Biology curricula at universities

European Communities Biologists Association

ECBA publication Nº 1

Biology curricula at universities

Report of a Workshop organized by the European Communities Biologists Association

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1. Introduction

The European Communities Biologists Association (ECBA) was founded in 1975 as a result of a deeply felt need for co-operation between the national organizations of biologists in the countries of the European Communities. The aims of ECBA, as given in Annex 1, have a direct bearing on the professional interests of biologists. These professional interests cannot be separated from the way biologists are educated. One of the first activities of ECBA was, therefore, to get an insight into the educational systems of the countries which are adhering bodies to ECBA. This resulted in a survey on the biology curricula at Universities.
On discussing the contents of this survey, it became clear that a more thorough discussion of the problems which are related to contents and duration of the University courses in biology was essential.
Through the co-operation of the Royal Academy of Arts and Sciences of the Netherlands, and with financial support of the Netherlands Ministry of Education and Sciences, a workshop on Biology Curricula at Universities was organized. The report of this workshop, which was held in Amsterdam at the Royal Netherlands Academy of Arts and Sciences from November 1-5, is presented in this document. The workshop was attended by representatives of the member-countries of the European Communities; it was highly appreciated that a number of European countries outside E.C. responded to the invitation to join the workshop, thereby broadening its scope and impact. The list of participants is given in Annex 3.

The workshop nominated Prof. Dr. L. Vlijm (Netherlands) as its chairman, and Prof. Dr. J.M. Dodd (United Kingdom) and Prof. Dr. L.H. Grimme (Federal Republic of Germany) as vice-chairmen.
The reason why the workshop concentrated on University biology courses is that at the Universities, through the combination of teaching and research, new ideas about the function of biology in the total research effort appear and are implemented, thereby giving impulses towards both the way biology is taught at the primary and secondary schools and to the way biologists function in other parts of society.
Moreover, the problems encountered in the construction of University biology curricula are common to all countries concerned. The special character of biology derives from the fact that a biologist is the only scientist in the field of the natural sciences who requires insight, at all levels discernable in the living matter, from molecules and cells through organs and organisms to the levels of populations and ecosystems. This means that in the education of a biologist a rather extended period of general training in all these levels should be included, followed by a period of specialization in certain fields. This demand tends to come into conflict with the pressure (only partly originating from the economic situation), put upon Universities to shorten their courses.

Furthermore, as a consequence of the changing ideas about the place of biology in society and of changes in the educational system, the contents of University biology courses are subject to discussion in many countries. The workshop intends to give some guidelines for these discussions, by pointing out the requirements for the education of biologists, taking into consideration the manifold aspects essential for the way biologists function in society in different professions. The line followed in this report is first to define the `core-program' for the general education of biologists during the first period of the university training and subsequently to indicate the specializations that are based upon this core-program. The paragraph about this specialization into subjects is followed by a section on the specialization into the different professions, indicating the skills needed for the various fields in which professional biologists work, namely: fundamental and applied research, teaching, industry and public service.
Some general remarks are made, based on the core-program, about the post-academic education of biologists (see page 17).

This report is also expected to fulfil a function in the discussions both between biologists and the respective governments, and in those at the level of the European Communities. And last but not least, it is hoped that these discussions on the European level, which should be continued in the years ahead, may prove to be beneficial to the possibilities of exchange of biologists between the countries of Europe, giving them more opportunities to exert their skills in all aspects of teaching, research and management.

2. Objectives of the Workshop

The following objectives were approved as appropriate for the workshop:

- to compare the ideas in the different countries about the core of biological knowledge to be taught at the Universities, including qualifications with respect to skills and attitudes important for the applicability of the acquired knowledge, and to define the elements of this core-program.
- to agree upon a central core-program in order to achieve a comparable level of qualifications after four years of University training.
- to discuss the inclusion of other basic knowledge (in particular: topics from chemistry, physics, mathematics) in the above-mentioned core-program.
- to discuss specialized training in biology, including specialization into different topics (e.g. ethology, endocrinology, marine biology, microbiology etc.) as well as specialization into a professional career (research in industry, research in universities, medical biology, agricultural biology, teaching at schools, management).
- to ensure that specialization in a definite direction is possible by reorientation on the basis of the central core-program.
- to identify the fields in which the biologist can and should function.

