WORLD HEALTH ORGANIZATION

ORGANISATION MONDIALE DE LA SANTÉ

EXPERT COMMITTEE ON PROFESSIONAL AND TECHNICAL EDUCATION OF MEDICAL AND AUXILIARY PERSONNEL

THE TEACHING OF SCIENCES IN PRE-MEDICAL COURSES OF STUDY

Geneva, 10-16 November 1964

THIRTEENTH REPORT

CONTENTS

This report contains the collective views of an international group of experts and does not necessarily represent the decisions or the stated policy of the World Health Organization.

PA/66.65

Members

Dr A. L. Aboul-Nasr, Director of the Cancer Institute and Professor of Cancer Surgery, Faculty of Medicine, University of Cairo, United Arab Republic.

Professor P. de Goes, Director, Institute of Microbiology, University of Brazil, Rio de Janeiro, Brazil.

Professor A. L. Mjasnikov, Director, Institute of Therapy, Academy of Medical Sciences of the USSR, Moscow, USSR (Vice-Chairman)

Professor N. N. Pesonen, Director-General, National Board of Health, Helsinki, Finland

Dr A. Quenum, Professeur agrégé d'Histologie et d'Embryologie, Faculté mixte de Médecine et de Pharmacie, Université de Dakar, Senegal.

Dr V. Ramalingaswami, Professor of Pathology, All-India Institute of Medical Sciences, New Delhi, India (Rapporteur)

Professor R. W. Scarff, Director, Bland-Sutton Institute of Pathology, Middlesex Hospital, London, England.

Dr F. Verzár, Professor of Physiology, University of Basle, Switzerland (Chairman)

Representative of the United Nations Educational, Scientific and Cultural Organization

Mr R. E. Ganeff, Division of Science Teaching, Department of Advancement of Science, UNESCO, Paris, France.

Secretariat

Professeur G. Amat, Laboratoire de Spectroscopie moléculaire, Faculté des Sciences de Paris, Paris, France (Consultant)

Dr M. Etemadian, Chief, Education in Medicine and Allied Subjects, WHO (Secretary)

Dr E. Grzegorzewski, Director, Division of Education and Training, WHO.

Dr G. E. Miller, Director, Office of Research in Medical Education, College of Medicine, University of Illinois, Chicago, Ill., United States of America (Consultant)

Dr A. Rabbi, Professor of Biochemistry, University of Parma, Italy (Consultant)

The WHO Expert Committee on Professional and Technical Education of Medical and Auxiliary Personnel met in Geneva from 10 to 16 November 1964.

Professor F. Verzár was elected Chairman; Professor A. L. Mjasnikov, Vice-Chairman; and Professor V. Ramalingaswami, Rapporteur.

Dr P. Dorolle, Deputy Director-General, opened the meeting on behalf of the Director-General, and welcomed the members. He said that the task before the Committee was to discuss the most appropriate manner in which a student might be trained in basic sciences as a preparation for a career in medicine and "to review the minimum level of knowledge in natural sciences in pre-medical courses of study necessary to prepare the students for the effective pursuance of medical studies proper".[1] This issue arose partly from the observation, in some countries, of a high proportion of failures during the initial stages of medical education which seemed to result from inadequate preparation in basic sciences. A similar problem was sometimes encountered in the WHO fellowships programme, particularly in the case of developing countries. The convening of an expert committee in order to render advice in this area was approved by the Sixteenth World Health Assembly.

