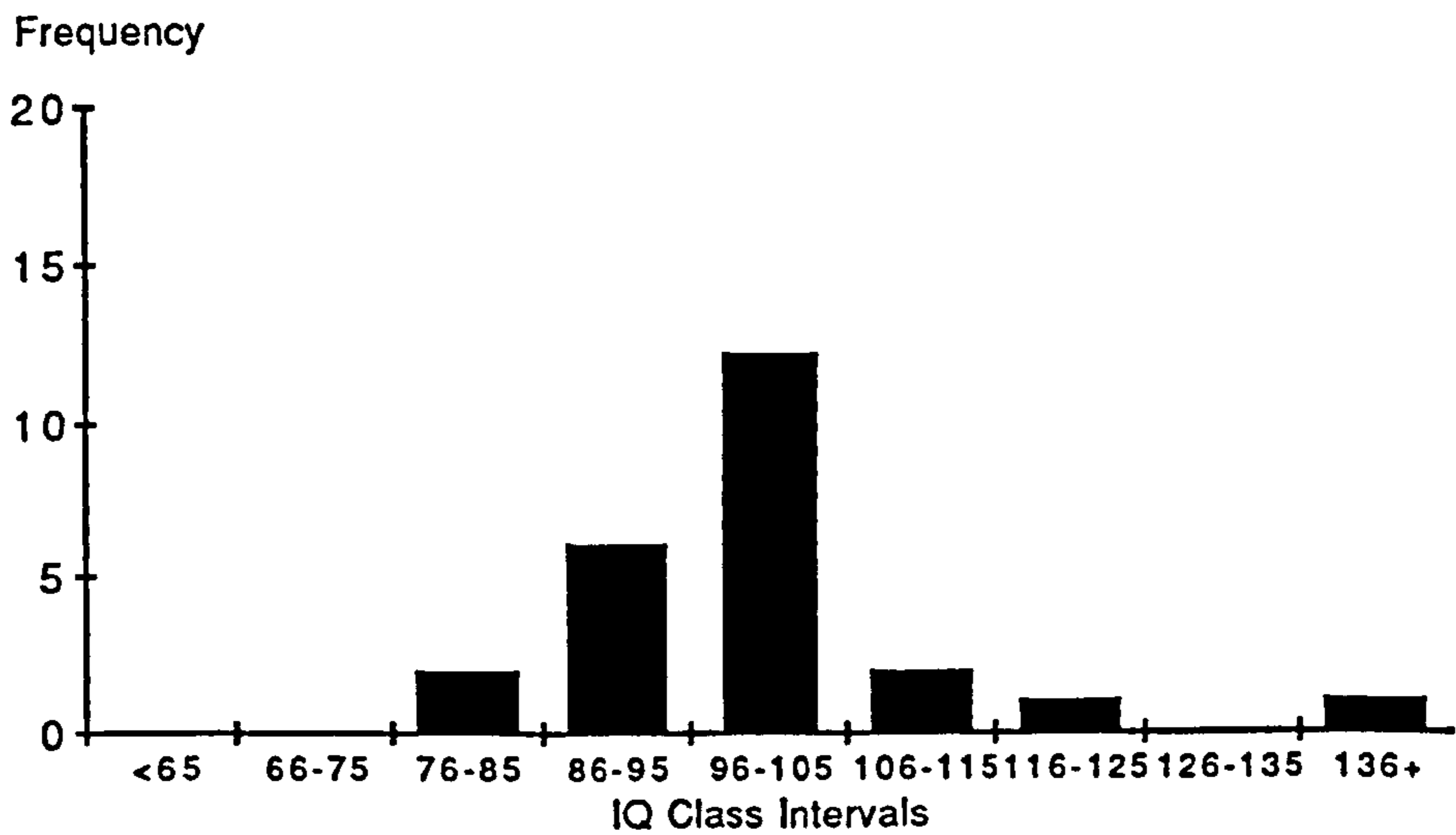
School 7



Mean	105.7
Range	87-139
Median	104
Mode	96-105

Graph 3.23

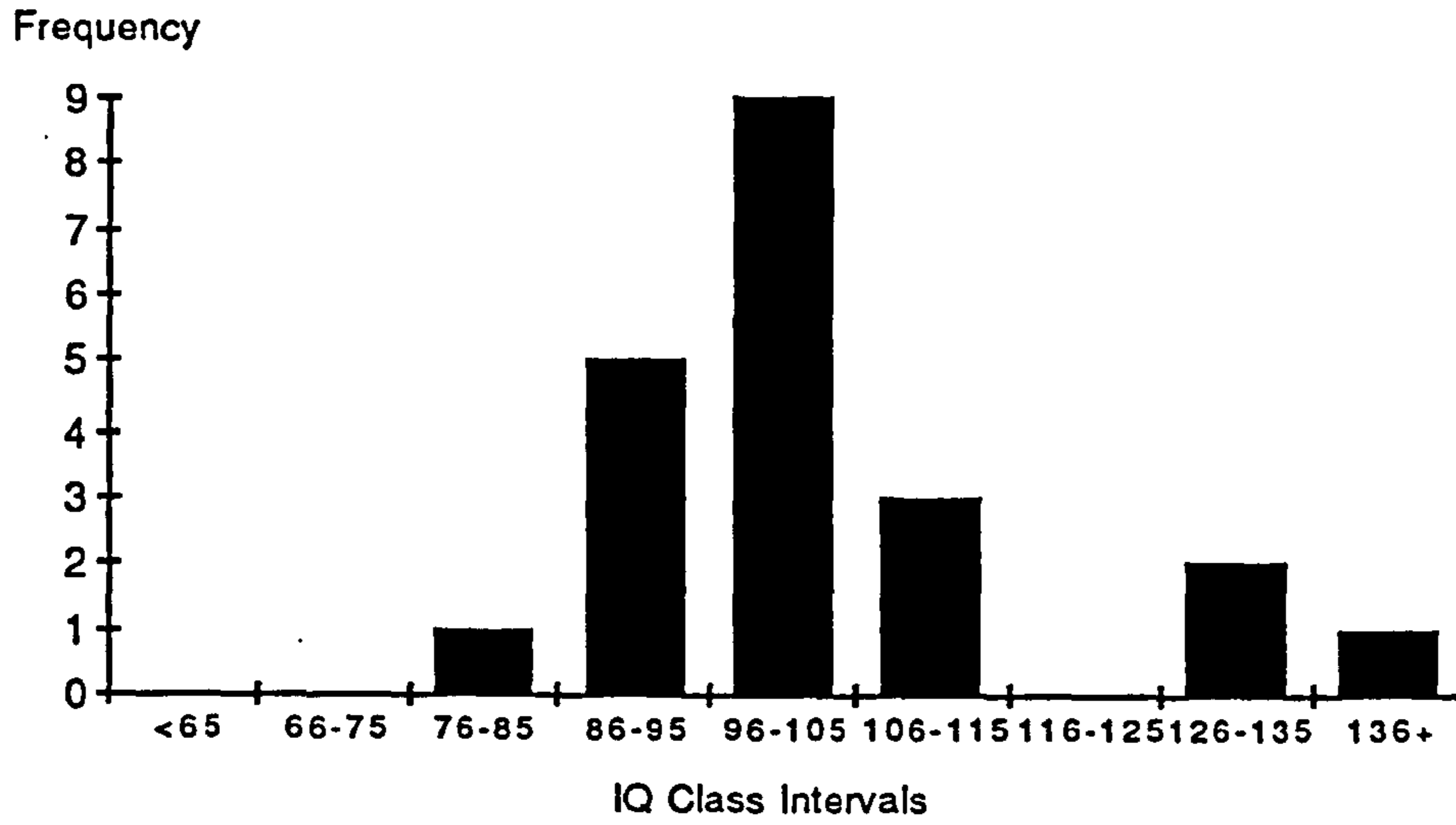
School 8



Mean	99.2
Range	83-139
Median	96-105
Mode	96-105

Graph 3.24

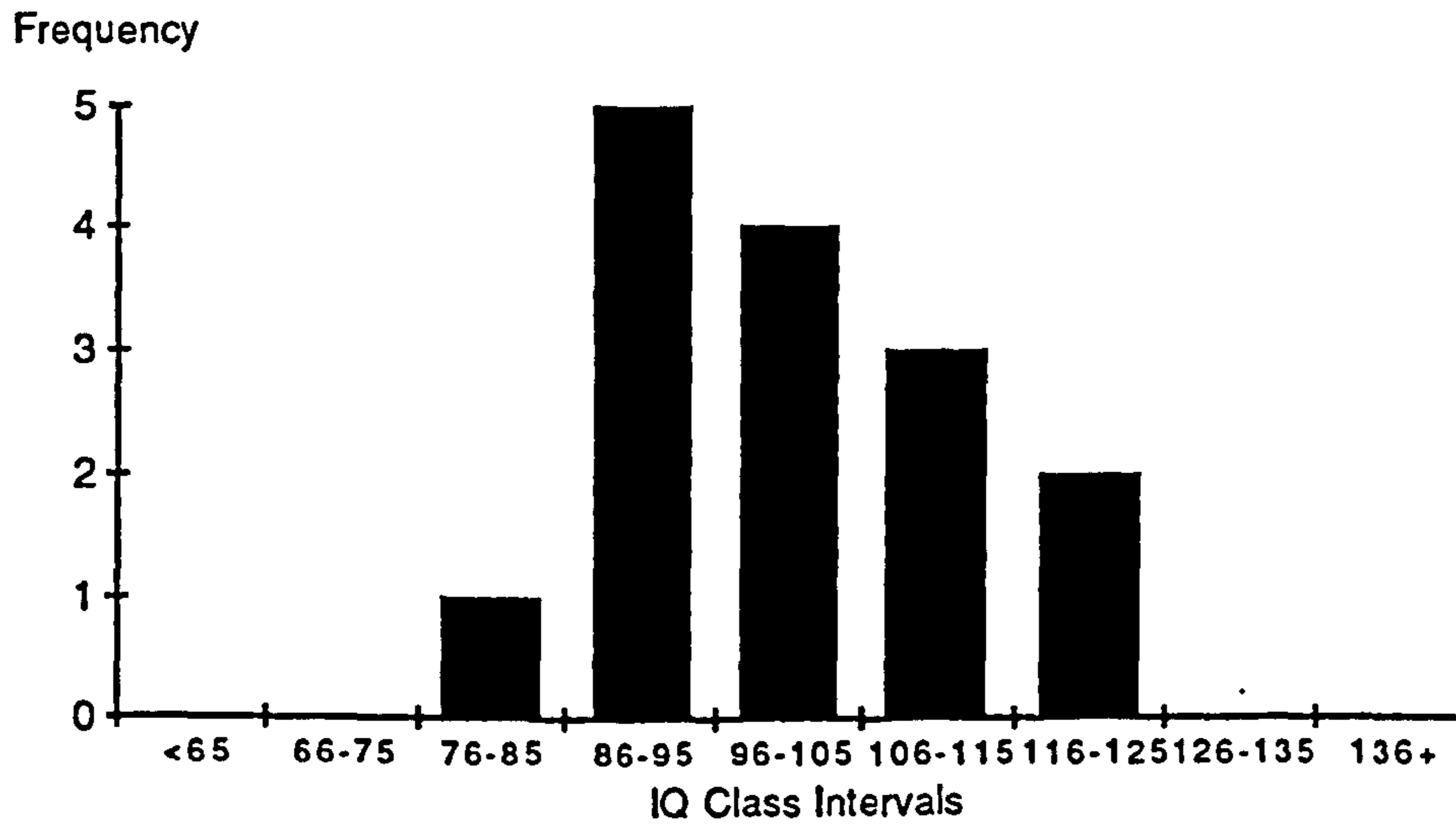
School 9



Mean	102-108
Range	84-139
Median	96-105
Mode	96-105

Graph 3.25

School 10

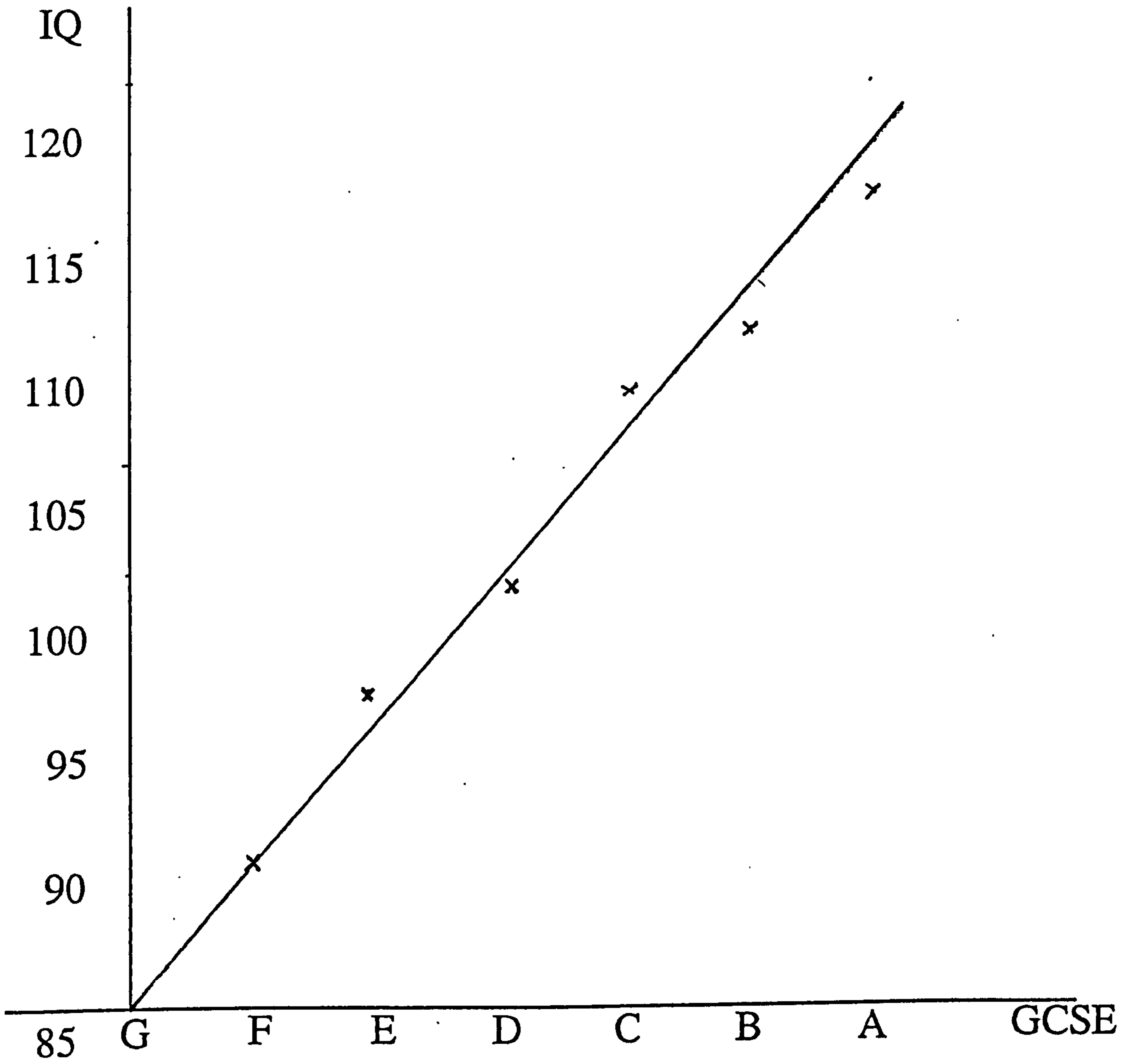


Mean	109.6
Range	84-122
Median	96-105
Mode	86-95

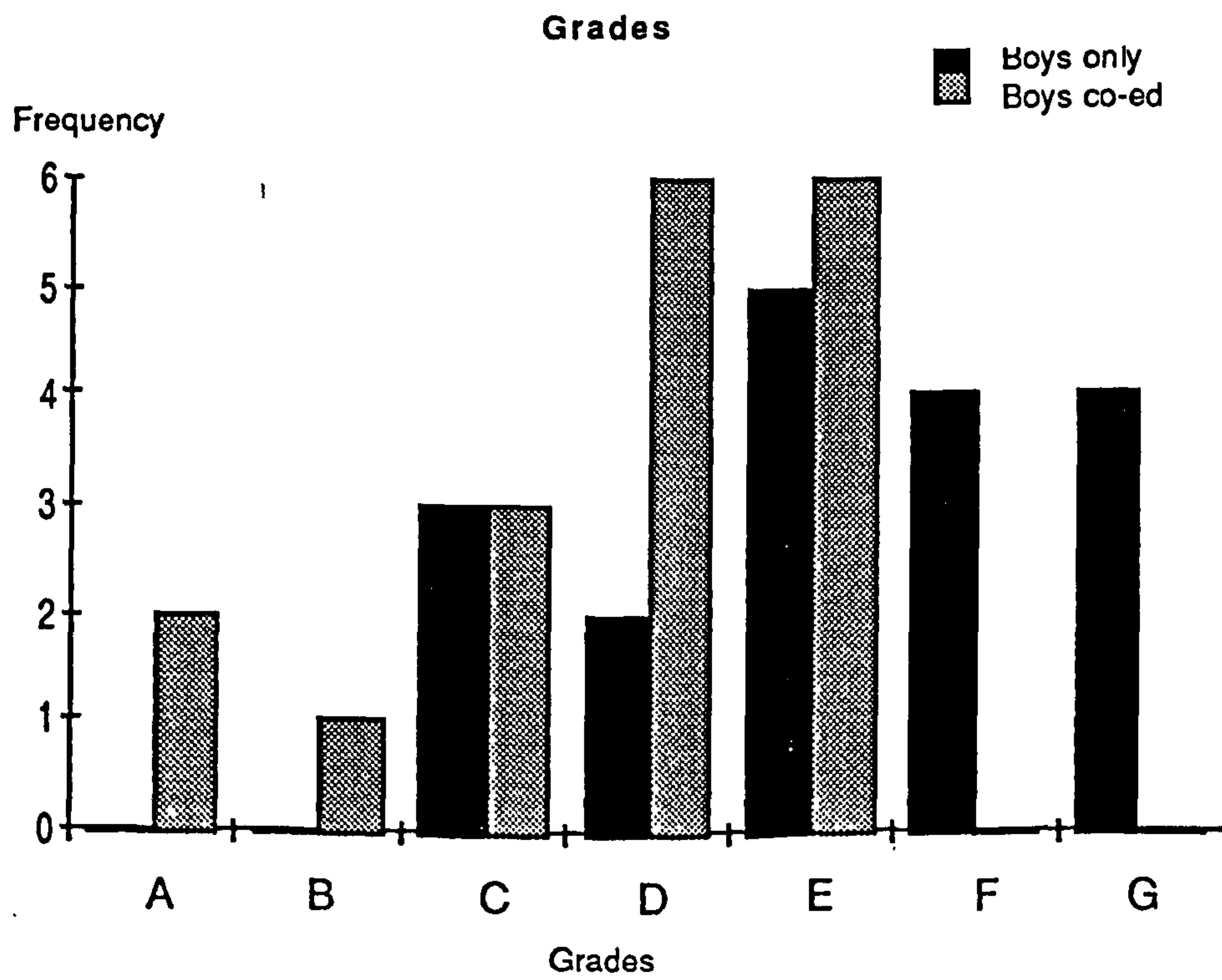
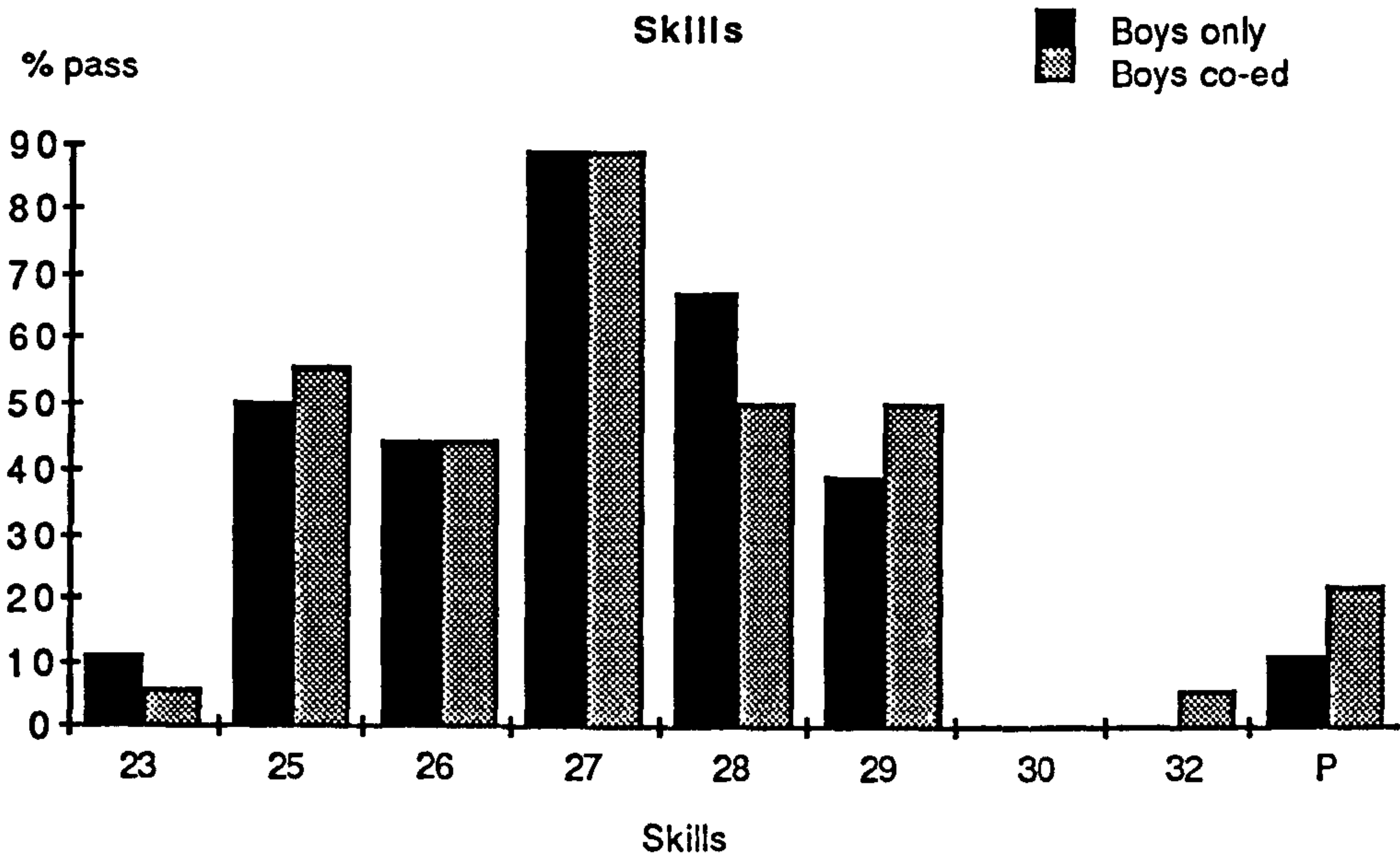
30