3. General considerations

Biology as a scientific discipline has recently experienced an explosive phase. The operational field of biology has been notably enlarged. It started as a study of the variety of forms of living organisms, and therefore originally consisted mainly of morphology and systematics. Shortly afterwards the question arose as to how this variety of forms originated during the history of the earth and by what mechanisms. This led to the idea of descent as well as to genetics. There-after the functional aspects of organisms and thus physiology became important. Recently this subdiscipline, by the introduction of more elaborate techniques and apparatuses and in co-operation with physicists and chemists, studied the most elementary cellular structures and processes (molecular and cell biology). This resulted in the conclusion that all organisms, notwithstanding their variety, share the same basic principles of life. This development also had important implications on the knowledge of the functioning of the human body, and this brought about a rapid development of the biomedical sciences.
In the meantime it was realized in biology that the variety of organisms was related to the variety of physical and chemical properties of the earth's crust and also that intricate and very delicate dynamic web-structures operated between different organisms, that are of primary importance in controlling their absolute and relative numbers. The qualitative and quantitative aspects of these relationships are the primary field of study of population-biology and ecology. A further important development in the last decades has been the study of behaviour and behavioural patterns (ethology). Nowadays important questions on fundamental structure and function of the nervous system (neurophysiology) and processes in learning and memory are tackled, leading to general principles which help to explain the behaviour of animals including man.

These advances in different directions have not only resulted in an enlargement of the field of biological sciences, but have also demonstrated more fundamental relationships between the different aspects. Nowadays development in any of the fore mentioned biological disciplines advances in mutual relationship with the others. The biological sciences therefore are more than the sum of their parts and every biologist should ideally have a global and integrated knowledge of the whole field.
As to the relationship between the biological sciences and society it is observed that originally there was hardly any effective relationship. Even the improvements in plant and animal husbandry which developed from ancient times onwards was
of no general interest to early biologists. Society was, for the first time, made dramatically aware of biology through the development of the evolution hypo-thesis, through which light was thrown on the prolonged and complicated origin of living organisms and the position of man in this framework. Questions about the role of man have stimulated reflection on the ways of structuring society.
The increase in the knowledge of genetics and plant- and animal-physiology have had a major influence on the wellbeing of mankind through their application to agriculture and horticulture as well as to the breeding of cultivated plants. Furthermore, in collaboration with chemistry and the medical sciences, the biological sciences have contributed to the investigation and the combat of pathogens, pests and other threats to plants, animals and man. The consequences of research in phytopathology, parasitology, bacteriology and virology may be mentioned in this context. The development of the biomedical sciences was highly stimulated through the ever increasing involvement of biologists in research on cancer, immunological problems (resistance, transplantation), haematology (bloodgroups, blood-transfusion), gerontology (senescence), endocrinology (hormones) etc. It should be noted that these types of research frequently use animals as experimental organisms which, on the basis of universality of the phenomena, can be used as `models'.
A fourth relation between biology and society has resulted from the increasing volume of field research in ecology, and the related increase in the knowledge of systematics. Biologists detected the disastrous and impoverishing effects of modern society on the environment, by destruction of the landscape and of precious and sometimes unique habitats, by pollution of land, water and air, by the extermination of living organisms and by uncontrolled exploration of natural resources.
Biologists therefore initiated activities in connection with nature conservation, environmental care, nature education and nature management. Originally strong opposition was encountered, since these activities were thought by often powerful groups in society to be exaggerated and sentimental.