1. INTRODUCTION AND GENERAL ASPECTS

For the purpose of this report, the term pre-medical sciences refers to chemistry, physics, biology and mathematics which are taught as preparation for the medical studies proper beginning with anatomy, physiology and biochemistry. It is used without regard to the kind of institution under whose auspices this phase of instruction is conducted since systems of pre-medical education in these subjects differ greatly in various parts of the world. For example, in some countries, instruction in these topics is provided within the medical school itself and is the direct responsibility of the medical faculty. In others, it is given either in the university science departments and colleges or in higher secondary schools at the pre-university level. The duration and content of such courses also varies widely. Thus, in some countries, the period of pre-medical

---

[1] Off. Rec. Wld Hlth Org., 1963, 125, 47.

study covers one or two years while in others, such as the United States of America, three or, more often, four years of college education is the general rule before beginning the study of medical sciences proper. Furthermore, the average age at which a student commences his regular medical studies also varies widely in different parts of the world. Each of these systems has a relevance to local conditions, traditions and resources. It is realized that the pattern that exists in each country has evolved in accordance with its educational framework and that the goals of pre-medical education may be achieved by different systems.

Divergent views are held by educators regarding the most desirable pattern with reference to the factors mentioned above. For example, the 1952 WHO Expert Committee on Professional and Technical Education of Medical and Auxiliary Personnel[1] in expressing certain broad views about teaching basic sciences acknowledged that the student entering medicine should be well-grounded in these subjects. It further pointed out that "Study of the biological and physical sciences should provide basic understanding of the phenomena of living organisms and their adaptation to their environment". Later a WHO Study Group commented that "chemistry, physics and biology should be taught as general courses not specially designed for the future physician", and went on to say that "the applied aspects of these basic sciences would be instilled in the student later in his studies by his teachers in anatomy, physiology and clinical subjects".[2] The present Committee acknowledges that there is room for divergence of opinion on the extent of specific orientation towards medicine in pre-medical studies. It considers, however, that whatever system is selected it would be desirable for pre-medical studies to contribute to the development of student interest in living organisms and their environmental adaptation. Nonetheless, in view of the cultural and other reasons for variable approaches to pre-medical education it is necessary to recognize that in the present state of knowledge about the relative effectiveness of different patterns, it would be undesirable to recommend any rigid set of courses, with arbitrary stipulation of duration and orientation.

---

[1] Wld Hlth Org. techn. Rep. Ser., 1953, 69, 7.

[2] Wld Hlth Org. techn. Rep. Ser., 1962, 239, 26.

While the term basic sciences, as used in this report refers only to chemistry, physics, biology and mathematics, the Committee fully recognizes the importance of the behavioural sciences, including psychology and sociology, as well as the humanities - history, languages etc. - in pre-medical studies. However, in view of the extensive nature of these subjects and of the fact that some have received their due emphasis in earlier reports, they are not considered further in this report. It is the view of the Committee that pre-medical education should retain its liberal and scientific character, but within this scheme the achievement of a minimum body of knowledge necessary for the more specific purposes of pre-clinical and clinical education in later years must be accomplished.

As a primary task this Committee was charged "to review that minimum level of knowledge in natural sciences in pre-medical courses of study necessary to prepare the students for the effective pursuance of medical studies proper".[1] The Committee recognized that the ultimate goal of pre-medical education should go beyond considerations of curricular outline and content and should encompass the specific behavioural objectives of teaching basic sciences in pre-medical courses of study. There has been extensive discussion in the past about the number of hours to be spent in teaching specified areas of knowledge and a wide variety of courses have been designed, but the primary object of pre-medical education should be to create a programme that leads a student steadily toward the professional behaviour he must ultimately exhibit and not towards the acquisition of knowledge alone.

As they are organized to-day in many parts of the world, pre-medical courses of study seem largely directed to the memorization of a vast body of knowledge. Such courses are often regarded by students as a tiresome necessity, to be "cleared" before entering medical studies proper. This discontinuity between pre-medical and medical courses of study requires the most thoughtful attention.