Graph 3.26

Graph of mean IQ against GCSE Grade Achieved

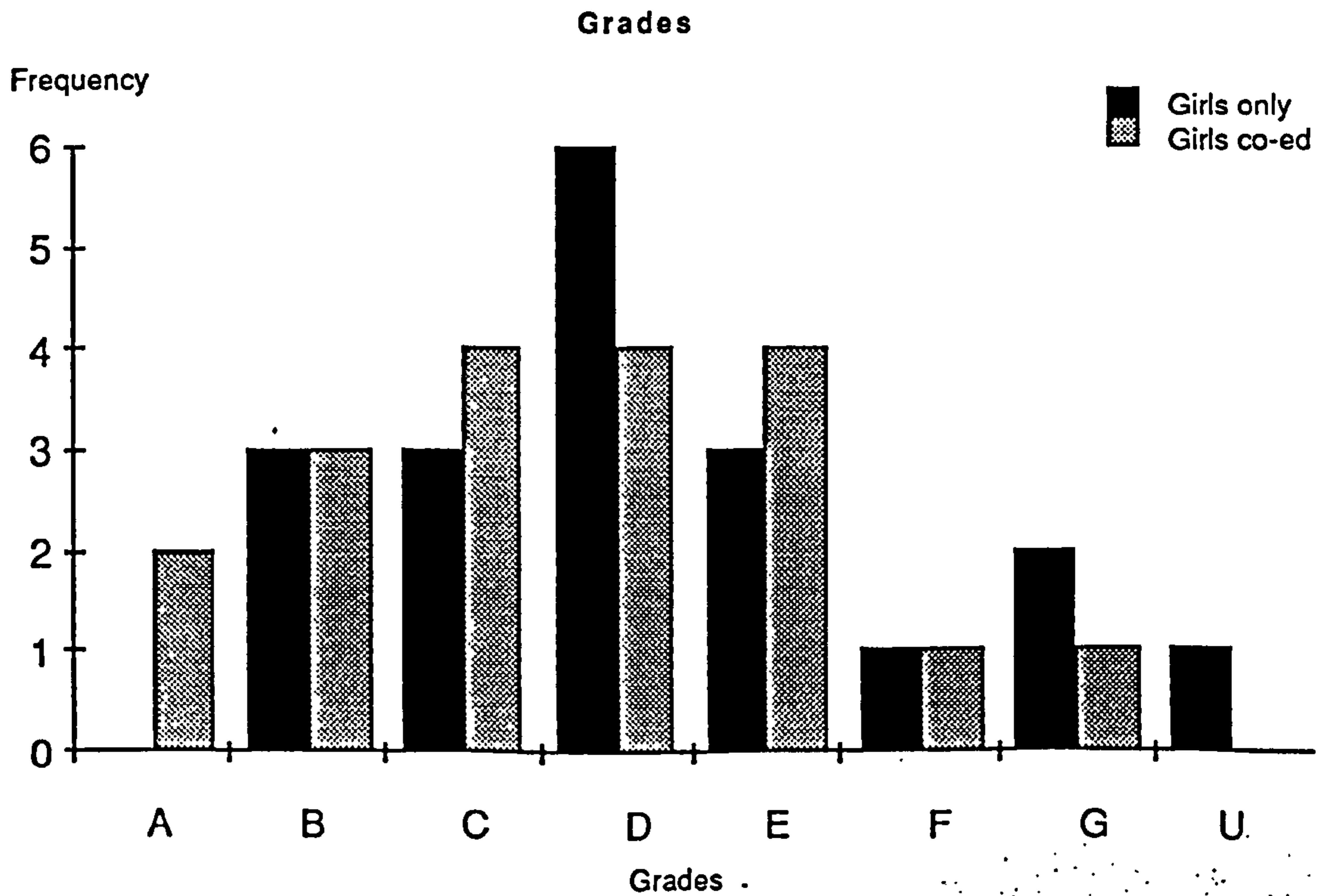
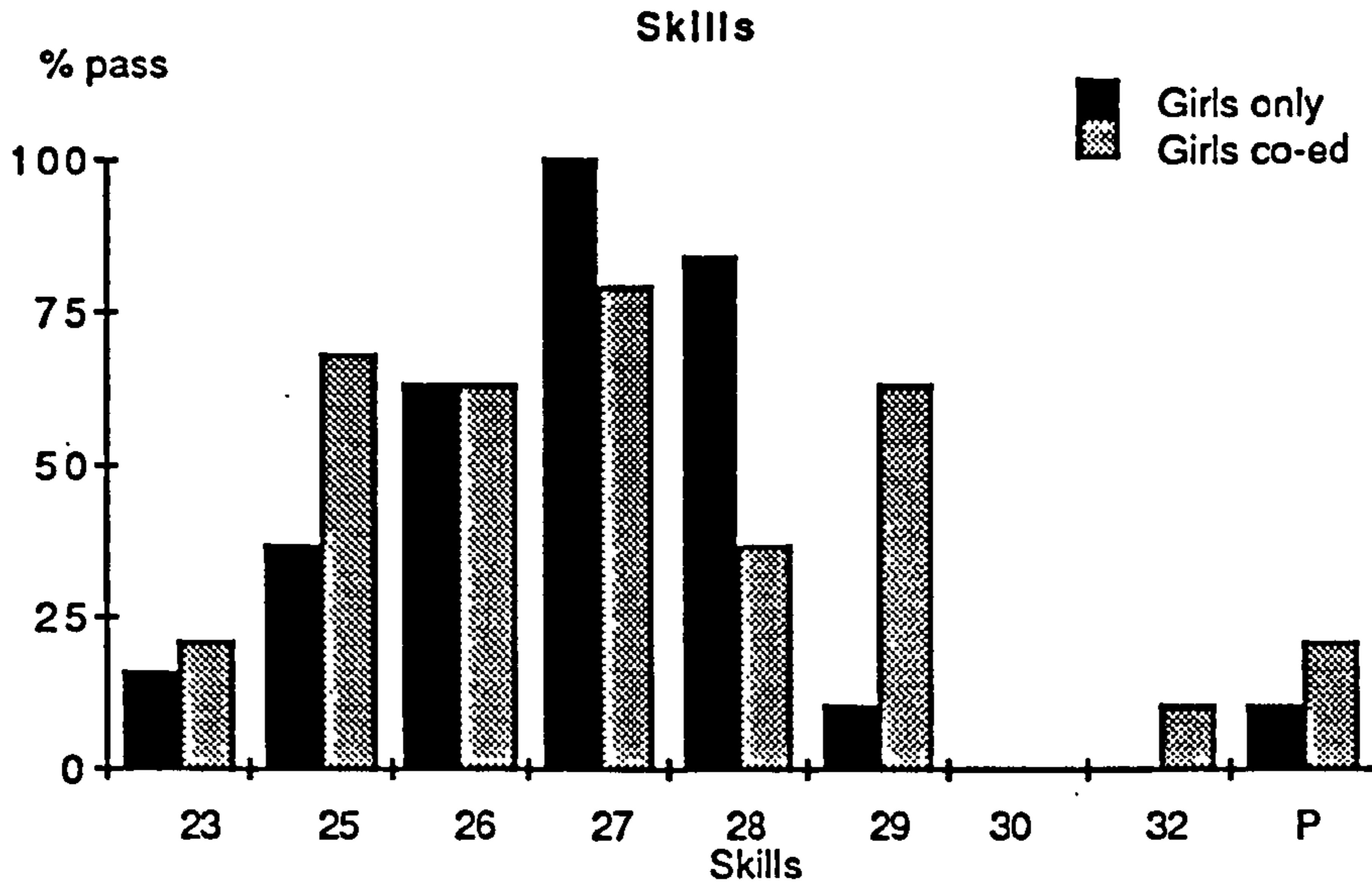


% pass rate in the selected skills and grades for two samples of boys cross matched for IQ. One group educated in an all boys' comprehensive, the other in co-educational comprehensives.



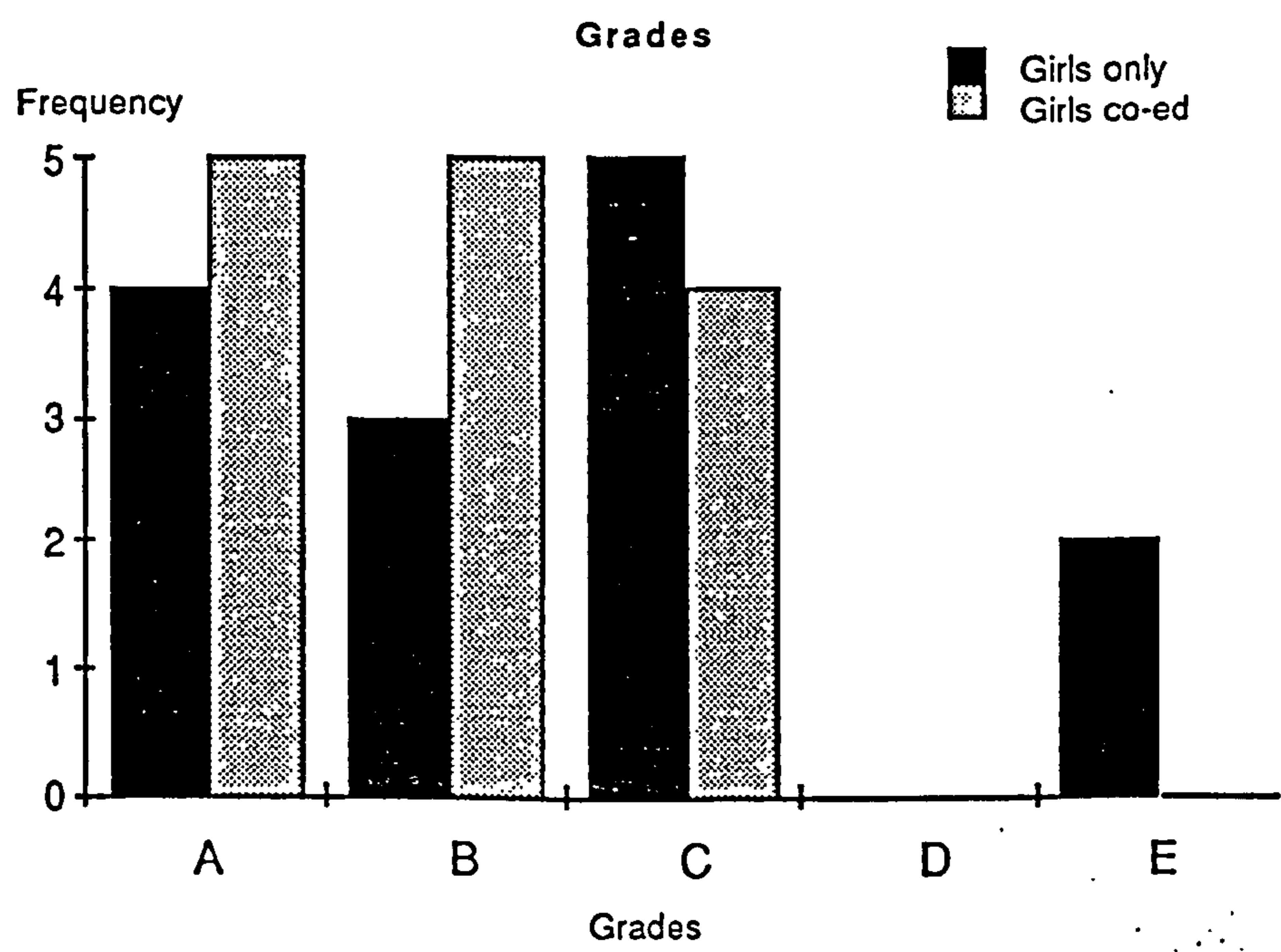
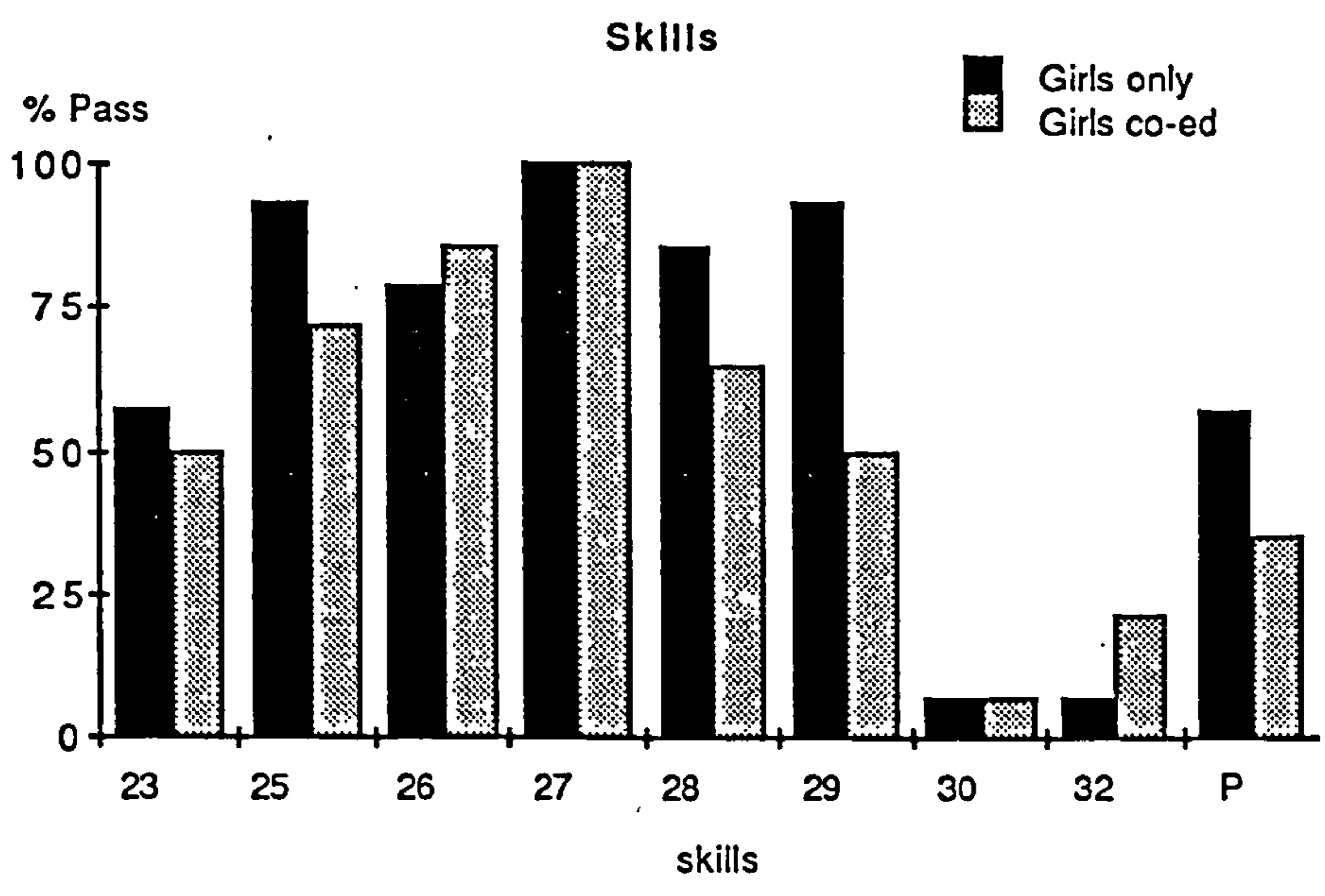
Graph 3.28

% pass rate in the selected skills and grades achieved for two groups of girls, cross matched for IQ . One group studying in a girls only comprehensive school the other in co-educational comprehensives.