This leads to a final remark in this chapter. The biological sciences have intensively co-operated in the enlargement of food production and the improvement of human wellbeing and have warned against the demolition of nature as well as pointed to the unique position of man in affecting ecological processes.
In summary one could state that on the one hand the biological sciences have contributed to the explosion of the human population (more food, less mortality), on the other hand biologists have also drawn attention to the serious consequences of this explosion. Thus the biological sciences are deeply involved in the many important, contemporary problems which are wholly or at least partially of a biological nature (e.g. foodsupply, numbers of human beings, vulnerability of natural communities and conflicts between individuals as well as groups of individuals).

These problems are very complicated and they are all interrelated. Thus the biologist working on them can never be a narrow specialist. He must be aware of the wider implications of his work. He should therefore have a sound and broad educational basis from which he can be guided to his destination in a justified way. This is equally true for those biologists who are active in research and for those who are teachers or members of advisory and managing bodies. The latter categories though will have to contribute to the training and forming of opinions of mankind in the future.

4. The basic training biologists prior to specialization (The 'Central Core')

4.1. Introduction

A trained biologist, prior to specialization, must have a basic insight into the structure, function and evolution of the three levels of biosystems: cells, organisms and populations. He must also have a secure grounding in the physical sciences and mathematics since so much of contemporary biology springs from biochemistry, biophysics and mathematics. Thus the basic core of knowledge gathered by a biologist during the initial training period must include certain aspects of chemistry, physics and mathematics (see section II B).
A trained biologist should also have an understanding of the relationship between biology and society, be aware of his special social responsabilities and have a basic knowledge of the didactics and history of biology and the philosophy of science, topics which are treated in more detail in sections II B and III.
Here follows in outline a core-program for the basic training of biologists. It is expected that the knowledge acquired during the study of the core-program will result in, and be associated with, a range of techniques, skills and attitudes which are specified and considered in more detail in section III.
It should be noted that the subject headings listed in the core-program are arbitrarily arranged. Students must cover all the aspects of the biological and related disciplines specified in the core-program, though the depth to which the different aspects are treated will depend to some extent on the situation in each university and also, in relation to his future specialization, on the particular choice of the student.

4.2. Topics to be included in the central core-program

A. Biological topics

The systematics of organisms
This should lead to an acquaintance with major Phyla and Classes, including palaeobiological groups, and to a more detailed knowledge of the systematics of selected groups. These studies should also include taxonomic principles and techniques and lead to a familiarity with the local flora and fauna.

Biology and biochemistry of cells and sub cellular systems of prokaryotes and eukaryotes
The structure, function and biochemistry of cells and their organelles; the accumulation and exchange of solutes and water by cells; unicellular and multi-cellular grades of organization; communication between cells; movement and differentiation of cells; cell division, growth and ageing. Interaction between cells and viruses. Origins of life,

General and comparative physiology and developmental biology
Reproduction, growth and development; metabolism and its regulation; energy metabolism, including photosynthesis; movement; 'nervous and hormonal integration; response to stimuli in plants; neurophysiology and sensory physiology in animals; biocybernetics.

Ethology
a. Patterns of behaviour.
Habitat selection; feeding, courtship and territorial behaviour; motivation; learning; aggression; behaviour of social animals.
b. Inheritance, evolution and modification of behaviour.
The ontogeny of behaviour; genetic and environmental (including social) determination of behaviour; behaviour as an ecological determinant.

Genetics and the process, mechanism and pattern of evolution

a. Variability, its physical basis and inheritance,
Organization of genetic material in prokaryotes and eukaryotes; patterns of inheritance and their physical and chemical bases; the gene, structure, mutability, mode of action and control.

b. Variation and evolution.
Sources of variation, including molecular and structural change; sexual recombination as a factor of variability; polyploidy and gene-mutation and their significance in evolution; population genetics; evolution as a deviation from the Hardy-Weinberg Law; genetic polymorphism, genetic drift, selection; isolation of populations; speciation.