There is obviously an urgent need to inject new ideas and adopt a fresh approach to the teaching of basic sciences during pre-medical studies. The Committee agrees that these courses must first introduce a prospective medical student to the processes

---

[1] Off. Rec. Wld Hlth Org., 1963, 125, 47.

of scientific thinking and methodology which enable him to formulate precise and cle concepts and to gain some skill in the inter-disciplinary approach to problem solvin Undoubtedly, social sciences and general education, which are outside the purview o the present discussion, should also encourage a student to cultivate such attitudes of mind and intellectual skills. The Committee is impressed by the paucity of clear evidence on the precise influence of quantity and level of basic science teaching on the competence a student ultimately develops. Such studies as are available appear to show little or no correlation between the two. It should thus be the proper aim of pre-medical education to stimulate a student's learning capacity rather than to load him with a mass of factual knowledge, for the evidence is persuas that the most efficient, effective, and lasting learning occurs when a student is an active inquirer into, rather than a passive recipient of, what he must know.

Pre-medical education, as any other form of instruction, must attain not only the subject-matter goals but also the intellectual process objectives of education. The instruction may be designed merely to assist a student to recall the bits and pieces of information he has been taught or to recognize from these certain generalizations, but in either case the learning may be used in solving familiar problems. Further refinement of a somewhat more complex learning objective would lead a student to skill in solving unfamiliar problems, a capacity to analyse and interpret data, or finally to synthesize bits of evidence into a meaningful whole. Teaching should aim at both content and intellectual process, but as the process goals become more complex it will become necessary to sacrifice some content goals in order to provide the time necessary for their achievement. Examples of this orientation to pre-medical education are already in evidence in some parts of the w For example, in the teaching of physics the Physical Sciences Study Committee in th United States of America and UNESCO have developed new courses which serve as good illustrations of this Committee's general viewpoint on teaching pre-medical science as a whole.

2. THE CONTENT OF TEACHING

In the following discussion of the actual content of teaching, it should be understood that even though examples of course content have been provided, the extent to which it will be necessary to offer this material in the pre-medical period will depend upon the level attained in the respective subjects during earlier years of schooling. The content is set forth to illustrate what should have been achieved before a student takes up anatomy, biochemistry and physiology. It is not necessarily intended as an outline for specific and individual courses of instruction.

2.1 Biology

No other branch of pre-medical science has undergone such a profound change as biology in the opportunities it offers for illustrating the scientific basis for medical practice. The basis of medicine lies in biology, and it should be taught as a dynamic, multilateral and comparative science ranging from the molecular level to that of individual human beings, communities and populations. In teaching biology, increasing emphasis should be laid on the underlying principles rather than on descriptive aspects. It is a matter of opinion as to whether any special advantage is to be gained by directing the educational experience for a prospective medical student exclusively towards the medical field.

In order to understand a living organism, an acquaintance with the minute structure and function of the organism is essential. Therefore, the structure of the cell and its chief components, both morphological and chemical, should be taught. In connexion with the understanding of the function of the organism, the teaching of the basic phenomena of life is necessary.

The future physician should certainly know the essential principles that underly the cause of malformations and hereditary diseases and the possible effects of certain agents on the future development of the race. Therefore, a general outline in genetics, including the finer structure of the cell, its nucleus and chromosomes, should be offered to the student before he undertakes his medical studies proper.

A knowledge of the forms of multicellular organisms presupposes an understanding of the main characteristics of embryogenesis of the whole organism. As human life is only one part, though an essential part, of all life on the globe, its exceptional position and its relationship to other forms of life should be understood, and thus a knowledge of evolution is important to the future physician. In this connexion, some reference to comparative anatomy and to physical anthropology could be beneficial. For a comprehension of the main lines of the propagation of the human race an understanding of the fertilization phenomena would also be necessary.

Within this framework, students should acquire a basic concept of the structure and function of living organisms. In attempting to convey these and other aspects of biology, it is essential to eliminate dogma and to introduce students to a series of inquiries with greater emphasis on laboratory work. Therefore, students should be encouraged to investigate rather than to copy and reproduce a set demonstration.

It is possible to devise a variety of courses in biology, all emphasizing these principles and concepts.