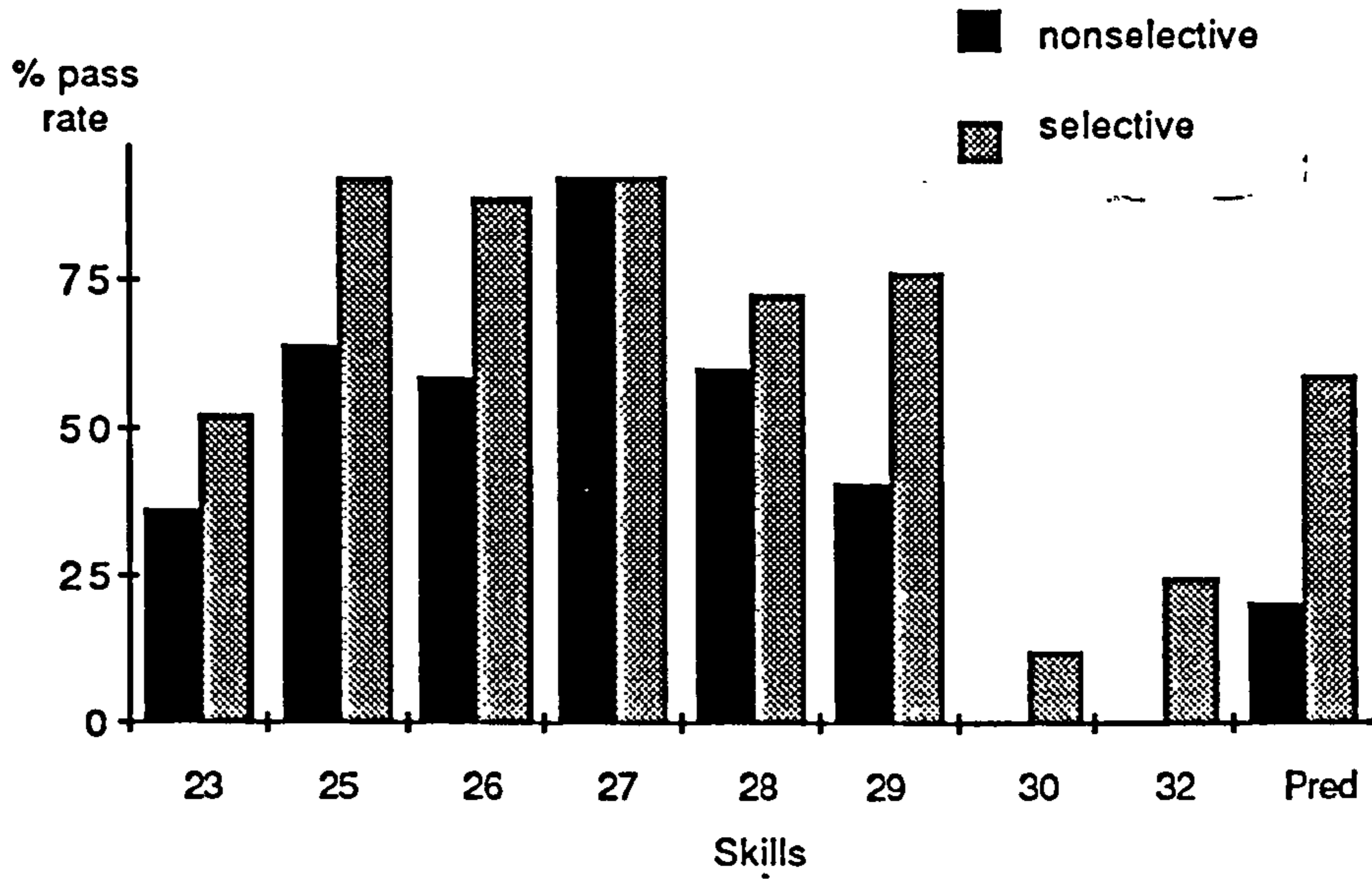


Graph 3.29

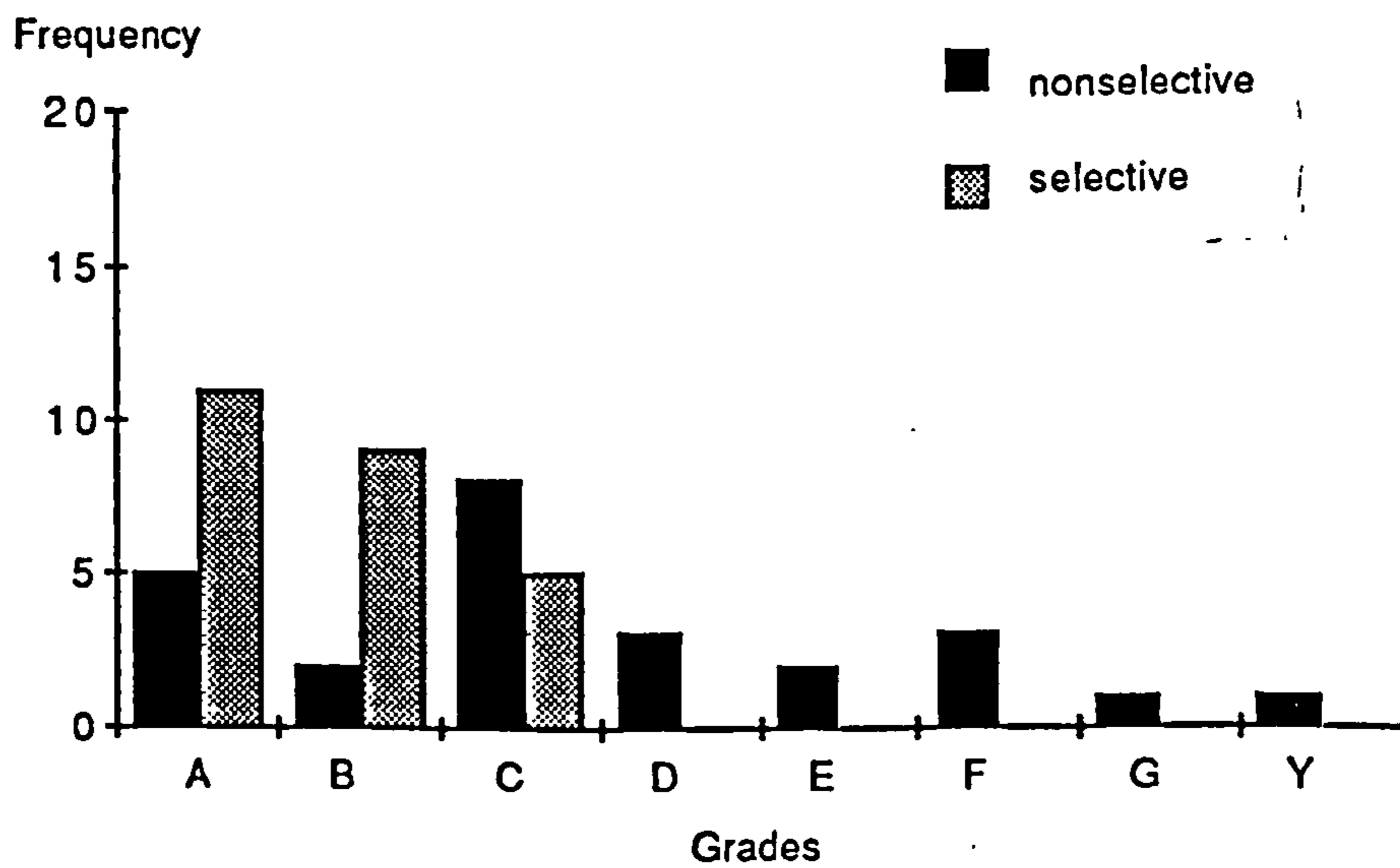
% pass rate in the selected skills and the grades achieved for two samples of girls cross matched for IQ. One sample from a girls' semi-selective school the other from a co-educational selective school.



**% Pass Rate of Skills in nonselective and selective Schools
(Cross matched for IQ.)**

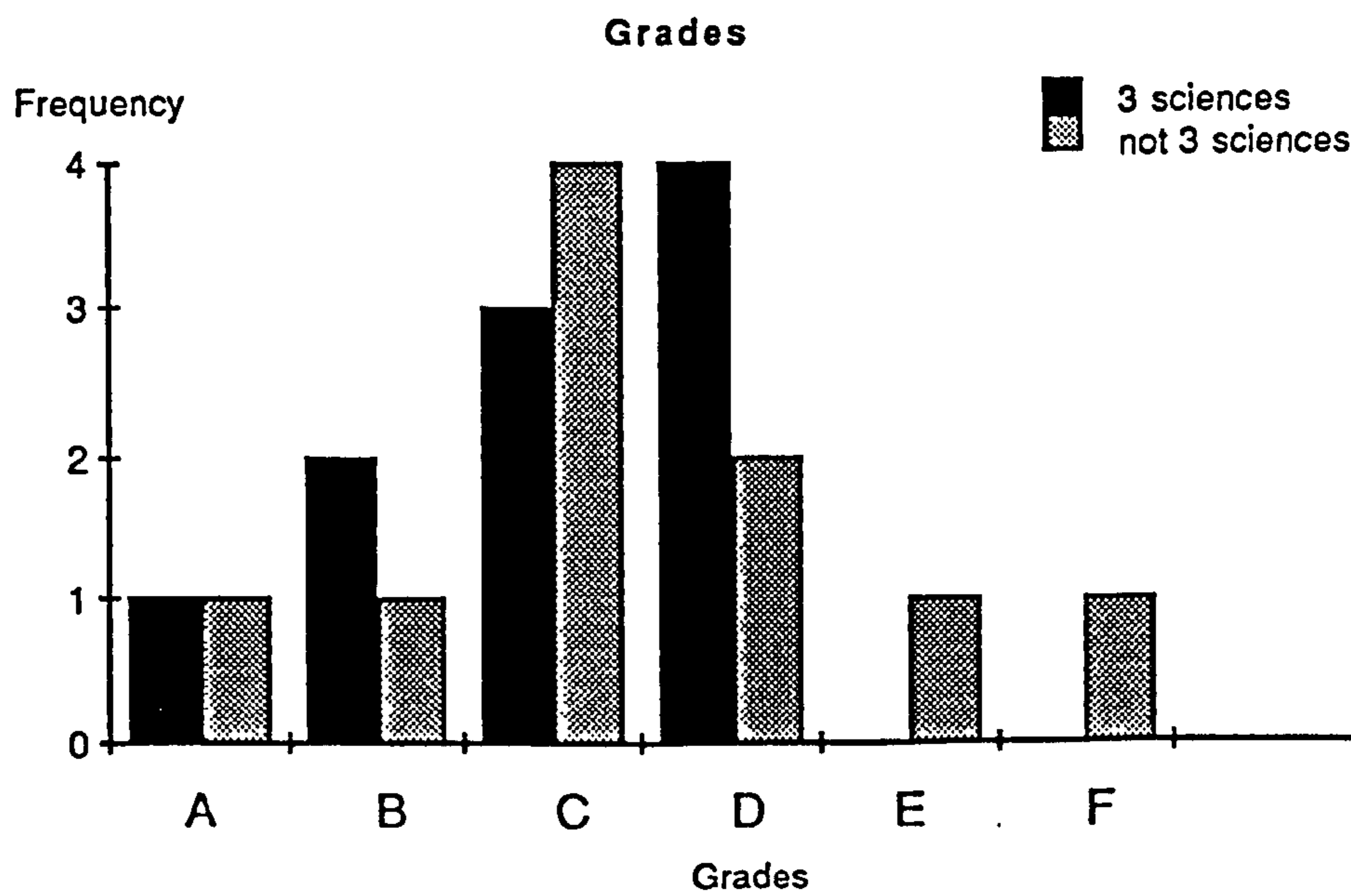
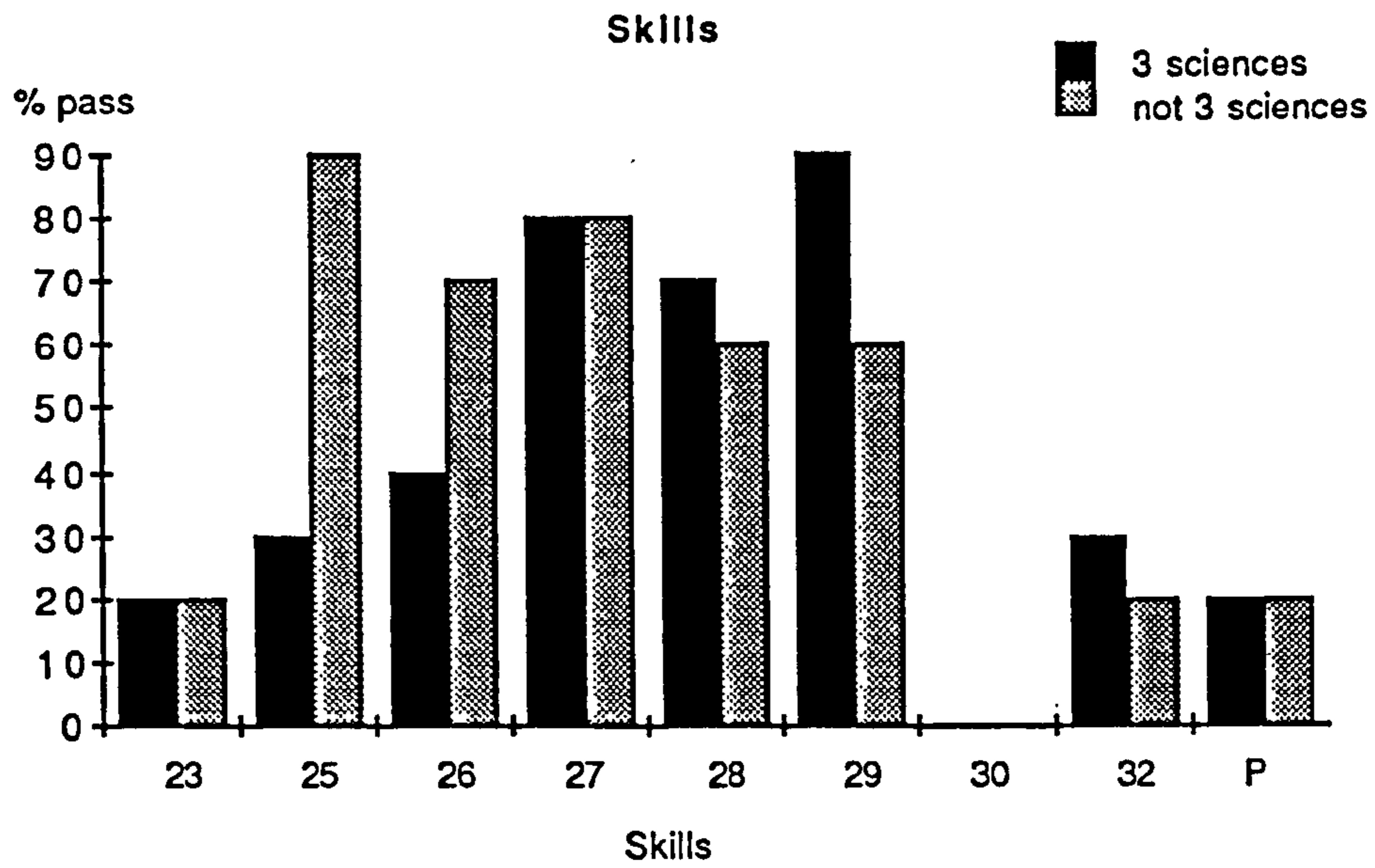


**Grade Distribution in nonselective and selective Schools
(Crossed matched for IQ.)**

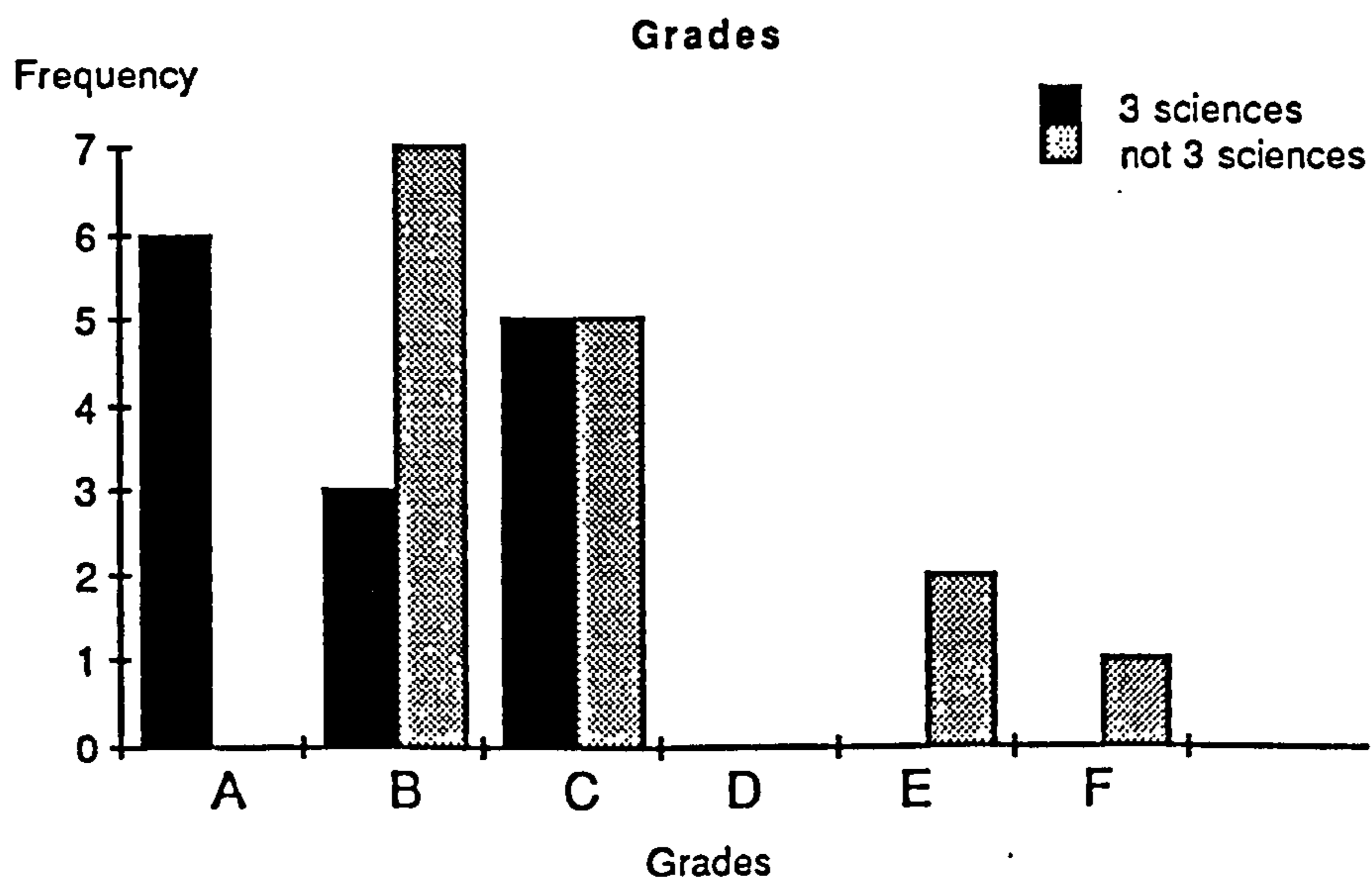
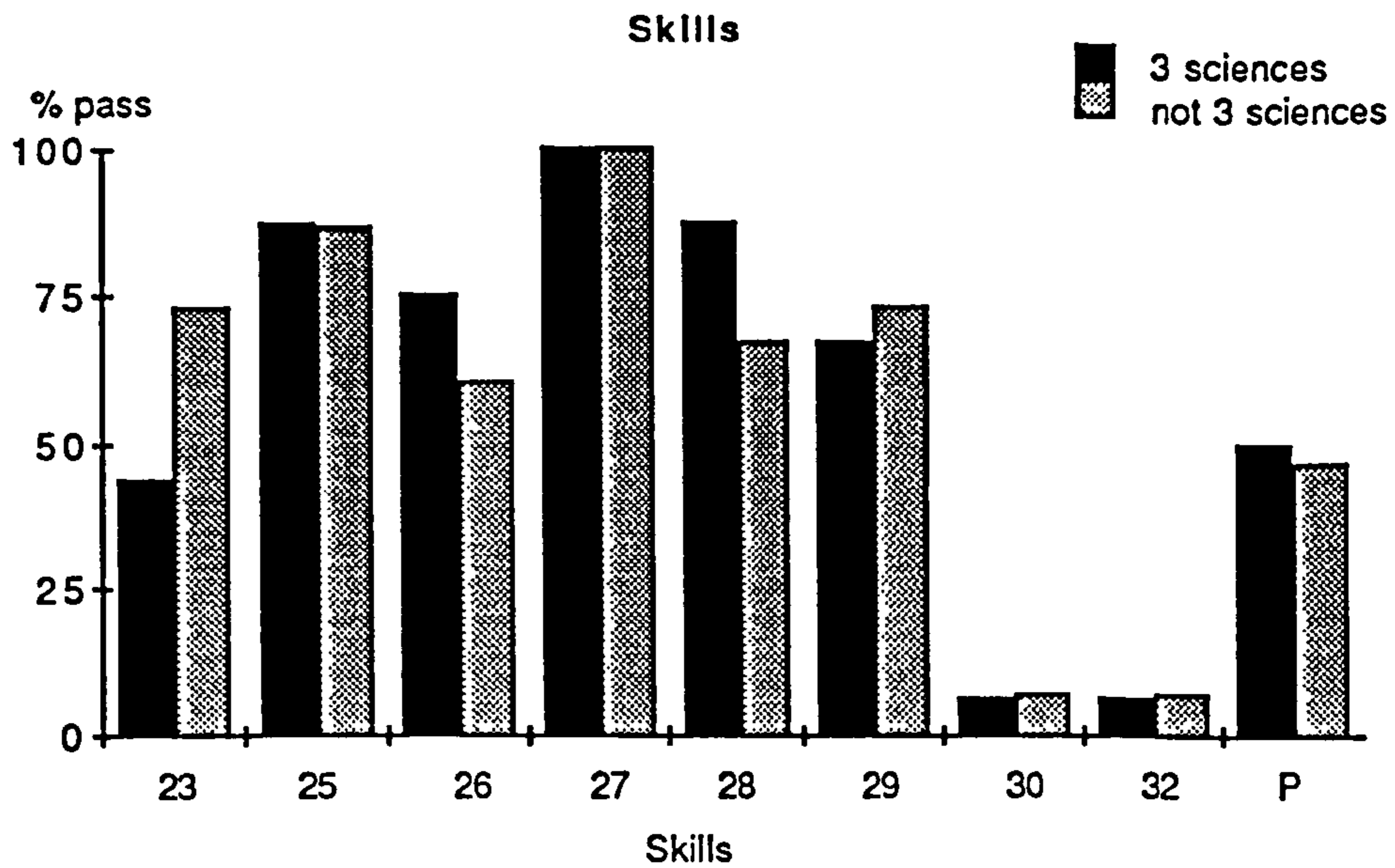


Graph 3.31

% pass rate for the selected skills and the grades achieved by two groups of students cross matched for IQ, studying in comprehensive schools. One group studying three sciences the other not studying three sciences.