Ecology
a. Levels of ecological organization of the biosphere; ecosystems, communities, populations, individuals.

b. Population ecology.
Population growth; methods of control and regulation of populations, including human populations; predator-prey and host-parasite interactions; renewable and non-renewable resources.

c. Structure and function of ecosystems.
Productivity: food chains and webs, trophic levels, energy flow, nutrient cycles;
pollution; relevance of micro-organisms; global aspects of human ecology; the biosphere as an ecosystem, past, present and future.

d. Ecological and historical aspects of plant and animal geography.

B. Topics related to biology

Physics
Basic knowledge of physical disciplines and of methods in physical research relevant for biology.

Chemistry
Basic knowledge of general chemistry, particularly biochemistry, which is of paramount importance in many of the aspects of biology specified in the core-program, and the methods of chemical research relevant to biologists.

Geosciences
Basic knowledge of stratification, paleontology including paleobotany and -zoo-logy, biogeography.

Mathematics
Basic knowledge of statistics, theory of functions, analysis, theory of sets, and general systems theory.

History of Biology
Basic knowledge of the big revolutions in the history of science and of biology.

Philosophy of Science
Methodology of research, the problem of `truth', classification of the sciences, the problem of reductionism, methods of explanation.

Foreign Languages
At least English as means of international scientific exchange.

The above scheme of study will normally occupy 4 years, including the time spent on subjects related to biology. Some students will use this period of time to acquire additional knowledge and skills in the basic sciences, especially bio-chemistry and biophysics, for use in later specialization in various fields of biological research.
The teaching methods recommended to implement the study of the core-program include well-known items as lectures, projects, seminars, laboratory exercises, training in research, field studies, as well as new training

techniques, relevant to the study of biology. We wish to stress that biological studies are often possible only if there is liberal access to living material.

4.3. Skills and attitudes

The following skills and attitudes are essential constituents of the central core of biology studies. Some of them are specific for a biologist, some are necessary or desirable requirements for all scientists and also pertain for biologists.

a. Basic skills

Necessary skills of a biologist

- The use of classical and advanced instrumental techniques.
- Experimental skills (planning, performing and evaluating experiments),
- Mathematical skills (use of statistical techniques for collecting, evaluating and presenting biological data, special forms of diagrams and logarithmic scales).
- Verbal and reporting skills (discussion techniques, lecture techniques, techniques of writing scientific texts).
- Bibliographical techniques (reading techniques, use of libraries).
- Observation techniques (intellectual skill towards separation of syntactic and. semantic aspects of data i.e. of sensory experience and interpretation).
- Hypothesis techniques (the technique of solving a problem by forming hypo-theses that can be tested by empirical data).
- Methodical skills in science (at least the clear distinction of: causal explanation/teleological explanation, deductive/inductive thinking, linear causal thinking/complex thinking in causal networks).

Desirable skills of a biologist

- Drawing skills (diagrams, cross sections, microscopical and macroscopical models).
- Application skills (application of biological knowledge to problems of everyday life by means of associational thinking).
- Dissection and conservation of plants and animals.
- Breeding and maintenance of living organisms.

B. Basic attitudes

Necessary attitudes of a biologist

- Tendency towards empirical proof on data (`empirical basic attitude').

- Readiness to test formal theories for use in biology (e.g. theoretical physics, theoretical chemistry, mathematics, general systems theory or philosophy of science).

- Awareness that biology is not an `easy subject', but on the contrary needs a particular standard of training in complex thinking and of wide-ranging know-ledge in different fields.

- Openness to new aspects of biology (openness for innovations in the biological sciences and for continuous learning and re-learning).

- General cautiousness in changing biological systems.

- Openness for co-operation, teamwork and interregional (also international) exchange.

Desirable attitudes of a biologist

- Engagement in promoting the use of biological knowledge for the benefit of society.