The way in which a course is given, particularly the opportunity the student has for his own learning, is more important than course content itself. In section of the Annex, an outline of the subjects to be taught in biology is given as an example; it is not intended to be a course universally applicable to all countries but rather one that should satisfy minimum requirements in this field.

2.2 Physics

As with biology and other pre-medical sciences, the essential purpose of education in physics should be to encourage "active student learning" and not merely to deliver a certain mass of factual information. Ideally, each student would be placed in a position to discover answers to questions about physics rather than be presented with set information. Even if this approach cannot be implemented for the entire course, it is worth while to attempt it in teaching selected topics.

While agreeing with the recommendation contained in the Eighth Report of the WHO Expert Committee on Professional and Technical Education of Medical and Auxiliary Personnel[1] regarding the need for enhancing the emphasis on electrical phenomena in the study of physics, this Committee would stress that the entire course should be designed with the general objective or facilitating the understanding of science and a scientific way of thinking. It is realized that prospective medical students enter their pre-medical studies with varying levels of competence in mathematics and physics and this factor will determine the quantity of training that should be given. In section B of the Annex an illustrative outline of a physics course is presented. This can serve as an example of the minimum knowledge of physics a student should have before starting his pre-clinical studies in anatomy, physiology and biochemistry. The actual instruction in physics included during the pre-medical period will of course depend on the knowledge of this subject the student has acquired during his earlier education.

As indicated in the Introduction, physics, like other sciences, can be taught in various ways. Some are of the opinion that physics courses for prospective medical students should have a general character and not differ fundamentally from those given to other students; others believe that the courses should be specifically oriented to medicine; still others take an intermediate position. In the absence of precise data on the relative value of these systems, the Committee does not wish to make a choice between them. However, it is the intermediate view that is reflected in the programme given as an example in the Annex. The topics listed are not very different from those required by other students, but the spirit in which the course is given takes into account the fact that it is intended for prospective medical students.[2]

---

[1] Wld Hlth Org. techn. Rep. Ser. 1961, 209, 10

[2] For example, this would be reflected in: (a) the choice of illustrations (e.g., when studying optical instruments, the microscope would be a better example than the telescope); (b) the relative importance given to the different branches of physics (as already mentioned, electricity should occupy the first place) and in the importance given to the various chapters of a branch such as optics (e.g., the study of dioptrics would be more useful than the study of mirrors); (c) teaching the basic principles of physics, where reliance should be on facts rather than on theoretical considerations (e.g., the second principle of thermodynamics could be explained in relation to concrete experimental processes rather than in relation to the properties of mathematical formulae).

The Committee wishes to emphasize that the bulk of the subject matter listed is capable of being covered in laboratory exercises and practical demonstrations, with opportunities for students to make their own observations and analyse those observations critically. Variants of the course shown in the Annex could be devised to suit individual situations, but it is believed that all such courses should as a minimum contain mechanics, hydrodynamics, thermodynamics, electricity including electronics, optics, X-rays, nuclear physics and radioactivity. Furthermore the course should be designed not as an end in itself but as preparation for continuation of this education during the medical years, with the introduction of biophysics. At that stage physics would be introduced once again to facilitate the understanding of electro-physiology, radio-biology, physiology of the special senses, physical chemistry of solutions and tracer methods.

2.3 Chemistry

The rapid developments in the various branches of chemistry and the extensive inroads that chemistry has made into medical science (with benefit to both) make it apparent that in the education of a physician an important place must be found for learning the elements of chemistry. The essential purpose of this study is to provide a scientific basis for an understanding of the chemistry of medico-biological problems. It is realized that a completely satisfactory pattern for teaching chemistry is difficult to organize and to conduct. The solution, even if partial and imperfect, must be found in a careful selection of the aspects of chemistry appropriate for pre-medical education. Chemistry is essentially an experimental science and it would be advantageous to preserve this character in the instructional programme. As in biology and physics, the courses should be so designed that students are challenged to make observations on given problems rather than allowed to be passive spectators of set demonstrations.