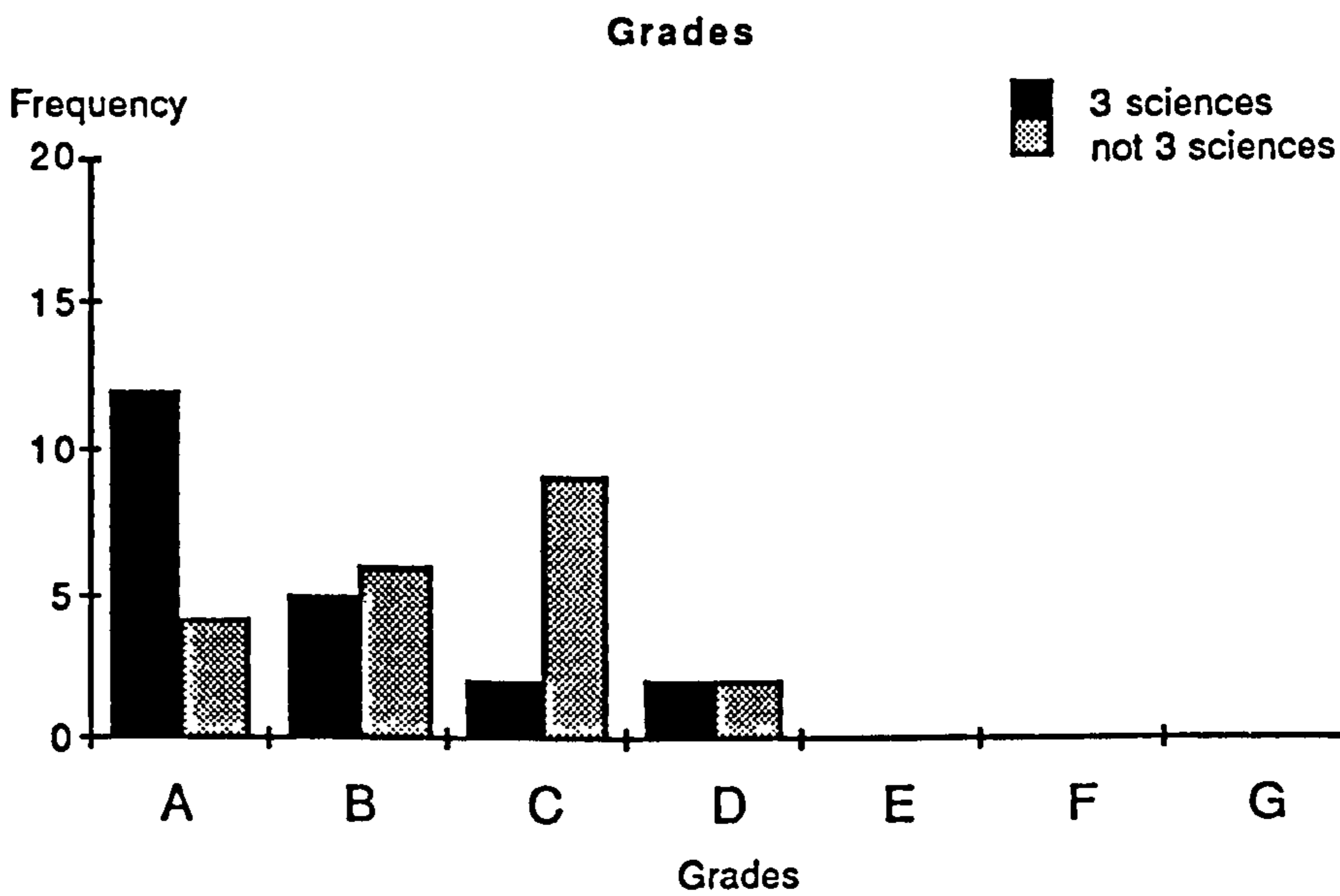
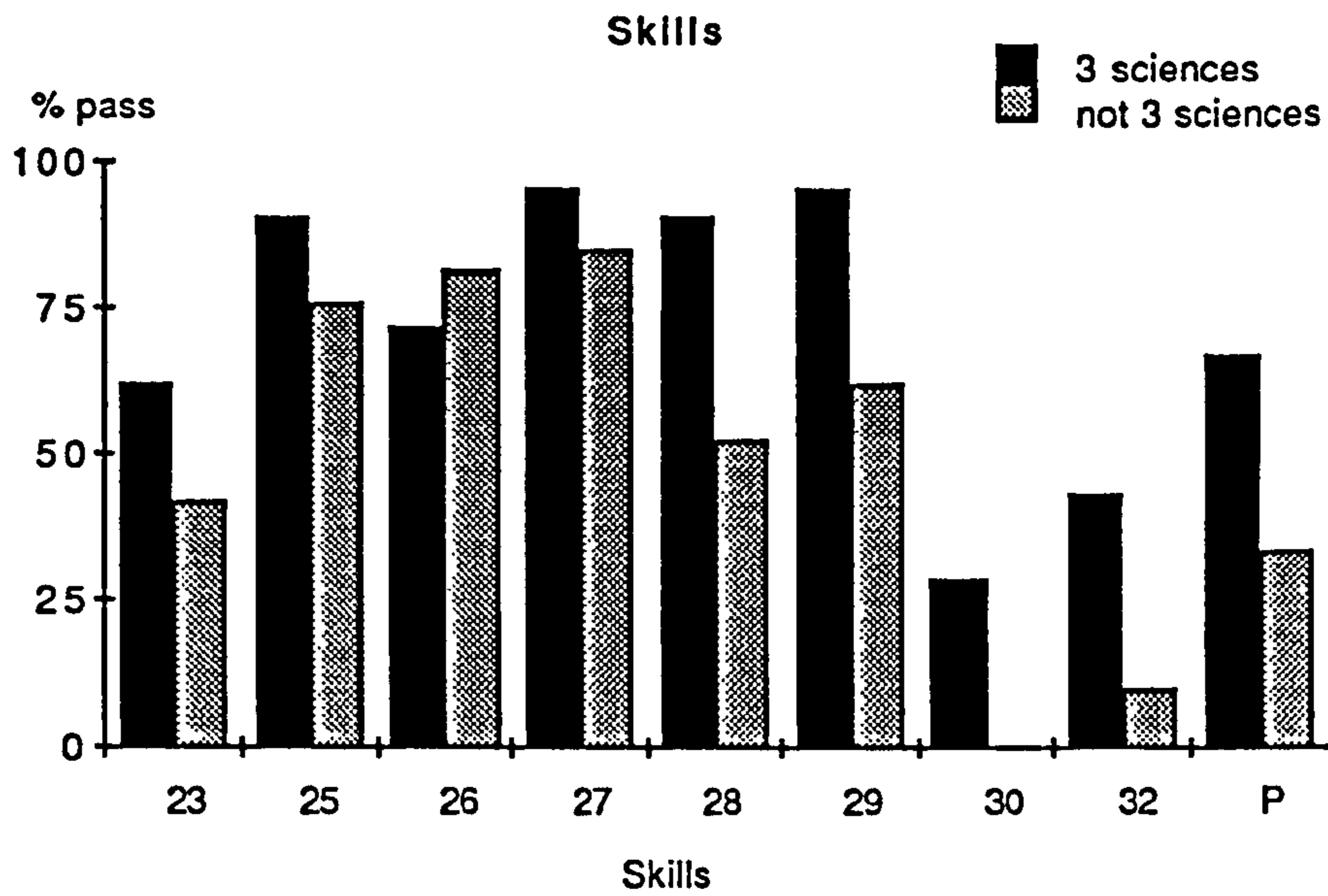


% pass rate in the selected skills and the grades achieved by two groups of girls from a girls semi-selective school, cross matched for IQ . One group studying three sciences the other group not studying three sciences.

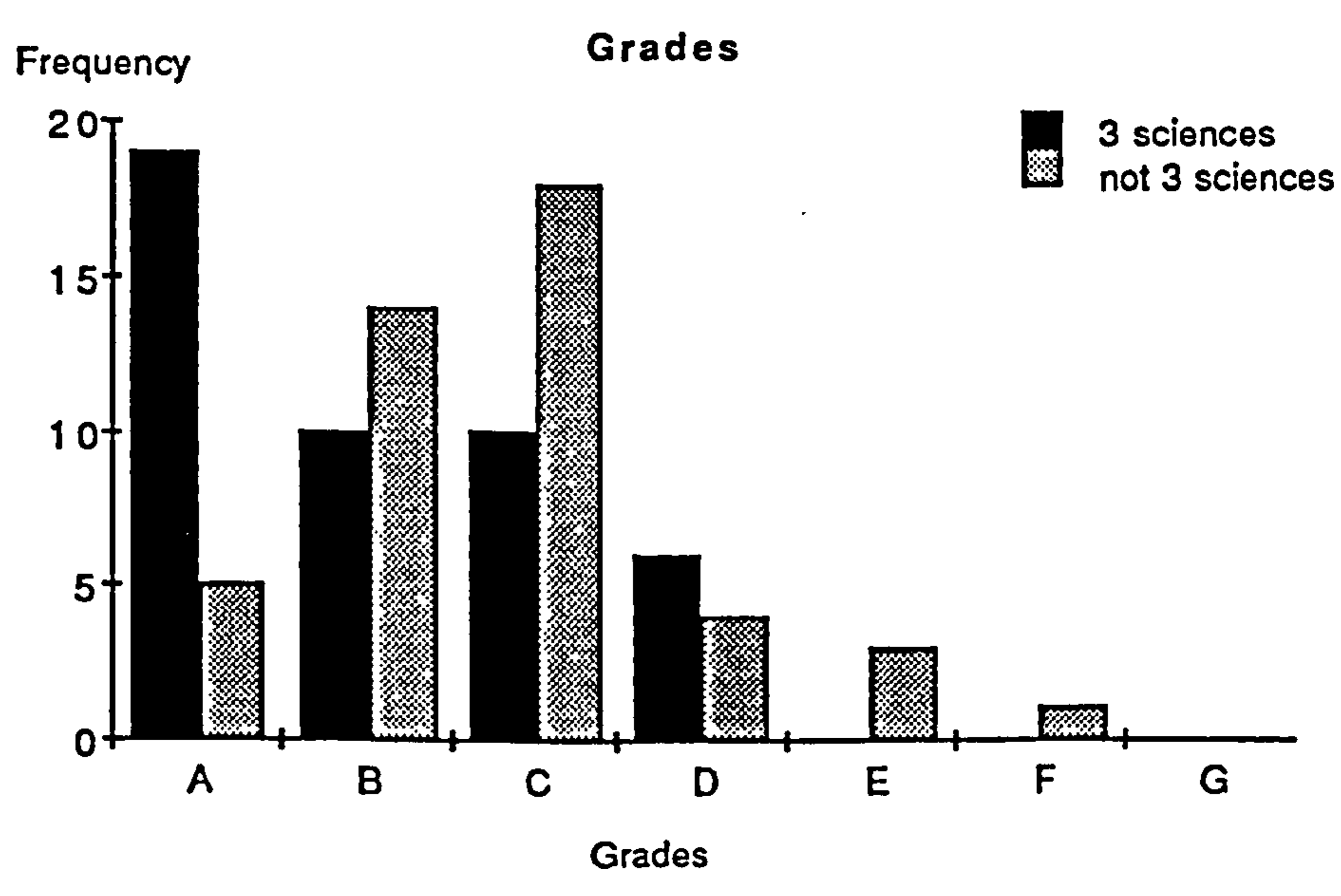
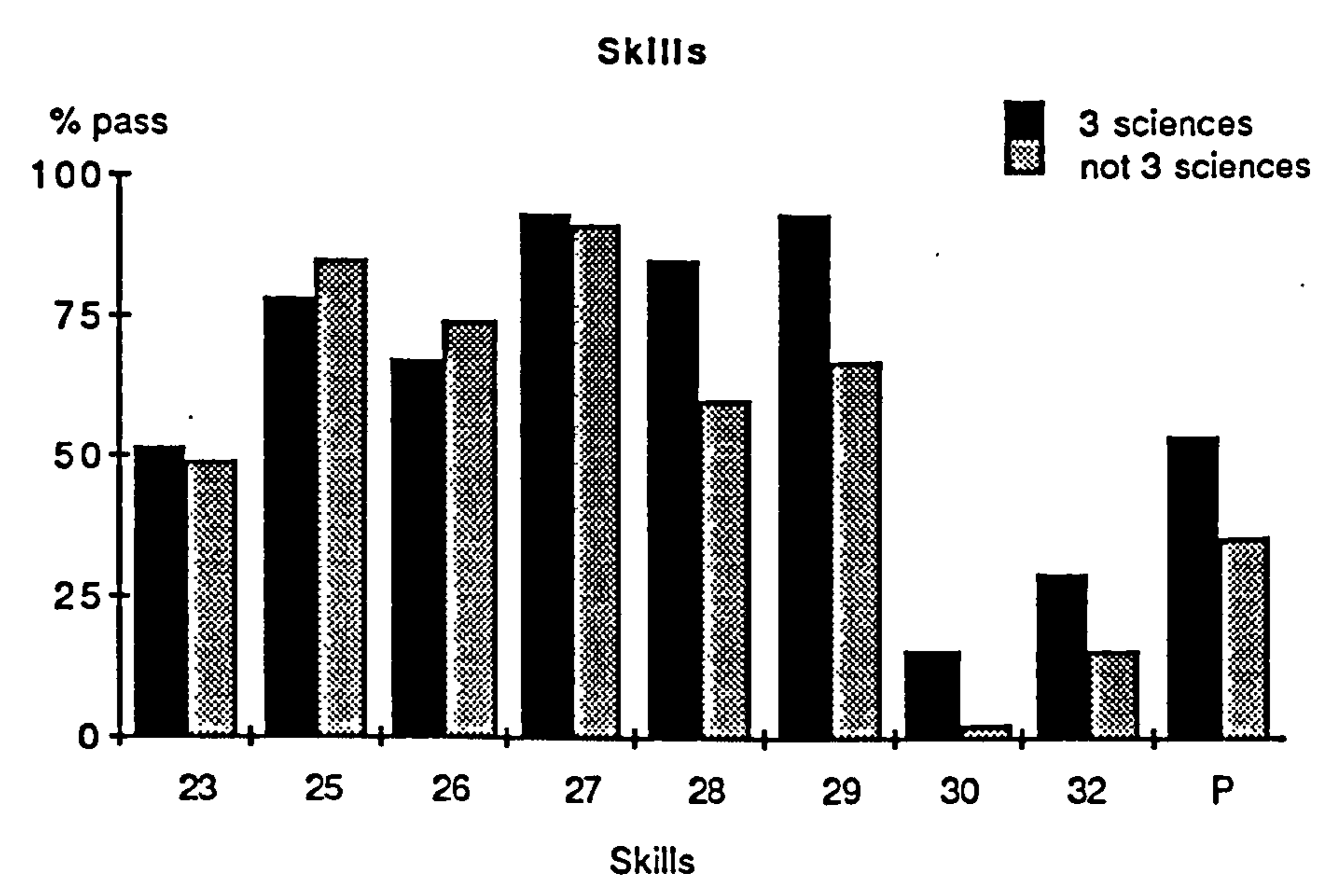


Graph 3.33

% pass rate in the selected skills and grades achieved for two groups of students, cross matched for IQ, from a selective school. One group studying three sciences the other not studying three sciences.



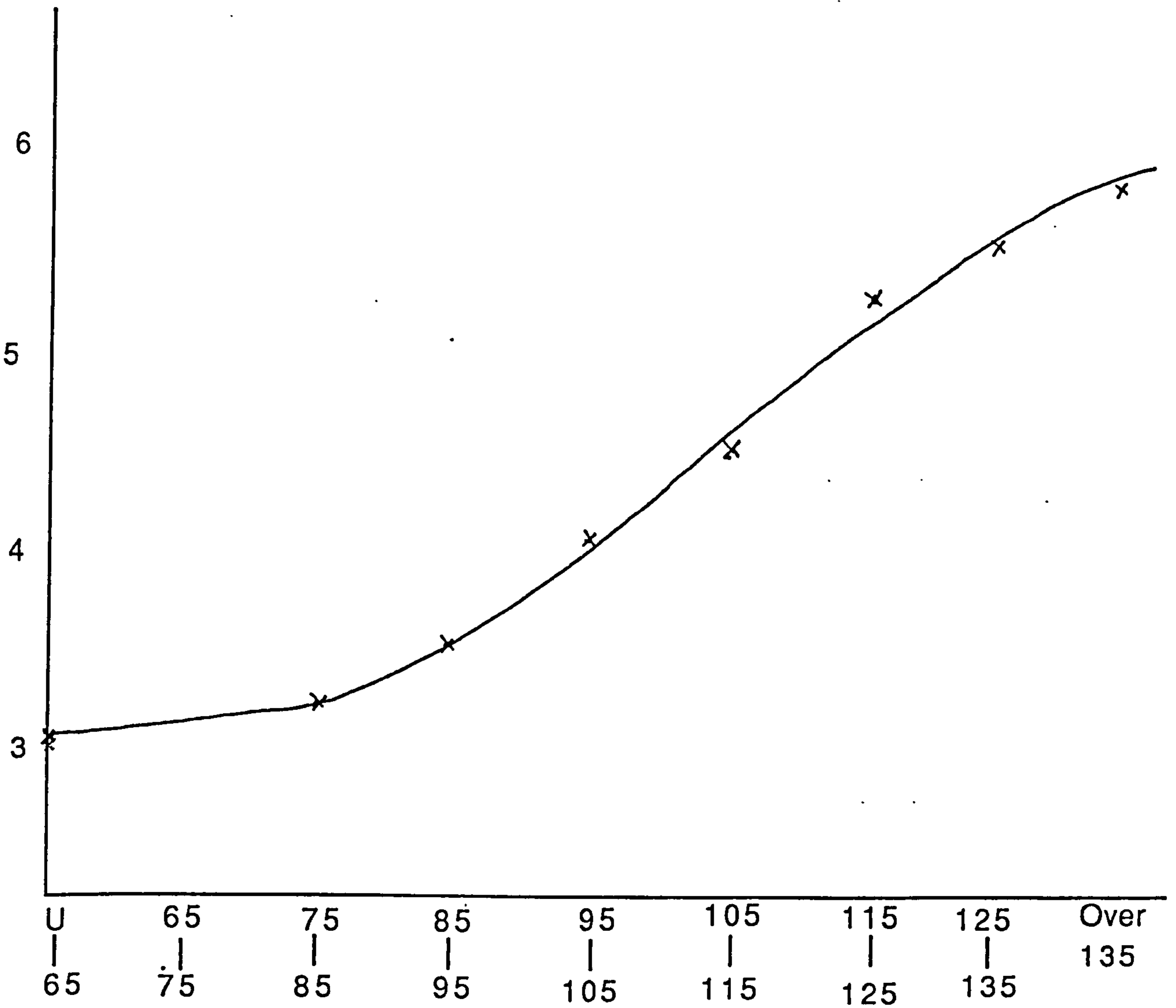
% pass rate for the selected skills and the grades achieved for two groups of students, cross matched for IQ . One group comprising all the students in the sample who studied three sciences the other group did not study three sciences.



Graph 4.1

Mean number of skills passed in the original test by candidates banded by IQ

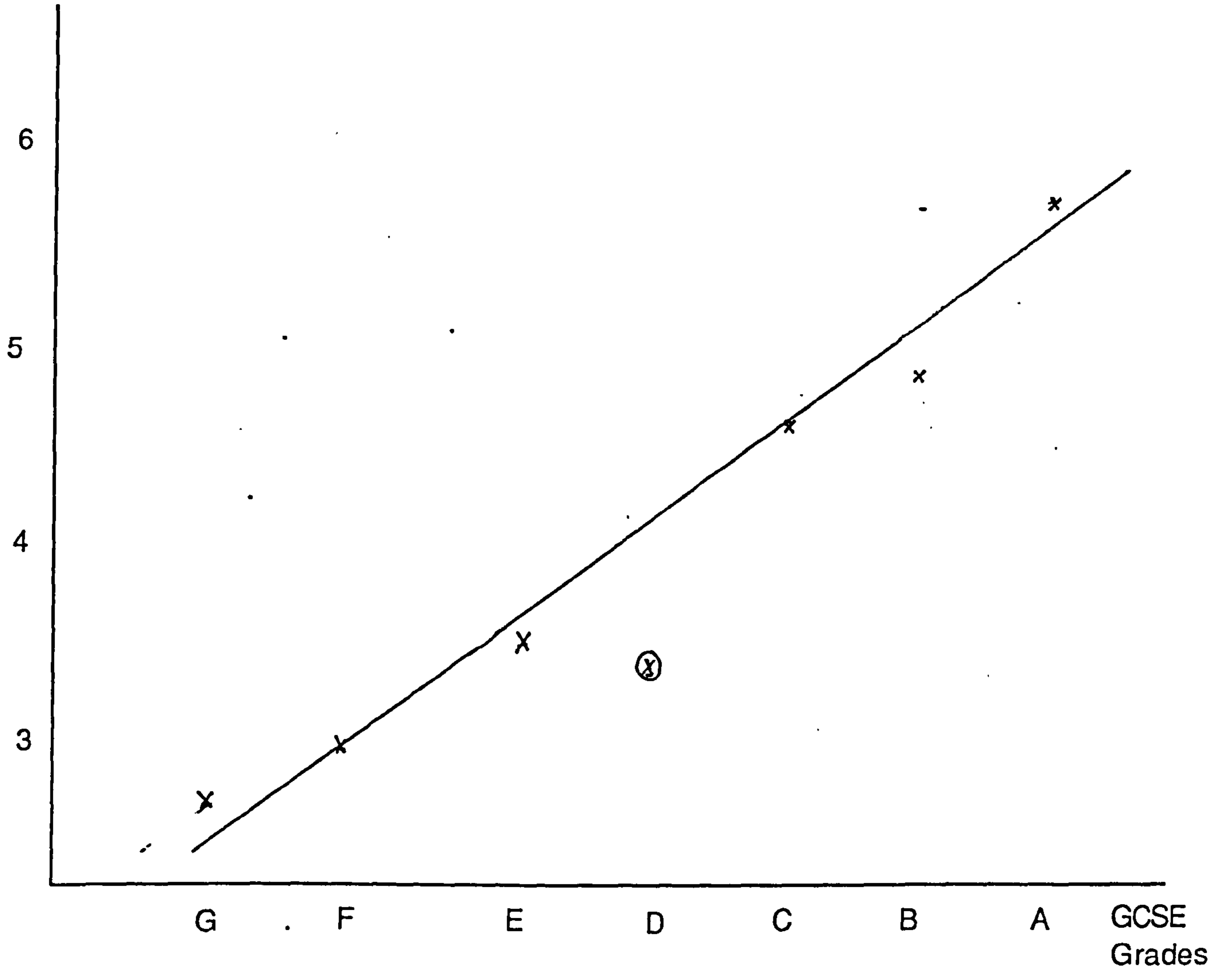
Mean number of passes/head



Graph 4.2

Mean number of skills passed in the original test
against Grade achieved at GCSE

Mean number of
skills passed



Appendix V

Letter of Introduction sent to the Original Schools

Cannock House,
Ivy Farm Lane,
Cannon Hill,
Coventry, CV4 7BW.

September, 1989.

The Headmaster,
Stoke Park School and Community College,
Dane Road,
Coventry, CV2 4JW.

Dear Mr. Wolger,

I am currently undertaking research for a Ph.D. in the Department of Science Education at the University of Warwick. I am a practising school teacher; my supervisor is Dr. P.A. Screen. The research involves the ability of pupils to deal with the more difficult theoretical skills involved in GCSE Biology.

I would like to test one or more 4th Year classes using questions to cover these particular skills and also assess the pupils' verbal reasoning quotient. I would then provide the school with marked lists of these skills and the completed papers, but excluding the verbal reasoning section. The skills would be suited to your particular Board's requirements. The exercise would take approximately 1½ hours in total.

I would like to know whether you are willing to allow this to take place, with the agreement of the Biology teacher; also which GCSE Board you are using and whether you are presenting the candidates for Biology or Science.

I enclose a SAE for your reply.

Yours sincerely,

Lesley A. Dunham

Conclusions concerning the effect of the study of three separate Sciences at GCSE on the success rate in the skills selected for study and also the final GCSE Grade.

When the cross matched groups from the non-selective school were considered there was a slightly higher overall performance in the GCSE Grades achieved. However, the situation in the selective schools and semi-selective schools was very different. The Grades achieved were far higher when the three separate sciences were studied and in the selective co-educational schools the success rate for the skills was also much higher even at the very beginning of the course.

If the 'whole cross matched sample of students studying three sciences is considered they are more successful at the majority of skills prior to tuition in these processes and considerably more successful in the grades achieved by the end of the course. Table 3.20, Graph 3.34. (Appendix IV, Page 39)

3.1.12 Investigating the significance of the study of a particular science subject.

Using the cross tabulation from Appendix 3, Page 32, the effect of study of one or more of the Science subjects on the Mean % pass rate for the skills was examined

Table 3.21

A table to find the effect of studying a particular science subject or a combination of the subjects on the mean pass rate for the skills.

Subject/s	Mean % pass rate if subject studied	Mean % pass rate if subject not studied
Chemistry	40.9	41.0
Biology	33.9	40.8
Physics	41.0	40.7
Integrated/combined Science	40.9	40.9
All three Sciences sample cross matched for IQ	64.9	53.3

From the results it appears that individuals studying chemistry or physics have no significant advantage when completing the skills over those not studying these

subjects. Biology appears to put the candidate at a disadvantage, integrated/combined sciences does not affect the performance. However, if students crossmatched for IQ who study the three sciences are compared with those who do not, the pass rate is much increased. Also the final results are considerably better. These results maybe explained as follows. With regards to Biology many of the candidates presenting only Biology were weak candidates. They may have chosen Biology as the perceived easier Science option, although unfortunately their actual grades achieved at GCSE did not indicate that they found it an easy option. The study of all three Sciences considerably improves the success rate in the 9 skills and additionally the final grades achieved as described in Section 3.3.11

The effect of the study of all three sciences on the % success in the nine skills and also the final grades achieved.

Students studying the three sciences were compared to those who were not studying three sciences in comprehensive schools, a semi selective school and a selective school, additionally all those available in the whole sample, all cross matched for IQ tables 3.17-3.20 and Graphs 3.31-3.34. (Appendix IV, Pages 36-39)

The overall pattern in the results when students studying three sciences were compared to students not studying three sciences, with the two sets cross matched for IQ, is that at the beginning of the course there is a small but perceptible difference in success in the skills in favour of those studying three sciences. By the end of the course the difference is greatly accentuated, a person studying three sciences being almost four times as likely to receive a grade A in Biology as those not studying three sciences, a ratio of 19 to 5. Table 3.20 graph 3.34 (Appendix IV, Page 39) this is statistically significant. (Appendix IV, Page 13)

However, this trend was not displayed in the comprehensive school sample, available in this study for comparison, but is very obvious in the semi selective and selective school sample.

The author suggests four possible explanations to account for this trend and its absence from the comprehensive school sample.

The greatly improved success rate for the three sciences sample could be because those who chose sciences actually thought in a 'scientific' way which improved their performance at the skills. The author questions the validity of such an explanation.

There are fewer candidates in the comprehensive school sample, capable of achieving an A Grade as the mean IQ for an A Grade is 117.5, Graph 3.26 (Appendix IV, Page 31), consequently there is less probability of the trend for an 'A' Grade for three science students to be displayed.

The students studying three sciences may be receiving more specialist teaching and possibly greater encouragement in science which probably facilitates particularly high results.

Lastly, the students studying the three Sciences may perceive themselves as 'Scientists', gain confidence and work harder, resulting in greater success.

A combination of some or all of these factors may be involved in this very apparent trend.

When the National Curriculum is fully operational, and if the option to present separate sciences is retained, it may be possible to compare results of talented pupils who consider

themselves not to be scientists but in fact offer three sciences, with students of equal calibre and similar inclination who offer integrated science.

3.2 Results Section II

This section attempts to obtain some correlation between the cognitive skills under investigation and the final success of the candidates in their GCSE and 'A'Level Biology examination where applicable. With the possibility of isolating some predictive factor for success in Biology.

To expand the sample, and also to incorporate the opportunity for candidates to undertake these skills on more than one occasion as intended by the GCSE Boards, the author examined the record cards of a large number of students from several years examinations entry. The record cards covered the students' two year course.

3.2.1 Grades obtained at GCSE

Table 3.22

Grades	A	B	C	D	E	F	G
School 8 Comprehensive	9	9	23	16	2	6	8
School 4 Selective	115	81	48	24	1	0	0
School 2 Selective	26	24	10	5	0	0	0
Total	150	114	81	45	3	6	8

The sample shows a skewed distribution in favour of the top grades because of the large number of pupils from selective schools in the sample.

The sample could not be more representative because no results were available from the GCSE board direct and only the three schools included used teacher

accessed record cards which displayed the separate skills (NEA) and were willing to make them available for the study.

The record cards were used to establish the number of students in each grade who failed a particular skill and consequently the order of difficulty. The level of difficulty was also assayed by the presence of a recorded resit for an individual skill, prior to success in that skill.

The author also tabulated and compared the pass rate in four selected skills:

23, Recognising an anomalous result,

29, Proposing a hypotheses to explain a set of results,

30, Proposing 3 hypotheses to explain a single set of results, and

32, Planning a procedure to test a hypothesis,

from the original test paper, chosen because they appeared to show more discrimination between candidates, against the grades achieved by the candidates.

Tables 3.27, 3.28 and 3.29.

Consideration of success in the eight skills tested and the final result obtained in the GCSE examination

The author also monitored the candidates who continued their study of Biology to 'A'Level,

The author considered whether each skill was successfully passed and also whether this skill was passed on the student's first attempt.

Prior to this section of the work the author had contacted NEA Board with the objective of finding whether the final grade obtained showed any relationship to the teacher assessed skills under investigation in this study. Unfortunately the Board was unable or unwilling to release this information.

To cover this aspect of the work, the author examined the Record Cards completed by the teacher assessing the candidates, to find whether the candidate had passed all the skills in question and whether one or more attempts were needed. The author had access to the Record cards of 337 candidates from the three schools offering NEA GCSE Biology.

It was found that the majority of candidates that passed 32 assessed skills obtained a Grade A. 161 candidates passed 32 skills, of these, 92 obtained a Grade A pass, 43 obtained a Grade B, 22 obtained a Grade C and 4 obtained a Grade D.

The results of these 337 candidates were then examined in more detail.

Table 3.23

Grades obtained by candidates passing 32 skills

Grade	A	B	C	D
Selective	92	42	22	4
Comprehensive	-	-	17	3

The grade cards were examined to see whether a particular skill under consideration in this work had been failed. People who had successfully passed 32 skills were thus excluded.

Table 3.24 (a)**Skills failed during the course against Grades Achieved**

Final Grade Achieved	Skills Failed							
	23	25	26	27	28	29	30	32
A	5	2	2	0	5	0	3	2
B	14	9	2	1	5	2	16	12
C	12	6	9	5	14	5	11	15
D	7	5	11	6	13	6	9	8
E	1	0	1	3	2	0	2	2
F	5	3	4	6	6	2	6	6
G	8	8	8	8	8	6	8	8
Total 333	52	33	37	29	53	21	55	53
% Degree of Difficulty	15.6	10	11.1	8.7	15.9	6.3	16.5	15.9
Order of Facility	7	3	4	2	5=	1	8	5=

Four skills were particularly difficult, 30, 32, 28 and 23 in order of difficulty as a percentage of the total failures:- 16.5, 15.9, 15.9 and 15.6 respectively as displayed in Table 3.23.

Table 3.24(b) gives additional information from the survey to show the degree of difficulty of the selected skills as indicated by the skill not being achieved at the time the GCSE examination was attempted. Results from 176 candidates.

Table 3.24(b) distribution of failed skills at the time of examination entry.

Number of candidates - 176

Skill	23	25	26	27	28	29	30	32	Total
Number of Failures	40	22	25	13	39	13	42	40	234
Relative	17.1	9.4	10.7	5.6	16.7	5.6	17.9	17.1	100

Skills 27, Recognising an uncontrolled variable and 29, Suggesting one hypothesis to explain a result, are skills which proved particularly easy. This may be due to the fact that each is an independent entity, so successful completion of another skill is not a prerequisite for success.

3.2.2 Success in the different skills as indicated on the grade card

Skill 27 degree of difficulty 8.7 (according to number of fails as displayed in tables 3.24 a and b) asks students to recognise one uncontrolled variable. This affords several possible correct lines of thought.

Skill 28, however, suggesting a control for this variable requires a far more specific answer.

Skill 29, the skill failed least often, degree of difficulty 6.3 (table 3.23) requires the candidate to formulate one hypothesis to explain an experimental outcome. There are usually many reasonable suggestions to explain a result and as the hypothesis merely has to be reasonable and not a Biologically exacting explanation, precise answers are not essential.

Skill 30, the most demanding of all the skills, degree difficulty 16.5, asks candidates to suggest three mutually exclusive hypotheses to explain a single set of results. This requires considerable mental agility and the ability to think in a 'lateral fashion' and obviously affords three opportunities to make a mistake. It is in fact fairly surprising that so many candidates do eventually achieve this skill.

Skill 32, which asks candidates to devise a plan to test one hypothesis, degree of difficulty 15.9, also proved very daunting for many candidates, even though only one sequence is required.

Skills 25, 26 and 23 (table 3.24(a) degrees of difficulty 10, 11.1 and 15.6) respectively depend on the student's ability to analyse results, recognise any pattern that exists (skill 25) and therefore be able to isolate results which do not conform to the sequence.(Skill 23).

Skill 26 likewise depends on skill 25, as the results must be analysed effectively before a valid conclusion can be drawn. However, there are frequently several acceptable conclusions facilitating a successful outcome. Also, many students who have studied science for several years are already familiar with this process.

Skills 23, 26 and 28 may in fact have been passed on a later occasion to these skills 25 and 27 on which they depend, because it is impossible to tell in some instances whether the second skill was actually available for assessment.

Summary

When considering the grades obtained, Table 3.25 candidates with A grades had few failures. B Grade candidates appeared to find skills 23 and 30 most difficult.

Table 3.25

3.2.3. Skills failed as a percentage of the candidates obtaining the grade.

Final Grade Achieved	Percentage Failing Each Skill								
	Number	23	25	26	27	28	29	30	32
A	150	3	1	1	0	3	0	2	1
B	114	12	8	2	1	4	2	14	11
C	81	15	7	11	6	17	6	14	19
D	45	16	11	24	13	29	13	20	18
E	3	1	0	33	100	100	33	100	100
F	6	83	50	66	100	100	33	100	100
G	8	100	100	100	100	100	75	100	100

Very many people passed all of their skills.

The lowest grades are under represented in the table because it contains results from two selective schools and only one non-selective school. No other schools were available to provide the internal results for practical skills.

C Grade candidates had difficulties with 23, 28, 30 and 32. D Grade candidates showed no definite pattern.

E, F and G candidates which made up a very small proportion of the sample had difficulties all round.

Resitting Skills (Table 3.26)

The record cards of the two selective schools and the one comprehensive school sitting NEA Biology were available. Close examination of these cards enabled one to establish whether the candidate successfully passed the skill on the first attempt or whether a resit was required. If a skill was passed within a teaching group on a specific date, candidates credited with the pass on a later occasion was presumed to have needed one or more resits. The teachers undertaking the assessments confirmed that this assumption was correct for the majority of cases. Exceptions to this would be if a student had been absent on the first occasion when the skill was tested or if the group had been split for an assessment. The first situation was fortunately not too common and the second had not occurred for these cognitive skills.

It was quite impossible from the record cards to identify more than one resit for a particular skill.

Table 3.26

Number of recorded resits for each skill and the relative % of resits per skill

Skill	23	25	26	27	28	29	30	32	Total
Recorded Resits	146	141	152	94	127	76	126	141	1000
Relative % of Resits	14.6	14.1	15.2	9.4	12.7	7.6	12.6	14.1	100.0

When analysed 1003 resits were identified and classified:- Table 3.26 the following deductions were made.

Skill 29 required least number of resits a result of 7.6%

Skill 27 required 9.4% of the resits. At the other end of the scale skills 26, 25 and 23 required 15.2, 14.1 and 14.6 resits respectively, but 25 and 26 were usually passed eventually. See table.

Skills 30 and 32 were recorded as a smaller number of resits 12.6 and 14.1 but they were quite often never passed at all, so they were recorded among the failures and didn't appear in the resit column. Also these skills were usually attempted late in the course so the students were more mature and likely to be more successful. These skills did show a steady improvement as the age of the samples rose. In addition, this sample contained a disproportionate number of students from the selective schools who had shown much greater facility in these high level skills. % Pass rates 28.4 and 20.9 as compared to 1.4 and 10.6 in the non-selective schools. Figures derived from computation from the data on the SPSSX computer printout. (Appendix 111 page 32)

3.2.4. Analysis of the result of the skills in the test paper in relation to the final grade achieved by the candidate.

A grade of C or higher was considered to be particularly successful for the purpose of this discussion, with Grade A the highest level of achievement.

A superficial examination of the results of all the candidates enabled skills 25, 26, 27 and 28 to be eliminated because these were successfully passed by a large number of candidates in all grade categories. However, skills 23, 29, 30 and 32 and predicting, showed much more discrimination.

Table 3.27

The % of candidates passing each skill within each grade band.

Grade	A	B	C
Skill % Pass			
23	51.2	52.9	42.0
29	79.1	79.4	58.0
30	23.3	8.8	4.0
32	25.6	14.7	26.0
Prediction	44.2	55.9	30.0
Number of Candidates	43	34	50

Two tables were constructed to examine the pass rate for skills 23, 29, 30 and 32 and making a prediction.

Table 3.28 applies to the students obtaining grades ABC, taken to be the equivalent to the original 'O'Level pass.

The pass rate is presented as a percentage as there was a sufficiently large number of candidates to render this meaningful. The number of candidates of each grade passing skills, 23, 29, 30, 32 and making a prediction was entered into Tables 3.29 a and b, Page 165. The numbers were so small that percentages became necessary.

The % distribution of grades achieved by candidates passing a skill

Table 3.28

Grade/Skill	23	29	30	32	Prediction	Candidates
A	36.1	36.9	62.6	37.9	42.2	44
B	29.5	29.3	18.7	17.2	24.4	38
C	34.4	33.8	18.7	44.8	33.3	56
Number of Passes	61	92	16	29	45	

Only skill 30 shows discrimination, with A grade candidates making up far the largest proportion of successful candidates. This is not unexpected considering the mean level of intelligence of those succeeding in skill 30:- IQ - 124. However

as the measurement of IQ is not normally available to anyone, therefore skill 30 could be used as an indicator for a candidate's potential for very high achievement at GCSE and for further study to 'A'Level. The probability that the high level of Grade A's for students passing skill 30 is due to chance is less than .001.

No other skill appeared particularly useful as a means of prediction.

Two tables to contrast the pass rate for skills 23, 29, 30, 32 and making a prediction, between students obtaining grades A, B, C and those with Grades D to G.

Table 3.29a. The % of each grade that passed these skills within Grades A,B,C

Total: 138

Grade/Skill	23	29	30	32	Prediction	Candidates
A	36.1	36.9	62.6	37.9	42.2	44
B	29.5	29.3	18.7	17.2	24.4	38
C	34.4	33.8	18.7	44.8	33.3	56
Number of Passes	61	92	16	29	45	

Table 3.29b

The % of each grade that passed these skills within Grades D, E, F, G. Total 86

Grade/Skill	23	29	30	32	Prediction	Candidates
Number of Passes - D	3	14	0	1	4	32
% Pass Rate	9.4	43.8	0	3.1	12.5	
Number of Passes - E	4	14	0	1	5	28
% Pass Rate	14.2	50	0	3.6	17.9	
Number of Passes - F	2	7	0	2	3	17
% Pass Rate	11.8	41.2	0	11.8	17.6	
Number of Passes - G	1	2	0	0	0	9
% Pass Rate	11.1	22.2	0	0	0	
TOTALS	10	37	0	4	12	86

The numbers of people scoring passes in skills at these lower grades were small, also some of the weak candidates who actually attempted the original tests did not sit the papers. It becomes apparent from these lower grade results, that these candidates find it very difficult to recognise anomalous results, predict the outcome of an experiment or plan a sequence to test an experimental hypothesis. No person was able to suggest three different hypotheses to explain experimental results. This information could be a useful diagnostic tool for a teacher.

3.2.5 Analysis of the Eight skills present in NEA Biology GCSE Syllabus as a predictive tool for 'A'Level Candidates

The author examined the record cards which had been compiled during the two year GCSE course for 40 candidates in one year group who had proceeded on to 'A'Level Biology. The results are displayed in tables 3.31a and 3.31b. Page 168.

As there are relatively few candidates, their results are listed individually, in tables 3.31a and 3.31b, the candidates are banded according to the result they achieved in the 'A'Level examination. Within the grade band they are listed alphabetically. All but two students submitted themselves to the IQ test. One person was absent and the other preferred to abstain. The unexpectedly low IQ result of candidate 5 was probably due to exceptionally bad eyesight. The IQ booklet (Appendix V) requires fairly good visual acuity.

Table 3.31 lists the students 'A'Level and GCSE grades, their IQ and sex. They all attended the same school (number 4) but may have been taught by a combination of 4 biology teachers during GCSE and 'A'Level. The eight available skills are listed.

/ indicates a pass at the first attempt

R indicates a resit was required

- indicates that the skill was never passed

29 candidates had gained A Grade at GCSE

8 candidates obtained a B Grade

3 obtained a C. The 'P' following the C indicates the easier GCSE paper as opposed to Q taken by the majority of these candidates.

As most of the students had obtained an A at GCSE, the use of the skills as a predictive tool for success at 'A'Level would be helpful.

Table 3.31 includes the results of the 40 candidates, this table is then further expanded to give table 3.31b with the percentage pass rate for each skill calculated within the grade bands. The overall percentage pass rates for each skill is also calculated.

Overall % Pass Rate Table 3.30

Skill	23	25	26	27	28	29	30	32
% Pass Rate	62.5	72.5	55	70	55	80	57.5	60

Mean Pass Rate = 64.1%. These results are not strictly comparable with the results shown in the first part of the work. The results of the 40 'A' Level students are not the result of a specific test. The task used to test the skill would have varied and the pass/fail decision would also be subjective, dependent on the decision of the student's particular teacher. However, they are comparable with the other results derived from record cards.

Table 3.31a Analysis of Final 'A' Level Result in relation to skills passed at the first attempt during GCSE.