The studies should be considered an introduction to, and preparation for, further training in biochemistry, physiology, pharmacology and chemical pathology in the succeeding years of medical education. The exact type of course will depend upon the knowledge a student has acquired in earlier years in school.

In any such course of studies, the greatest possible emphasis should be laid on the fundamental principles of general and organic chemistry. Inorganic chemistry should be limited. An illustration of the content is given in section C of the Annex. It is emphasized again that this is not recommended as the only course; there could be several modifications but in all it would seem desirable to emphasize valency (electronic theory of valency); chemical nomenclature; chemical bonds; chemical equilibrium; chemical kinetics; electrochemistry (electrolytes and amphoteric electrolytes); theory of solutions (especially dilutions); osmotic pressure; redox-potentials; and thermochemistry. In order to reduce the chemistry syllabus, certain topics, such as the laws and principles of radioactivity, might be left to physics. In teaching inorganic chemistry, the most rational method is an application of fundamental principles of general chemistry to the descriptive treatment of single elements with emphasis on the most characteristic properties of each. From the biological point of view it would be useful to begin with the elements H, O, N, C. Carbon might be given special attention as the basic element in an enormous number of biological compounds. Other non-metals (B, F, Si, P, S, Cl, As, Bi, J), and certain metals (Li, Na, Mg, Al, K, Ca, Va, Mn, Fe, Co, Ni, Cu, Zn, Mo) might then be dealt with from the point of view of their biological interest.

With regard to organic chemistry, it would be advisable to introduce the student to such general concepts as isomerism and the functional groups, and to such general compounds of biological interest as the amines, aldehydes, ketones, saturated and non-saturated acids, ethers, esters and other substances that form a direct part of living organisms and participate in their metabolism.

Subjects for laboratory study could usefully include; (1) laboratory material; (2) scales and weighing; (3) concentration of solutions and the relevant calculations; (4) densimetry; (5) actual and potential acidity and methods of measuring pH; (6) procedures for the separation of substances (filtration, dialysis, centrifugation, etc.); (7) measurement of rotatory power; (8) buffer solutions; (9) osmotic pressure of solutions; (10) some qualitative analyses; (11) some volumetric quantitative analyses (acidimetry, alkalimetry, iodometry); (12) notions of chromatography; (13) colorimetry; (14) photometry and (15) electrophoresis.

2.4 Mathematics

Modern mathematics subserves an important function in precise formulation of concepts and in exact thought. It provides the basis on which future studies in statistics, physics and chemistry can be developed effectively. It prepares a student's mind for the quantitative measurement of biological processes. The Committee thus accepts the value of a grounding in mathematics in the preparation of a student for medical studies, but considers that the minimum requirements are usually met in the secondary schools before the commencement of pre-medical studies. For this reason it is the general opinion that mathematics need not be required as a separate subject in pre-medical education, although it is clearly desirable to include in the study of chemistry, physics and biostatistics some instruction in the application of mathematics.

3. METHODS OF TEACHING

3.1 New developments in methodology and organization

The teaching of science in elementary and secondary schools, and to a lesser but important extent in institutions of higher learning, is to-day undergoing a quiet revolution in many parts of the world. Among the most prominent examples are the programmes encouraged and supported by UNESCO, by the Organization of American States and by the National Science Foundation (which has sponsored such efforts as those of the Physical Sciences Study Committee, the Biological Sciences Curriculum Project, the School Mathematics Programme, the Chemical Bond Approach Study and the Chemical Education Material Study).

Both disciplinary specialists and educational specialists have participated in these programmes and their work has resulted in the creation of new course outlines, syllabuses and other instructional aids. Teachers and students alike have benefited from these developments, which have enabled students to move more rapidly and more efficiently to a level of achievement often far beyond that exhibited by students of the same level in more traditional courses.