// = pass both 'A' 7 GCSE R = Resit - = Fail P - Paper

Student No.	Grades		IQ	Sex	23	25	26	27	28	29	30	32	Total
	'A'	GCSE											
1	A	A	142	F	/	/	/	/	/	/	/	/	8
2	A	A	128	F	/	/	/	/	/	/	/	R	7
3	A	A	128	F	/	/	R	/	/	/	/	/	7
4	A	A	128	M	/	R	R	R	R	R	R	R	1
5	A	A	(94)	F	/	R	R	R	R	/	R	R	2
6	A	A	113	F	R	/	/	/	R	/	/	/	6
7	A	A	116	F	/	/	/	/	/	/	R	R	6
8	A	B	113	M	-	R	R	R	R	/	R	R	1
9	A	A	113	M	/	/	/	/	/	/	/	/	8
10	A	A	140	M	/	R	R	/	R	/	/	/	5
11	A	A	124	F	/	/	/	/	/	/	/	/	8
12	A	A	124	F	/	/	R	/	R	/	/	/	6
13	A	A	109	M	/	/	R	/	/	/	R	/	6
14	B	A	116	F	R	/	R	/	/	/	/	/	6
15	B	A	116	M	/	/	R	/	-	/	/	/	6
16	B	A	124	M	R	R	R	/	R	/	/	R	3
17	B	A	124	F	R	/	R	/	/	/	/	/	6
18	B	A	121	M	/	/	R	/	/	/	/	/	7
19	B	A	128	M	/	R	/	/	R	/	R	R	4
20	B	A	117	M	R	R	/	/	R	/	R	/	4
21	C	A	-	F	/	/	/	/	/	/	/	/	8
22	C	B	128	M	R	/	R	R	/	/	/	R	4
23	C	A	145	M	/	R	R	/	R	R	R	R	2
24	C	A	-	F	/	/	/	/	/	/	/	/	8
25	C	A	137	M	R	/	/	/	/	/	/	/	7
26	C	A	116	M	R	R	/	R	R	R	R	R	1
27	C	A	113	M	/	/	/	R	R	/	R	/	5
28	C	A	121	F	/	/	/	/	/	/	/	/	8
29	C	A	133	F	/	R	/	R	/	/	R	R	4
30	C	A	140	F	/	/	R	R	/	/	R	R	4

Student No.	Grades		IQ	Sex	23	25	26	27	28	29	30	32	Total
	'A'	GCSE											
31	D	A	128	F	/	/	/	/	/	/	/	/	8
32	D	B	117	F	R	/	/	/	R	R	-	R	3
33	E	B	106	F	/	/	R	R	R	R	/	R	3
34	E	B	131	M	/	/	/	/	/	/	-	-	6
35	N	C	131	M	-	/	-	/	/	/	/	/	6
36	N	B	103	M	R	/	/	/	/	/	/	/	7
37	N	CP	128	M	-	/	/	-	R	R	-	R	2
38	U	B	103	M	/	R	R	R	-	R	-	/	2
39	U	CP	96	M	R	/	/	R	-	R	R	/	3
40	U	B	106	M	R	/	/	/	/	/	/	/	7

Table 3.31b Expanded. Analysis of Final 'A' Level Result in relation to skills passed at the first attempt during GCSE

= pass at first attempt R=resit -- = Fail P = GCSE Paper p

Student No.	Grades		IQ	Sex	23	25	26	27	28	29	30	32	Total
	'A'	GCSE											
1	A	A	142	F	/	/	/	/	/	/	/	/	8
2	A	A	128	F	/	/	/	/	/	/	/	R	7
3	A	A	128	F	/	/	R	/	/	/	/	/	7
4	A	A	128	M	/	R	R	R	R	R	R	R	1
5	A	A	(94)	F	/	R	R	R	R	/	R	R	2
6	A	A	113	F	R	/	/	/	R	/	/	/	6
7	A	A	116	F	/	/	/	/	/	/	R	R	6
8	A	B	113	M	-	R	R	R	R	/	R	R	1
9	A	A	113	M	/	/	/	/	/	/	/	/	8
10	A	A	140	M	/	R	R	/	R	/	/	/	5
11	A	A	124	F	/	/	/	/	/	/	/	/	8
12	A	A	124	F	/	/	R	/	R	/	/	/	6
13	A	A	109	M	/	/	R	/	/	/	R	/	6

11 9 6 10 7 12 8 8
85 69 46 77 54 92 62 62

% Pass

14	B	A	116	F	R	/	R	/	/	/	/	/	6
15	B	A	116	M	/	/	R	/	-	/	/	/	6
16	B	A	124	M	R	R	R	/	R	/	/	R	3
17	B	A	124	F	R	/	R	/	/	/	/	/	6
18	B	A	121	M	/	/	R	/	/	/	/	/	7
19	B	A	128	M	/	R	/	/	R	/	R	R	4
20	B	A	117	M	R	R	/	/	R	/	R	/	4

3 4 2 7 3 7 5 5
43 57 29 100 43 100 71 71

% Pass

Student No.	Grades		IQ	Sex	23	25	26	27	28	29	30	32	Total
	'A'	GCSE											
21	C	A	-	F	/	/	/	/	/	/	/	/	8
22	C	B	128	M	R	/	R	R	/	/	/	R	4
23	C	A	145	M	/	R	R	/	R	R	R	R	2
24	C	A	-	F	/	/	/	/	/	/	/	/	8
25	C	A	137	M	R	/	/	/	/	/	/	/	7
26	C	A	116	M	R	R	/	R	R	R	R	R	1
27	C	A	113	M	/	/	/	R	R	/	R	/	5
28	C	A	121	F	/	/	/	/	/	/	/	/	8
29	C	A	133	F	/	R	/	R	/	/	R	R	4
30	C	A	140	F	/	/	R	R	/	/	R	R	4

7 7 7 5 7 8 5 5
70 70 70 50 70 80 50 50

%
Pass

31	D	A	128	F	/	/	/	/	/	/	/	/	8
32	D	A	B	F	R	/	/	/	R	R	-	R	3

1 2 2 2 1 1 1 1
50 100 100 100 50 50 50 50

%
Pass

33	E	B	106	F	/	/	R	R	R	R	/	R	3
34	E	B	131	M	/	/	/	/	/	/	-	-	6

2 2 1 1 1 1 1 0
100 100 50 50 50 50 50 0

%
Pass

35	N	C	131	M	-	/	-	/	/	/	/	/	6
36	N	B	103	M	R	/	/	/	/	/	/	/	7
37	N	CP	128	M	-	/	/	-	R	R	-	R	2

0 3 2 2 2 2 2 2
0 100 67 67 67 67 67 67

%
Pass

38	U	B	103	M	/	R	R	R	-	R	-	/	2
39	U	CP	96	M	R	/	/	R	-	R	R	/	3
40	U	B	106	M	R	/	/	/	/	/	/	/	7

1 2 2 1 1 1 1 3
33 67 67 33 33 33 33 100

%
Pass

Discussion of the GCSE skills in relation to 'A' Level success

The mean percentage pass rate was comparable with the selective school results from previous samples Table 3.2. The Mean IQ = 128.6

The Intelligence Quotient of the 'A' Level students appears to show little correlation with the grade achieved, presumably by this stage in the student's career, other factors are of greater significance. However, the three candidates with the 'U' grade had a mean IQ of 101.8 perhaps suggesting that 'A' Level Biology is aimed at a level higher than the general population average.

The mean IQ of the candidates exceeded the level 124 previously found to be the mean for success at skill 30.

The relative success rate in the skills shows little differentiation overall. A likely outcome because the tasks used were not standardised, the marking used was varied, as was also the time when the skills were tested.

Grade 'A' students scored marginally better in the skills than grades B and C but the difference was not significant. Predictably many of the candidates obtaining Grades D, E and F had needed resits, although no particular skill appears to cause excessive difficulty.

It can be concluded that proficiency in particular skills will not predict 'A' Level potential with any degree of accuracy.

3.2.6 Ability to undertake the nine skills at the age range 17 to 18 years

To assay the 40 'A' Level students' ability to undertake the selected skills, suitable questions were set on the 'A'Level Trial examination paper. It has been noted previously that the JMB is including questions involving these skills in examination papers. It was therefore a relatively easy task to incorporate questions to test the skills within the compulsory sections of the papers without upsetting the balance of the papers.

The advantages of this procedure was that the questions, conditions and marking were all standardised; the disadvantage was that the candidates were under great pressure for time and were probably less able to think clearly than was normally the case.

The results are displayed in tables 3.32, 3.33 and 3.34. Pages 175-178. Table 3.32 shows the skills passed during the 'A'Level Mock Examination alongside the first attempt at the skills for GCSE also shown in Table 3.31. As previously, the candidates are entered in bands determined by their final 'A'Level Grade, within the band they are in alphabetical order.

Discussion: By this stage the candidates ability to pass the skills had increased for skills 23, 25, 26, 27, 28 and 29. However under the examination conditions they were less successful at skills 30 and 32. It should be appreciated that when the skills were initially undertaken during the GCSE course each would have been presented as a single task with consequently more time and less pressure for the candidate. Also the 'A'Level material being used to test the skills was considerably more taxing. Overall, the success rate at the skills increased.

The data was further analysed to establish the retention and loss of the ability to succeed at the skills between the ages of 15/16 and 17/18. Table 3.34. This

information is of limited value, as it relates to each individual's performance in two very disparate isolated situations.

Candidates from all grade bands except 'D' and 'N' showed retention and improvement at the skills. Interestingly the D and N candidates who showed a loss were able students whose final grade was below their anticipated result. However, the numbers involved were too small to allow any viable deductions to be made.

Table 3.32 Analysis of Final 'A' Level Result in relation to skills passed at the first attempt during GCSE and at 'A' Mock

= pass at first attempt R=resit - = Fail p = prediction

Student No.	Grades		IQ	Sex	23	25	26	27	28	29	30	32		Total
	'A'	GCSE												
1	A	A	142	F	//	/	//	/	//	//	/-	/		8 6
2	A	A	128	F	//	//	//	/-	/-	/-	/-	R-	p	7 3
3	A	A	128	F	//	//	R/	//	//	//	/-	/	p	7 6
4	A	A	128	M	//	R/	R/	R/	R/	R/	R/	R-		1 7
5	A	A	(94)	F	//	R/	R/	R/	R/	//	R/	R-	p	2 7
6	A	A	113	F	R/	//	//	//	R/	//	/-	//	p	6 7
7	A	A	116	F	//	//	//	//	//	//	R-	R-	p	6 6
8	A	B	113	M	-/	R-	R/	R-	R/	//	R/	R-		1 5
9	A	A	113	M	//	//	//	//	//	//	//	/-		8 7
10	A	A	140	M	//	R/	R/	//	R/	//	//	//	p	5 8
11	A	A	124	F	//	//	//	//	//	//	//	//		8 8
12	A	A	124	F	//	//	R/	//	R/	//	//	/-		6 7
13	A	A	109	M	//	//	R/	//	//	//	R/	/-	p	6 7
14	B	A	116	F	R/	//	R/	//	/-	//	/-	//	p	6 6
15	B	A	116	M	//	//	R/	//	-/	//	/-	//	p	6 7
16	B	A	124	M	R/	R/	R/	//	R/	//	//	R/		3 8
17	B	A	124	F	R/	//	R/	//	//	/-	/-	//	p	6 6
18	B	A	121	M	//	//	R/	//	//	//	/-	/-		7 6
19	B	A	128	M	//	R/	//	//	R/	//	R/	R-	p	4 7
20	B	A	117	M	R/	R/	//	/-	R-	//	R/	/-		4 5
21	C	A	-	F	//	//	//	//	//	//	/-	/-		8 6
22	C	B	128	M	R/	//	R/	R/	//	//	//	R-		4 7
23	C	A	145	M	//	R/	R/	//	R/	R/	R/	R/		2 8
24	C	A	-	F	//	//	//	/-	/-	/-	/-	/-		8 3
25	C	A	137	M	R/	//	/-	//	//	/-	/-	/-		7 4
26	C	A	116	M	R/	R/	//	R/	R/	R/	R/	R/	p	1 8
27	C	A	113	M	//	//	//	R/	R/	//	R/	//	p	5 8
28	C	A	121	F	//	//	//	/-	/-	//	/-	//	p	8 5
29	C	A	133	F	/-	R/	//	R/	//	//	R/	R-	p	4 6
30	C	A	140	F	//	//	R/	R/	//	//	R/	R/	p	4 8

Student No.	Grades			Sex	23	25	26	27	28	29	30	32		Total
	'A'	GCSE	IQ											
31	D	A	128	F	//	//	//	/-	/-	/-	/-	/-		8 3
32	D	B	117	F	R/	//	//	//	R/	R-	-/	R-		3 6
33	E	B	106	F	//	//	R/	R/	R/	R/	/-	R-	p	3 6
34	E	B	131	M	//	//	//	//	/-	//	--	-/	p	6 6
35	N	C	131	M	-/	//	-/	//	//	/-	/-	/-		6 5
36	N	B	103	M	R/	//	//	/-	//	//	//	/-		7 6
37	N	CP	128	M	-	/	/	-	R	R	-	R		2
38	U	B	103	M	//	R-	R/	-/	-/	R/	--	//		2 6
39	U	CP	96	M	R/	//	//	R/	-/	R/	R/	/-	p	3 6
40	U	B	106	M	R-	//	//	/-	/-	//	/-	/-	p	7 3

By this stage, the candidates ability to pass the skills had increased for skills 23, 25, 26, 27, 28 and 29. However, under examination conditions they were less successful at skills 30 and 32. It should be appreciated that when the skills were initially undertaken during the GCSE course each would have been presented as a single task with consequently more time and less pressure for the candidate. Also, the 'A' Level material being used to test the skills was considerably more taxing. Overall, the success rate at the skills increased.

Table 3.33. To compare the percentage pass rate of the selected skills of 'A' Level candidates when aged 17/18 years, as opposed to the % success rate by the same students at their first attempt when aged 15/16 years

Skill	Success at 15/16	Success at 17/18
23	62.5	94.8
25	72.5	94.8
26	55	97.4
27	70	79.5
28	55	79.5
29	80	82.0
30	57.5	51.3
32	60	46.7
Prediction	-	62.2

39 candidates only are represented at 17/18 years.

Mean Intelligence Quotients of 'A' Level candidates at each grade

Grade	Number of Candidates	IQ
A	13	123.2
B	7	120.9
C	10	129.1
D	2	122.5
E	2	118.5
N	3	120.6
U	3	101.8

Mean IQ 128.6

The data was further analysed to establish the retention and loss of the ability to success at the skills between the ages of 15/16 and 17/18. Table 3.34. This information is of limited value, as it relates to each individual's performance in two very disparate isolated situations.

Table 3.34a To record both the retention and loss of the selected skills between GCSE and 'A' Level

Skill	Improvement / Loss of Skill			
	Number	%	Number	%
23	12	30	1	2
25	9	22.5	0	0
26	11	27.5	3	7.5
27	7	17.5	5	12.5
28	16	40	7	17.5
29	7	17.5	6	15
30	14	35	15	37.5
32	6	15	14	35

Table 3.3.4b**Retention and loss of the selected skills by candidates grouped by 'A' Level Grade**

	Grade		No. of Improve-ments	% Improve-ments	No. of Losses	% Losses
13 candidates	A					
8 Skills		104 attempts	23	22	12	11.5
7 candidates	B					
x 8 Skills		56 attempts	18	32.1	9	16.1
10 candidates	C					
x 8 Skills		80 attempts	26	32.5	15	18.6
2 candidates	D					
x 8 Skills		16 attempts	3	18.8	6	37.5
2 candidates	E					
x 8 Skills		16 attempts	6	37.5	1	6.0
3 candidates	N					
x 8 Skills		24 attempts	2	8.3	5	20.8
3 candidates	U					
x 8 Skills		24 attempts	9	37.5	4	16.7

Candidates from all grade bands except 'D' and 'N' showed retention and improvement at the skills. Interestingly the D and N candidates who showed a loss were able students whose final grade was below their anticipated result. However, the numbers involved were too small to allow any viable deductions to be made.

3.3 Results Section III

This section of the work aimed to extend the age range under consideration with regards to students' ability to undertake the 9 specific skills. The objective was to see whether there was any hierarchy in the order for the achievement of the skills and whether the ability to perform the skills fluctuated with different age ranges.

Ideally this work would have been undertaken following the same group of students over the entire age range. This unfortunately was not practical. The author attempted to partially standardise the sample by using cohorts of the chosen age groups from a selective school population which had the advantage that the mean IQ of the samples would be within the range already established as the mean to achieve the majority of the skills. Table 3.38.

In addition the study included very young children aged between 5 and 7 years, Table 3.35. Unfortunately, this part of the study cannot be reliably compared with the rest of the work because it was impossible to establish the IQ of the children by an equivalent IQ test as none was available suited to such young children. The teachers of the children gave an estimate of the intelligence of each candidate as high, medium or low, but this is not included because of the subjective nature of the information.

The Biological Questions used for the candidates at ages 5 to 7, 11 to 12 and 13 to 14 are included in Appendix II. In the case of the two younger age groups the experiments were demonstrated practically, prior to the questions being attempted (as already mentioned in the method) in an attempt to improve the childrens' understanding of the questions.

**3.3.1 Results for the children aged 5 to 7 years. Table 3.35. Page 181 and 182.
Candidates entered individually.**

Three schools were involved. School 1, worked by the Montesorri Method using a large measure of 'hands on' experience for the children in all areas of their work, Schools 2 and 3 did not. Children at Schools 1 and 3 had had regular opportunities to watch or perform simple experiments.

Achievement of Skills

In all the schools, recognition of an uncontrolled variable, (skill 27) had the highest pass rate, devising a method of controlling the variable (skill 28) they had selected, was successfully accomplished by more than half the children in schools 1 and 3.

In school 1, all but one student was able to devise a hypothesis to explain some results presented to them. Skill 29, and amazingly, four could provide two additional acceptable explanations to fulfil skill 30. The teacher of these pupils had estimated them to be of medium to high ability level. In their normal class situation the groups were very small with a high teacher/pupil ratio. Unlike the children from the two other schools they were quite willing to put forward tentative explanations for data presented to them. The author however, appreciates the lack of significance of this information due to the very small sample.

Skills 25 and 23, which requires the recognition and comprehension of a pattern in a sequence of results, eluded all but 4 of the 41 candidates, however, 10 students were able to draw valid conclusions from the data.

Table 3.35 Results of children aged between 5 and 7 years from 3 schools

Skills		23	25	26	27	28	29	30	32	Pred	Total	Age	
School 1	Sex												
1	F	-	-	/	/	-	/	/	-	-	4	7	10
2	M	-	-	-	/	/	/	/	-	-	4	6	0
3	M	-	-	/	/	-	/	-	-	-	3	7	0
4	F	-	-	/	/	/	/	/	-	-	5	7	4
5	M	/	-	/	/	/	-	-	-	-	4	6	0
6	F	-	-	-	/	/	/	/	/	-	5	6	2
		1	0	4	6	4	5	4	1	0	25		
	%	16	0	66.6	100	66.6	83.3	66.6	16	0	Mean 4		

School 2													
1	M	-	-	-	/	-	-	-	-	-	1	7	0
2	M	-	-	/	-	-	/	-	-	-	1	7	0
3	F	-	-	-	-	-	-	-	-	-	0	7	0
4	M	-	-	-	-	-	-	-	-	-	0	7	0
5	M	-	-	-	-	-	-	-	-	-	0	6	6
6	M	-	-	/	-	-	-	-	-	-	1	6	0
7	M	-	-	-	/	-	-	-	-	-	1	6	0
8	F	-	-	-	-	-	-	-	-	-	0	6	6
9	F	-	-	-	/	-	/	-	-	-	2	6	0
10	M	-	-	-	/	-	-	-	-	-	1	6	0
11	F	-	-	-	/	-	-	-	-	-	1	6	9
12	F	-	-	/	/	-	-	-	-	-	2	6	0
13	M	-	-	-	-	-	-	-	-	-	0	6	0
14	F	-	-	-	/	-	-	-	-	-	1	6	4
15	F	-	-	-	/	/	-	-	-	-	0	6	0
16	M	-	-	-	-	-	-	-	-	-	0	6	0
17	F	-	-	-	/	/	-	-	-	-	2	6	6
18	M	-	-	-	-	-	-	-	-	-	0	6	0
19	M	-	-	-	/	-	-	-	-	-	1	5	9
20	F	-	-	-	-	-	-	-	-	-	0	5	6
21	M	/	-	/	/	-	-	-	-	-	3	7	0
22	M	-	-	-	-	-	-	-	-	-	0	7	0
		1	0	3	11	2	2	0	0	0	19		
	%	4	0	13	47.8	8.7	8.7	0	0	0	Mean 1	6	0

School 3													
1	F	-	-	-	-	-	/	-	-	-	1		
2	F	-	-	/	/	/	/	-	-	-	4		
3	F	/	-	/	/	/	-	-	-	-	4		
4	F	-	-	-	/	-	-	-	-	-	1	7	6
5	F	-	/	-	/	/	-	-	-	-	3	7	0
6	F	-	-	-	/	/	/	-	-	-	3	7	6
7	M	-	-	/	/	/	-	-	-	-	3		
8	M	-	-	-	/	-	-	-	-	-	1	7	1
9	M	-	-	-	/	/	-	-	-	-	2	7	7
10	M	-	-	-	/	/	/	-	-	-	3	7	4
11	M	/	-	-	/	-	-	-	-	-	2	6	7
12	M	-	-	-	/	-	-	-	-	-	1		
		2	1	3	11	7	4	0	0	0	28		
	%	8	8	25	91.6	58.3	33.3	-	-	-	Mean 2.3	7	3

3.3.

2 A comparison of children aged 10 to 11 years in a selective and a non-selective school

Two groups of children in the age range 10 to 11 years, were tested, the first group were from an all ability school, results are shown in table 3.36, page 185 (each candidates results are entered individually) the second, comprising 63 students were from a selective school. (Tables 3.37 and 3.38) The group from the first school did not undertake the IQ test for reasons of school policy. These students had regularly been undertaking practical science lessons with an extremely gifted teacher.

The students were very successful at recognising an uncontrolled variable (27) and controlling it (28). They were also able to devise one hypothesis to explain a set of results (29) and 7 out of 33 candidates could provide three explanations (30). The ability of this age group to interpret patterns in results and recognise an anomaly had improved considerably over the 6 to 7 year olds and the majority could draw conclusions. Few were able to predict an outcome for their experiment, frequently because they had only partly perceived the pattern, and the rather involved skill 32, requiring the student to plan an experiment to test a hypothesis, was completed successfully by only three people.

The author has made no attempt to compare the males and females in the study because they cannot be cross matched for IQ.

The second group of 10 to 11 year olds were from a selective school (School 4), 63 candidates in total. The same type of IQ test was used throughout but scale 2 was used for the 10 to 11 year olds and Scale 3 for all the older age ranges in the selective school.

The percentage pass rate for these students in the nine skills is listed in Table 3.37. Page 186.

Again, skill 27 and 28 presented no problem for the vast majority and devising one hypothesis was successfully achieved by 84% of the sample. Devising three different hypotheses and making predictions were passed by 23%. More than half of the children were successful in pattern recognition and interpretation. This sample from the selective school was used for comparison with the other three age ranges also from the selective school.

The sample of 13 to 15 year olds, shown in table 3.38 consisted of all the third year pupils (Year 9) from the selective school, available to be tested, three classes, the tests used are present in appendix 4, the results are included in table 3.38. The mean IQ of this sample was lower than expected.

The most striking result is this group's success in providing explanations for results. 95.8% and 59.2% passing skills 29 and 30 respectively. The majority of the skills 25, 26, 28, 29, 30 and 32 show an improvement, there was little room for improvement in skill 27.

The results for ages 15/16 and 17/18 are the ones displayed and discussed in sections (1) and (11) of the results.

Table 3.36

Table of Results to show the success in the selected skills of pupils aged 10/11 years in a non-selective school

Skill	23	25	26	27	28	29	30	32	Pred.	Total
Candidate Males										
1	/	-	-	/	/	/	-	-	-	4
2	-	-	-	/	/	/	/	-	-	4
3	-	/	/	/	/	-	-	-	-	4
4	/	-	/	/	/	-	-	-	-	4
5	/	-	-	/	/	-	-	-	-	3
6	/	/	/	-	-	-	-	-	-	3
7	-	-	-	-	/	-	-	-	-	1
8	/	/	/	/	/	/	/	/	/	9
9	-	-	-	/	/	-	-	-	-	2
10	/	/	/	/	/	/	-	-	-	6
11	-	/	/	/	/	/	-	-	-	5
12	-	-	-	/	/	-	-	-	-	2
13	-	-	-	/	/	-	-	-	/	3
14	-	/	/	/	/	/	/	/	-	7
15	--	-	/	/	-	-	-	-	-	2
16	/	/	/	/	/	/	/	/	-	8
Total	7	7	8	14	15	7	4	3	2	Mean 3.8
1	-	-	-	/	/	/	-	-	-	3
2	/	/	/	/	/	/	/	/	-	8
3	-	-	/	/	/	/	-	-	-	4
4	-	-	-	/	/	/	-	-	-	3
5	-	-	/	/	/	/	/	-	-	5
6	/	/	/	/	/	/	-	-	-	6
7	-	-	/	/	/	/	-	/	-	5
8	/	-	/	/	/	/	/	-	-	6
9	-	-	/	/	/	-	-	-	-	3
10	-	-	-	/	/	-	-	-	-	2
11	/	/	/	/	/	/	-	/	-	7
12	-	-	-	/	/	/	-	-	-	3
13	-	-	/	/	/	/	-	-	-	4
14	/	/	-	/	/	/	-	-	-	5
15	/	/	/	/	/	/	-	-	/	7
16	-	-	-	/	/	/	-	-	-	3
17	/	-	/	/	/	/	-	-	-	5
	7	5	11	17	17	15	3	3	1	Mean 4.6
Male & Female %	4.24	36.4	57.6	93.9	97	66.7	21.2	18.2	9.0	Overall mean 4.4

Table 3.37. To compare the pass rate in the selected skills at age 10/11 years in a selective and non-selective school.

Skill % Pass	Selective	Non-Selective
23	42.3	42.4
25	53.8	36.4
26	53.8	57.6
27	100	93.9
28	92.3	97.0
29	84.2	66.7
30	23.1	21.2
32	26.9	18.2
Pred.	23.1	9.0
Number of Candidates	63	33
Mean Pass Rate	5.1	4.4
Mean IQ	120.9	unknown

3.3.3 % Pass rate in the selected skills at 4 different age ranges.

Table 3.38 compares the percentage pass rate in the nine skills at the four age ranges.

Table 3.38. To compare the percentage pass rate of the selected skills by four different age groups all from samples are drawn from the same selective school.

Age Group Skills	10/11	13/14	15/16	17/18
23	42.3	36.6	50.7	94.8
25	53.8	54.9	86.6	94.8
26	53.8	81.7	80.6	97.4
27	100	95.8	95.5	79.5
28	92.3	95.8	74.6	79.5
29	84.2	95.8	74.6	82.0
30	23.1	59.2	19.4	51.3
32	26.9	38.0	20.9	46.7
Prediction	23.1	32.4	49.3	62.2

Skill 27 does not improve with age particularly when the level of difficulty of the experimental data increases. Skill 28, controlling variables, appears to fluctuate. Skills 23, 25, 26 and prediction, all related to pattern recognition and interpretation, show a steady improvement, possibly due to the establishment of schemata (Piaget, Introduction Section 1, Page 66)

Skill 30 was passed by just over half the 'A'Level candidates and surprisingly by even more, 59.2% of the 13/14 year olds. The author has noticed during her teaching experience that many pupils never achieve this skill before leaving school. The planning of an experiment to test a hypothesis, regularly required as part of 'A'Level work (although not normally tested under such restrictive time limits) was passed by only 46.7% of the 17 to 18 year olds, showing a considerable improvement at this skill in their final two years of Biology tuition.

The overall significance of these three sections of results are considered in Chapter 4, discussions and conclusions.

CHAPTER FOUR

CONCLUSION & DISCUSSION

The original aim of this work was to investigate the level of cognitive development of students in the context of their Science Education. In particular the effect of the different circumstances and approaches to teaching on the development of the skills required for NEA GCSE Biology was investigated. The study was extended to consider the acquisition of the skills in younger age groups and the possible correlation with 'A' Level performance.

The GCSE skills selected for investigation appeared to be pivotal to the rationale of "Scientific Thought" as originally expounded by Armstrong, 1903, at the beginning of the 20th Century and reinforced at regular intervals up to and including the present day in Science 1 of the National Curriculum, 1992.

Armstrong expected his students to observe events precisely, test hypotheses, think logically and verify provisional ideas. Similarly, Science 1 (Appendix 1) requires students to construct hypotheses, devise experiments with variables controlled to test these hypotheses, record effects and draw conclusions from their results. These two statements encompass the skills under investigation in this work.

4.1 Discussion Relating to the Original Sample of Students tested.

4.1.1 The Skills Under Test (are numbered according to NEA GCSE Biology)

The ability to appreciate and establish a 'Fair' test (one with variables controlled is assessed by skills 27 and 28.

The ability to recognise patterns in results, pinpoint anomalies to the patterns and draw valid conclusions are tested in skills 25, 23 and 26 respectively.

To hypothesise about the explanation for the results and to design an experiment to test such a hypothesis is monitored by skills 29, 30 and 32.

Extrapolation to make predictions from the pattern of the results is tested in this work but was not included as one of the NEA Biology skills.

Each skill was tested separately for NEA Biology GCSE, the author maintained this procedure in an attempt to isolate competence or the lack of it for each individual process.

4.1.2. Cognitive Development

The level of Cognitive Development of each candidate could not realistically be established on an individual basis but the use of the IQ test result served to give some approximation of the student's cognitive level relative to the test sample under investigation and to the norm of the population as a whole.

The tests used involved series completion, classification, matrices, pattern recognition and extrapolation of these four criteria. All of these procedures require the person to be using formal operational and hypothetico deductive reasoning (Brainerd, C. 1978). It therefore seems reasonable to assume that students obtaining a high score on the IQ test were thinking effectively at the formal operational level, conversely low scores implies incomplete mastery of this thinking mechanism.

The work of Shayer and Adey (1981) suggests that only 20 to 30% of an unselective British school population aged 14 to 15 years will be operating at the Early Formal Level 3A. Graph page 88.

4.1.3 Additional Factors

The author hoped to establish whether various factors relating to the students or their learning situation had any measurable effect on the acquisition of the skills under investigation and whether these skills showed any relationship to the grade finally achieved at GCSE and to the students' further progress in the study of Biology.

4.1.4 Conclusions relating to the GCSE Skills under investigation

Skill 27 Recognising an uncontrolled variable

This skill seems to have been successfully undertaken by the vast majority of students in the sample 89.8% even some of those in the youngest age group. The idea of a 'fair test' seems to be readily appreciated. Additionally, as there are usually several variables that the student could consider, they usually successfully select one. This skill is required in AT1 Science Strand (iii) Level 3 of the National Curriculum which might be achieved by some pupils in Key Stage 1 (5-7 years). An additional predisposition to success in skill 27 was the nature of the questions used both for the Author's tests and also on the examination papers. They are presented in the form of diagrams enabling students to work at the concrete operational level not just the abstract level.

Skill 28 Devising a means to control the selected variable.

The success rate for this skill was lower but still passed by the majority of candidates (-70.9%). Failure resulted when students selected one variable but suggested strategies which in fact controlled another variable instead.

The author noted that occasionally when questions concerning variables required a very specific response, then the success rate was much lower.

Skill 25 Recognising patterns in data.

The success rate for this skill was 66.0%. The data which had to be considered was presented in unsorted and numerical form, as recommended by the GCSE boards. Several patterns were present in the data and they were not immediately obvious. They also probably conflicted with prior knowledge which the student already possessed. Ausubel (1968) noted preconceptions are tenaciously held and are extremely resistant to extinction. To correctly solve this part of the test the student was therefore compelled to rely on logico deductive reasoning, not necessarily yet developed in all students, possibly explaining the reduced rate of success. Perhaps, if students had the opportunity to experiment and actually produce the results working at a concrete operational level, the patterns might prove to be more easily recognised and accepted.

Skill 23 Recognising an anomalous result

Recognising an anomalous result from among a pattern of results proved difficult for the majority of candidates, 30% pass rate, even for students who had already apparently discerned the patterns. The explanation may lie in incomplete comprehension of the pattern, so guesswork was used to select the anomaly.

Skill 26 Drawing a valid conclusion from experimental results

This skill was dealt with effectively by a higher proportion of candidates than skill 23, 61.5%. Initially this seems unexpected as 26 would appear to depend on complete recognition of the pattern in the data. However, students are specifically taught from an early age that a conclusion to experimental results is the norm, so

they have experience of this process. Additionally it is probably that there will be more than one viable conclusion available from a set of results consequently numerically improving the chance of success.

Skill 29 Formulating a hypothesis to explain a set of results

This skill proved to be within the capabilities of the majority of candidates 57.0%. Again the possibility of more than one acceptable suggestion facilitates success. However, when three separate hypotheses were needed relating to one set of data (Skill 30) the success rate was extremely low (9.8%). This skill proved to be the most taxing. The thinking required involves hypothetico deductive reasoning relating to several interacting variables, with the ability to generate at least three different interpretations and then reflect on alternative lines of thought. This is definitely at Piaget's Later Formal Operational Level 3B, as quoted by Shayer, M. and Adey, P. (1981).

Skill 32 Devising an experimental procedure to test a hypothesis

Skill 32 also had a high failure rate, 84.6%, (15.4% pass). Quite a detailed response was required in a totally novel and theoretical situation. Even candidates who had been relatively successful with the other skills appeared to be unwilling to make up a procedure relating to an unfamiliar situation.

This process is also required for the practical assessment of 'A' Level candidates and also causes considerable difficulty even to students at that age with far greater scientific experience.

This procedure is now the basis for assessment for Science AT1 Level 4 of the National Curriculum and is generating a tremendous amount of work involving a high level of cognitive skill from 14 and 15 year old pupils.

When attempting to make a prediction, candidates appeared unable to elucidate the general trend in an experiment and are thus unable to predict the likely outcome of further experimentation. The author, from discussion with some groups of candidates after the tests, got the impression that lack of confidence and fear of making a foolish response inhibited many candidates.

It appears that skills 27, 28 and 29, are within the reach of candidates working at the concrete operational level, whereas 23, 25, 26, 30, 32 and making a prediction require hypothetic deductive reasoning. Additionally, many candidates seem to be willing to use their full range of reasoning skills when working with familiar material that they deem to be easy, but cease to think logically and make reasonable deductions if the experimental information is outside their experience. This was also noted with 'A'Level candidates in part three of this work. Rosalind Driver has noted (1983) that familiarity or unfamiliarity of the material influences the students ability or inability to fully utilise his hypothetico deductive logic.

Bryant, P. (1974) finds that the child's cognitive skill (in this case required to reason about scientific data) is related to the capacity of their working memory, ie., the amount of information an individual can hold available in their mind at one time. This ability is also of great significance for the reasoning problems presented on the IQ paper and seems to explain the direct correlation between the degree of difficulty of the skill and the mean level of IQ of those passing the skill.

4.1.5. Consideration of Intelligence in the context of this work

The computer analysis of the results enabled the significance of IQ to be evaluated. Table 3.3 page 123 shows the mean IQ of the candidates that passed each skill Table 3.12 and Graph 3.26. Appendix IV, page 31, shows the grade achieved and the mean IQ of students obtaining each Grade. Additionally the

following table, produced from further analysis of the original data, shows the IQ presented in bands in relation to the mean number of passes per head.

Table 4.1

IQ Band	Mean Number of Skills Passes
135+	5.75
125-134	5.45
115-125	5.27
105-115	4.48
95-105	4.02
89-95	3.37
75-85	3.11
65-75	No candidates
<65	3.00

This information shows the relationship between IQ and success in the skills. In particular Skill 30 passed by the least number of people, showed those successful candidates to have a mean IQ of 124. There was direct positive correlation between IQ and the mean number of skills passed, Graph 4.1 appendix IV, page 40 and mean IQ and the grade achieved, Table 3.3, Graph 3.26, page 31.

A reasonable conclusion from this data is that although IQ tests in no way measure the same abilities as either the Biological Skills as tested in this work or the execution of the final examination at GCSE, the cognitive ability to score highly on an IQ test appears to facilitate success both in the Biology Skills and GCSE Biology.

As a result of this conclusion it became apparent that to make a comparison of the other factors under test meaningful, the influence of variation in individual IQs must be eliminated. To achieve this comparisons were only made between two samples of very close IQ distribution as in the case of Process Science as opposed to Traditional Science Comprehensives, or between sets of candidates individually matched for IQ, the latter method was used whenever possible if an adequate sample could be generated. The size of the samples under investigation were consequently much reduced, however, the subsequent comparisons should be more valid because of the removal of the variation in IQ.

4.1.6. The effect of the gender on the success in the skills

There were considerable fluctuations in the percentage success rate in the nine skills of the two genders, as discussed in the results section page 130 but no difference was great enough to show statistical significance. When a selected sample in the IQ range 115-125 was compared, male success was better than females on skill 30 (22.8% success as compared to 11.4% success for females). Males were also more successful at making predictions. Both these skills require the willingness to make deductions without the availability of all the information. Conversely, the reverse situation applied for skills 27, 28, 29 and 32. The skills not mentioned 23, 25 and 26 showed less polarity. The difference in the overall mean success rate for the skills 58.1% for males and 63.0% for females was below the level of statistical significance. Certainly neither sex was at an overall disadvantage relating to the GCSE Biology Skills assessed in this work. This conclusion was also supported by the Grades achieved at the end of the course with males and females compared Appendix IV Graphs 3.6 and 3.7.

4.1.7 The effect of single sex education on girls' and boys' success in science

It has been suggested by various studies (HMI 1979) (Harding, J. 1981) (Bone, A. 1983) (Kelly, A. 1987) and more recently as the result of a study in a particular school, Shenfield High School, Essex (TES 1993), that girls achieve better results if taught science in a single sex situation.

The results of the work in this thesis do not support that proposition, (results tables 3.14 and 3.15). Additionally boys taught in a boys only school achieved less well, (table 3.13). This latter result was as expected, according to previous research work. (Dale, R. 1969).

When considered in more detail, with the samples cross matched for IQ, the sample of girls from a semi-selective girls school showed some initial advantage in the skills at the start of the course. This was not the case in the girls only comprehensive school, but by the end of the course the grades achieved at GCSE were significantly lower in both cases of single sex education.

It is appreciated that the sample in this thesis is small and so, by definition, suspect. However, an explanation for the discrepancy with the accepted wisdom may be related to the original sample on which the classic research work was performed. The girl's results for the original research project contained those of students from many of the schools belonging to The Girls Public Day School Trust, schools of particularly high academic calibre. It would be very difficult to produce a sample from co-educational schools of the same ability range and the samples were not apparently, cross-matched for IQ. The results may well have been skewed by the sampling procedure.

The author did not attempt to measure the effect of single sex education on the uptake of science, which is also extremely significant if society wishes to increase the number of female scientists.

4.1.8 The Significance of students being of Asian Origin

The author was interested in examining this parameter because in the school where she teaches there are a large number of students of Asian origin who prove to be very successful in the sciences. However, when the raw results were evaluated the students of Asian origin appeared to be at a disadvantage, Table 3.10. However, when the sample was cross matched for IQ although there was considerable fluctuation between success in the individual skills, there was no

statistically significant difference that would have enabled a conclusion to be drawn.

4.1.9 The significance of Teaching Method

The method by which Science lessons are taught to students could well effect their ability to understand, retain and apply the received information.

Two of the possible methods are considered in this study. There is the content led approach where information is supplied or produced experimentally and is then evaluated and possibly retained. Alternatively, the process led approach, where the cognitive processes, considered to be an integral part of scientific reasoning, are taught and then applied to different topics. The second method is encapsulated in the Warwick Process Science Project (Screen, P. 1984). The first method is the technique traditionally used.

It was hoped that initial experience of Process Science in the first two years in the senior school would have improved the candidates performance in the nine skills which were specifically taught as the Processes. The sample contained 57 candidates who had experienced the Process Science methodology. These students were compared to a sample of equivalent IQ range who had been taught wholly by traditional methods.

When the abilities in the skills were compared there was no significant difference between the two groups, nor was there a difference in the overall GCSE grades achieved at the end of the course.

The result contrasts with the results reported by P.Adey, as a follow up to the CASE Project (1993). Although there was no measurable improvement in science

performance at the start of the study, there was a considerable improvement in the final grades in Science, Maths and English, of the group who had participated in the Cognitive Acceleration through Science Education scheme as compared to the control group.

The failure of the Process Science group to show improved facility in science may be explained by the small sample size and by the fact that they probably received a smaller and less regulated exposure to the processes. There was also a three year gap between the end of their process science experience and their GCSE examination. In addition, the experiences they received could well have been less standardised than those in the CASE project where the science tasks presented were precisely defined and undertaken at specific time intervals.

4.1.10 The influence of School Type

The effect of education in a comprehensive school as compared to a selective school was investigated . To make such a study meaningful it was necessary to cross match candidates for IQ. The difference in performance of the two cross matched groups was very significant. When investigating the performance in the skills at the beginning of the course the students from the non selective schools passed an average of 3.6 skills whereas the selective schools passed a mean of 5.7. The achievement of high grades in GCSE was also greater, none of the selective school sample getting a grade below C compared to 10 of the nonselective sample obtaining a Grade D or lower. Both of these results showed a high level of statistical significance - Appendix IV. Pages 5 and 6.

Various factors, all unexplored in this work, could be postulated to account for these differences, expectations high or otherwise of the pupils themselves, their parents or their teachers. The influence of the class environment and the peer

group, could provide a positive or negative influence on the work ethos. The author certainly noticed greater difficulty of pupils in the comprehensive school classes to concentrate on the test and IQ paper for the time allotted. No such problem was noted in pupils from the selective school. This evaluation is, however, subjective and additionally the comprehensive classes contained all the students regardless of IQ not just the ones eventually used in the cross match. It was not possible to explore the attitude to their work of the pupils, teachers and parents without exceeding the parameters agreed when permission was given for the survey. The part of the study originally intended to evaluate their performance was unsuccessful. Insufficient replies were received and many students who had performed abysmally claimed that they had no difficulty in concentrating and performing the tasks. Only the more mature and also high achieving candidates seemed able to critically evaluate their performance, and the answers given did not constitute a recognisable pattern although worry about performance and the pressure of time was cited on several occasions.

The conclusion relating to this section that selective education enhances pupil performance is not helpful to the education system as a whole. The selection procedure has separated students into two groups, who as far as is measurable by the IQ test used, are of equal potential, the selected pupils then go on to acquire more of the nine skills tested and achieve higher GCSE grades. Logically, however, everyone cannot be chosen for selective education, otherwise selection is no longer occurring, so the enhancement factor is only available to the chosen few, whilst others never get the opportunity to achieve their full potential at least in the academic field at this level. It would appear to be a very fruitful area for educational research to try to isolate the enhancement factors that seem to be assisting the selective school pupils, if such an enhancement is deemed to be desirable. Possible lines of enquiry might centre around expectations and concentration, with the hope of transferring the benefits to the system as a whole.

The author appreciates that this is not a new and unexplored area for consideration but it still appears to be relevant to the present day education system. It will be of considerable interest to see whether the discrepancy still remains when the National Curriculum is fully operational and the results of all schools are available for public scrutiny. Unfortunately, because no attempt is made to measure the cognitive potential of the candidates it will be impossible to make a fair comparison of groups of candidates by taking this into account. The comparison of raw results by uninformed persons may in fact cause more harm than good.

4.1.11 The effect of studying the three sciences as separate subjects.

The effect of studying a particular science on the success in the nine selected skills was examined using the results from the computer printout, Appendix III. Page 7.

When the whole sample was considered, table 3.21, page 151, the ability to pass the skills appeared unaffected by the study of physics or chemistry as opposed to integrated science. However, the students studying Biology only, seemed to be at a definite disadvantage. These findings are discussed in the results section with the tentative assertion that weaker students appeared to have chosen to study Biology only, which could account for their poor results.

When students studying all three sciences were considered, they performed better on the initial skills question paper, particularly in the context of the selective school. The final Biology GCSE results of the students studying the three sciences were significantly better, the number of students obtaining a grade A, being much higher, Tables 3.17 - 3.20, page 30-34, and graphs 3.31-3.34, Appendix IV, pages 36-39. When the study was repeated again in 1993 on two

classes taught by the same teacher under virtually the same conditions the initial difference in the number of skills passed was insignificant, but by the time the students were examined for their 'Mock' GCSE examination there was a striking difference in their results.

One is led towards the conclusion that it is the expectations and commitment of the students themselves to their different chosen subjects that has polarised the results of the two groups. The attitude to work within the two classes appeared very similar, although it did appear that students not in the 'Science form' were more reticent, when asked to hypothesise about unfamiliar areas of information.

Overall it would appear that the best chance of success in GCSE Biology is afforded to students in a selective school studying three sciences even when the effect of IQ is eliminated by cross matching.

4.1.12 The predictive value of success in the skills for GCSE success

Only skill 30, formulating three separate hypotheses to explain a multivariant problem showed predictive value. The probability of students passing skill 30, also obtaining a grade A at GCSE was very high. This could be useful to a teacher to recognise particular talent at a relatively early stage in the course.

This was, of course, found to correlate very closely with a high IQ but the information relating to IQ would not normally be available to a classroom teacher.

4.2 Discussion of the extension of the work to 'A' Level Students

4.2.1 Discussion relating to results section 3.2.5.

In order to establish whether success in the nine skills under investigation were of any predictive value for success at 'A' Level a particularly large group of 'A' Level candidates was investigated. Their GCSE grade cards listing the skills which they had passed was examined, looking particularly at the 8 skills under investigation. Their results are displayed in table 3.31a and 3.31b. Pages 168 to 171.

As almost all the candidates eventually passed all 32 skills, a pass on the first attempt is the criterion used in the tables.

It proved impossible to isolate any particular skill or other factor with a definite predictive value for future 'A' Level success. Even the attainment of an A Grade at GCSE was no guarantee of a high grade in 'A' Level. Although lack of a grade 'A' at GCSE was an inauspicious foundation for the 'A' Level course, only 2 candidates with grade B managed to achieve a C grade or higher at 'A' Level. This does of course explain the dearth of 'A' Level candidates available from the rest of the sample as very few candidates were obtaining high GCSE grades.

It would appear that the skills under investigation and the GCSE grading system is insufficiently accurate at the higher grades to be a predictive tool for future academic study. However, with the adoption of the National Curriculum and its 10 Level Scale particularly with regards to Science AT1, and the starred award at key stage 4 the really gifted pupils should certainly be highlighted. Whether educationally this is a useful objective, when the stated aim of the National

Curriculum is to improve and expand science education for all, is a questionable consideration.

An additional objective of this research was to establish whether skills acquired at GCSE were in fact retained and improved as the students proceeded through their 'A'Level course. When examining the results, table 3.33, page 56, it was found that skills 23, 25, 26, 27, 28 and 29 had all improved for the majority of the 'A'Level candidates. However, there was a reduction in the success rates for skill 30 generating three plausible hypotheses, and 32 devising a plan to test a hypothesis. These last results may be explained more by the testing method than an actual fall off in skills. At GCSE the tasks would have been presented as individual exercises with a longer time period for their completion rather than part of the examination paper. The planning of suitable experiments still continues to present difficulties for Advanced Level candidates, although work undertaken for Science AT1 of the National Curriculum may help to improve this facility.

The candidates obtaining low grades at 'A'Level also showed deterioration in the skills under test. This is possibly explained by a greater effort at GCSE which could not be maintained for an extended period and/or a loss of interest and enthusiasm for their studies.

4.3 Discussion of the work relating to younger students

4.3.1 Discussion relating to results section III. Ability to undertake the selected skills by different age groups

When considering very young children aged 5 to 7 years i.e. those now assessed for Levels 1, 2 and 3 of the National Curriculum, it was found that the majority were capable of recognising a fair test and to render it fair i.e. to control

uncontrolled variables. (Table 3.35). All the other abilities were not yet developed in the vast majority of children tested. The exception to this was a class of only six children who were customarily taught in very small groups and always discussed the results of their science work and its significance on an individual basis with their teacher. Their high level of science reasoning was very striking compared with the rest of the sample, although obviously the numbers were too small to provide any statistical significance. However, one suspects that this sample may reflect the situation occurring with Piaget's initial samples when individual children explored cognitive problems and achieved far higher levels than now seems to be the norm as reported by Shayer and Adey (1981). If this working technique could be replicated on a large scale, a considerable improvement in science reasoning might accrue. Regrettably it would be an extremely expensive use of teaching personnel.

4.3.2 The effect of selection on the 9 skills in children aged 10 to 11 years

When two groups of year six pupils one from a selective school and one from a non-selective school were compared, Results Table 3.37, Page 185, there was little actual difference in their skills performance. This result becomes more interesting because it was impossible to crossmatch the students by IQ as the use of IQ test was prohibited for the non-selective school pupils so this data was raw with no matching by IQ. It would appear that selective school education has not made an impact on the children's science reasoning at this stage. A factor of significance in these results is that the children in the non-selective school were taught by an exceedingly talented teacher who was very interested in incorporating science education into the classes' studies and encouraged her students' individual participation and reasoning.

This situation reflects the situation found in the 6 young children who were so successful in the previous age group.

4.3.3 The changes in the success rate in the nine skills at four different ages in a comparable IQ band. Table 3.38

For this comparison groups of pupils from a selective school were used so retaining the same IQ range. It was found that although there were minor fluctuations the majority of the skills improved with age. These results however, are open to question as the same tasks were not used for each group, even though the same skills were examined. The difficulty of the material used to test the skills was progressively increased with age. The tests were, however, taken under standardised conditions. Unfortunately the time limitation was particularly significant for the 'A' Level students and may have depressed their results. The skills which were interdependent, skill 23 recognising an anomalous result, 25 recognising a pattern in results and, skill 26, drawing valid conclusions, all improved. The ability to devise a suitable plan to test a hypothesis was more fully developed in 17 to 18 year olds but still only to a 46.7% level.

The ability to recognise uncontrolled variables was very high in younger ages but in fact appeared to decline when the test material relating to the variables became more precise and complex. The improvement recorded in the majority of skills appeared to be the result of maturation of the pupils and accrued experience, as in the school concerned the formal teaching of processes was not undertaken. In future however, for the national curriculum, these processes will have to be taught and tested. It will be interesting to see whether the additional formal input will accelerate the acquisition of the skills or whether on the theoretical stance of Piaget, one will have to await the development of appropriate schemata, to achieve the reasoning needed. Presumably the additional scientific experiences

provided should facilitate this development. Relating the AT Levels, targeted for each age range, to the results by Shayer and Adey (1981) it may well prove that the Attainment Targets are over ambitious for the school population as a whole.

4.4 Discussion of Issues Arising from this work

4.4.1 Discussion arising from this work which may be relevant to Science teaching

Various considerations arise when choosing strategies for teaching science in the classroom situation. No two classes are identical and each member of the class is an individual bringing a different experience and set of expectations with regards to science. To stimulate their imagination and kindle their enthusiasm a varied range of experiences are needed. The activities should be novel enough to maintain their interest but not so challenging so as to frighten them and inhibit their participation both practically and cognitively. This is particularly relevant to young or inexperienced pupils. Examples of this problem arise in chemistry experiments and using microscopes in Biology. In the latter case, fear of damaging the lenses may cause them to restrict their use of the instrument or prevent them from thinking constructively. They may be so concerned about the risk of damage to themselves or the equipment that the objective of performing the experiment is lost in the confusion.

The idea that the pupils shall participate in the experiment and collect data, hopefully increases their chances of conceptualising the facts derived from the material and incorporating them into their own schemata. One would hope that this method would be more likely to be successful than a didactic presentation of information as established facts. The obvious problem of pupil experimentation is the large amount of time required for the actual practical and the additional time needed to make sure that everyone has made the necessary cognitive connections.

This latter point is likely to be an unrealistic objective because of the variation in cognitive levels at which the students are operating, particularly in a truly mixed ability teaching group. Students will bring different experiences and levels of conceptualisation to the task. Different levels of interest and concentration and the practical results achieved will vary from working group to working group.

The current effect of outside influences is very pertinent. The National Curriculum in Science presents a hierarchical sequence of cognitive requirements to be undertaken for Science Attainment Target 1 together with three very extensive bodies of information required for AT2, AT3 and AT4. A great deal of time is necessary simply to enable the student to accumulate the facts for AT2, 3 and 4 whatever the chosen methodology, and still more time for the student to apply the reasoning skills involved in AT1. At the Higher levels of AT1, Levels 8, 9 and 10 students are required to reflect on their own hypotheses, devise alternative routes to verify or dismiss their original practical plans and predictions, and evaluate the accuracy of their practical work relative to the conclusions they have drawn. The final 'pièce de résistance' is to consider the validity of long established theories in the light of the results they have achieved. All this is to be accomplished within the constraints of a normal working school timetable using the equipment that the school has managed to accumulate. The additional pressure placed on teachers by politicians, is to achieve levels of performance which will appear creditable to the school in the eyes of the general public.

It is obvious from the results presented in this thesis and the work of Ausubel, Shayer and Adey and Driver that the last esoteric levels of AT1 are going to be way out of the reach of the vast majority of the school population, whatever their age. Additionally teachers are going to be desperately striving to get whole classes to levels deemed to be acceptable for the students' chronological age when

the pupils have not as yet managed to acquire the necessary schemata to comprehend the concepts involved. Additionally, previous information and experiences, that underpin the ideas the teacher is endeavouring to transmit, may not be in place for some of the children.

As one proceeds up the levels and through the years, the spread of degrees of comprehension will increase as weak points arise in different students' scientific knowledge. At this point self assessment by the student to establish the point of weakness together with appropriate individual input by the teacher, will be needed to restore the student to the general level of comprehension of his group. This thesis highlights a difficulty here relating to self assessment. In the original survey when students were asked about factors affecting their performance and studies, only mature highly intelligent individuals were able to reflect on their cognitive success. The vast majority did not recognise any problem, even when they were patently unable to tackle relatively simple problems.

Really weak candidates either don't realise that they do not understand, or prefer not to admit it, therefore neither they nor their teachers can take action to ameliorate the problem. The current fashion in education for constantly measuring the level of an individual's attainment could be a useful diagnostic tool for a teacher if any time remained to actually help individuals to overcome their difficulty. However, when these tests results are extrapolated to make a judgmental evaluation of the group as a whole, without the benefit of the knowledge of individuals' cognitive ability, a very stressful situation is established for all involved. More frequent and complicated methods of assessing does not actually achieve any improvement for the student but consumes time and energy insatiably.

An example to illustrate the difficulty as required for the National Curriculum AT1 Level 4 Strand III is shown here.

The ability to draw conclusions linked to patterns in results and observations relating to the student's original question and predictions. This requires the student to pick out the pattern, which poses a difficulty for many as illustrated by their lack of success with skill 25 in this study. Additionally they then have to reflect on their prediction and hypothesise about the possible causes to establish the validity of their original idea. All this is hypothetico deductive reasoning available to 7.1% of an unselected school population at age 14 years 4 months (Shayer, M. and Adey, P. 1981) and 9% in this study. According to National Curriculum children aged 11 to 14 years should be achieving levels 3 to 7.

At Level 7 they have to repeat the above process, simultaneously considering several variables to find the relative importance of each in the scientific strategy they have evolved, to study and then evaluate their hypotheses, predictions and conclusions. To succeed in this undertaking they need all the skills 25 to 32 inclusive as examined in this study with the addition of 23 and 24 should errors arise. As has already been established in the results section, skill 30, the ability to hypothesise in a multivariant situation appears to limit the success to just 9% of the sample.

For this level of cognitive skill they will need to use reflective hypothetico deductive reasoning (meta cognition) in a highly proficient way. Further difficulties relating to laboratory practice are posed by the student supposedly being able to design, undertake and freely adjust his experiment as he proceeds, a procedure remarkably extravagant with both time and equipment.

4.4.2 The Author's personal reflection on the significance of her findings to her own future teaching strategies.

The strategies I intend to employ in my remaining years of teaching relate to many of these results.

To successfully empower students in the area of science they must establish a range of reasoning skills, the level of understanding and application that can be expected from them relates to cognitive levels at which they are able to operate. Therefore, I intend to devise simple exercises, to be used initially with each new student group, to pinpoint each individual's reasoning level. e.g., can they recognise patterns and exceptions to them, recognise fair tests and think forwards to make predictions from available patterns?

Teaching and discussions will attempt to establish or reinforce these skills. Tests normally used during the year to assay their uptake of information will incorporate reasoning skills. However, the tests must contain some easy questions, in addition to the more difficult reasoning tasks, to establish and maintain confidence and a feeling of success for the students.

The subject must be both interesting and challenging to encourage the student to strive for mastery while simultaneously enjoying the subject.

To deal with difficulties that are diagnosed, teaching strategies and time will need to be made available. It is obvious that a spread of results will occur as people progress at different rates but hopefully a sense of individual satisfaction can be maintained. Also with the level of accuracy of the public examination system, at least at 16+, it will not split the teaching group unacceptably 'for them' within a selective school population.

These intentions stated above contrast markedly with the teaching, testing and examining methods employed 30 years ago at the beginning of the author's career. One considered that a topic had been successfully taught if the whole class obtained almost full marks by regurgitating neatly and exactly the information that the teacher had just imparted without recourse to question or evaluation on the part of the pupil. This method must also have been very acceptable to the examination boards who rewarded the students with very high grades at 'A' and 'O' Level on the basis of this technique.

4.4.3 Evaluation of the results of this Research Project and possible lines for further enquiry

In hindsight, limitations in the methodology used become apparent, consequently reducing the validity of the results, particularly if generalisations are to be made and applied on a wider scale. From the outset the production of a sufficiently large representative sample of candidates proved difficult to achieve because many of the schools invited to participate had to decline for a variety of reasons. Additionally, many of the comprehensive schools involved were within the same catchment areas as the two selective schools and so heavily 'creamed off'. Surprisingly, however, the mean IQ of most of the schools was not depressed below the norm for the general population. Another limitation is that most schools could only furnish one teaching group for one testing session.

The problem of the validity of the questions used requires consideration, the author at the time when the Biology questions were administered was confident that they did assay the relevant skills. Her confidence arose from her trial tests of the questions and from informal confirmation from other colleagues, additionally marking by one person working on the basis of an informal concensus opinion

ensured a uniform standard and restricted the work to the actual author. Retrospectively a more demonstrably reliable result would have been achieved if both the questions and the mark schemes had been formally cross checked by a group of colleagues, had they been willing and available.

An additional difficulty that imperceptibly arose in the biology questions, was that they ceased to be culture and gender free. Although the original sample bank included many questions that were constructed to be unbiased with regard to these factors, the ones finally selected for the booklet on the basis of reliability could be considered faulty on those two aspects.

During the work the author was quickly alerted to the significance of IQ on the results achieved and by cross matching, eliminated the effect of this variable. However, it was quite impossible to select samples in order to control all but one variable because samples would have been reduced to non-viable sizes. Also, unidentifiable factors are bound to be influencing many individuals all the time, a problem that arises in any research work involving human behaviour.

IQ appeared to correlate closely both with success in the skills and with the final GCSE grades achieved. However, at 'A' Level, the candidates were mostly of high calibre but of a restricted range and were distributed evenly among the grades. At the extreme end of the spectrum the students who were successful in obtaining Oxbridge places in a variety of disciplines, were the ones who had exceptionally high IQ scores in this study; however, the limited sample size precludes generalisations from this last statement.

It is appreciated that the procedure employed sampled each student on only one occasion, consequently individual anomalies are very likely, 'a bad day', a misunderstanding of the question or a time shortage. Such occurrences would

reduce the student's apparent performance, conversely opposite situations could inflate a student's results. It is hoped that the overall sample is sufficiently large to reduce the significance of such anomalies. However, a much more extended in-depth study of a small group of students throughout their school career could give very interesting linear information on cognitive development. Unfortunately, the constraints of expense and research time, make such a study very difficult to establish. With the customary re-assortment of groups of pupils between different classes at different ages and different schools at key stages it would be very difficult to follow such a group of pupils. Also such re-assortments would result in additional uncontrollable variables, eg., teaching style.

If a group is studied on several occasions it in itself becomes a focus of interest and the additional attention actually serves to stimulate performance in children of all ages. eg., the effect of the Head Start Project (Nimnicht, G. 1967) and the CASE Project. (Adey, P. 1992) Such inflated results would not therefore be comparable with the normal population of the same age. Exceptional performance was certainly produced in Piaget's samples and also the initial Nuffield Science Project trial schools.

The second area much in need of investigation is that of attitudes and expectations of all those participating in a student's education. The expectation of the students and their peers seems very significant. In selective schools students appear to achieve higher results than candidates of equal ability as measured by IQ in nonselective schools. A possible line of explanation is attitude and expectation. The vast majority expect to succeed and feel cheated if unsuccessful. Similarly, parents and teachers expect success and will exert pressure if failure appears likely.

The teacher's attitude seems very significant. As a very inexperienced teacher, teaching for the first time in a comprehensive school formed from an old secondary modern, I confidently expected the class to be successful at 'O'Level Biology, never having experienced an alternative situation. The students did indeed all pass to the amazement of themselves and their regular staff, who were more accustomed to and apparently anticipated failure. It is obviously inappropriate to draw conclusions from such an isolated incident but it remains of interest to the author.

It has been noted that the study of the three sciences inflates students grades in Biology although not their performance at the original skills.

It appears that the students see themselves as scientists and expect to succeed in the science, unlike their fellow arts and humanities students (Their own attribution) who, although of equal ability, are less confident of success. Perhaps less discrepancies will occur when three sciences or an integrated science option becomes the norm for all students in the National Curriculum.

The ability to concentrate on a piece of work for an extended period appeared to be the characteristic missing from many samples of students in the original group investigated. Further Educational Research into teaching strategies and working environments to improve pupils' levels of concentration could be invaluable for many future school students.

This research project was unable to isolate any measurable variables to explain the discrepancy in performance at 'A'Level Biology. The author was inclined to suggest that the competition from outside commitment, personal satisfaction and general motivation were probably the most important considerations for candidates above a certain intellectual level. Further research to try to find the

key to maximise students' personal satisfaction and commitment would be very helpful and also very difficult.

It became impossible to analyse the effect of selective education on 'A' Level performance, because the number of students from the nonselective part of the sample proceeding on to 'A' Level and actually completing it, was minuscule.

Also the effect of study of the three sciences and Maths at 'A' Level on success in Biology was not investigated, because the majority of the candidates presented this combination so there were too few students of equivalent IQ to cross match.

A further long term development as a corollary to this work would be to follow the cognitive development in science of several groups continuously for their last four years of science education i.e., up to 'A' Level. Such a project could furnish data of great value for the strategy of advanced science education.

Considering the value of assaying skills individually raises important areas for investigation. Is there a level at which a child fails to make a transition from one stage to another and is so precluded from success in the more demanding skills? If this proves to be the case can teachers evolve strategies to assist the transfer? Finally, will improved understanding by teachers of the cognitive implications involved in skill acquisition enable children to thrive and achieve in their scientific study?

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