The items on knowledge, skills and attitudes in the background training should not be seen separately from one another and from the central core-program of biology studies, they are interrelated in a very delicate way. It should be realized that a purely cognitive training restricted to knowledge, judgements and laws is hardly effective in professional life, and so should not be the only objective of university teaching. Cognitive training, however, should be accompanied by training in skills and attitudes as it will then have more chance to be applied as well as to remain accessible in long-time memory. Hence the qualification that is gained by the basic training of a biologist should be judged simultaneously by these three dimensions. This does not exclude, however, that basic knowledge (part II) may be accentuated more at the beginning, basic skills and attitudes (part III) more at a later stage of the studies.

5. The phase of specialization (into profession)

5.1. introduction

The four years basic training program (central core) is not sufficient for entering a biological profession. Therefore a phase of specialization, as described below, is a necessary part of biological studies. This phase will normally occupy one year.
Every student of biological sciences should within the total of five years, pass additional advanced studies and should have a period of biological research. Parts of the education-program during the phase of specialization should be arranged as problem-oriented project-studies. This will enable him to identify and to solve problems and to assess scientific results.
Because of the very rapid development and the great diversity of biological professions and research fields it is necessary to have a common general standard of biological training, which allows a great flexibility in the choice of further bio-logical specialization. Therefore the student must choose, among the possibilities offered in the Universities, those studies which are preparatory for specialization in one professional field, such as research, teaching and others, e.g. public service.

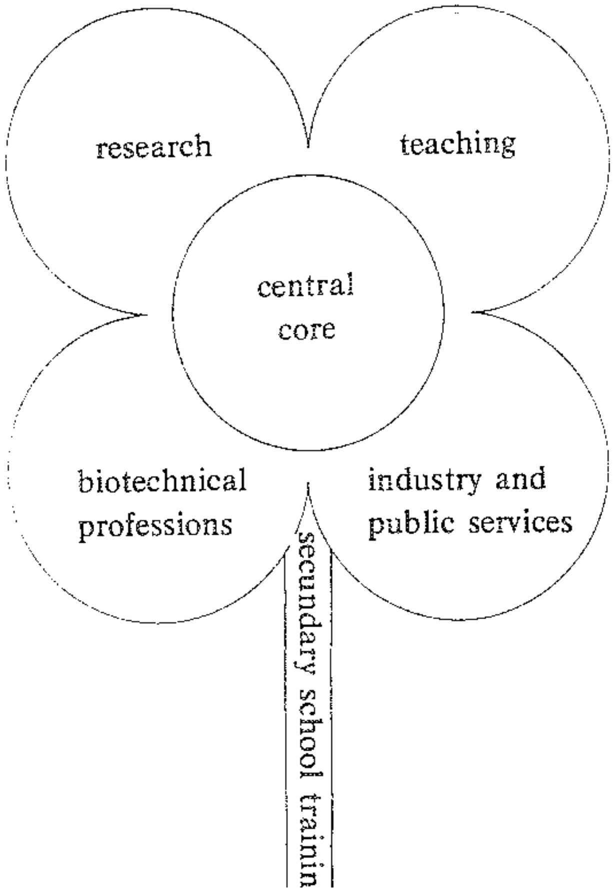

Fig. I. The Central Core and four possible directions of specialization that branch from it.

5.2. Further training in research

In addition to the central core the students should specialize in one or more related biological fields of basic or applied research, including borderline fields between biology and other sciences (e.g. physics, chemistry, mathematics, sociology) dependent on the disciplines. During this time of specialization the student will acquire deeper knowledge and skills, which enable him to do researchwork in his chosen field. The total time spent upon specialization for research should not be less than one year and may provide the basis for further work towards a Ph.D.

Below a survey of some of the research fields (the grouping represents an attempt to systematize these fields in basic research in biology, research in borderfields between biology and other sciences, and applied research in biology) is given.
1. Taxonomy, Morphology, Biogeography, Plant Physiology, Animal Physiology (incl. Pharmacology), Genetics, Developmental Biology, Cell Biology, Microbio-logy, Molecular Biology, Immunology, Toxicology, Parasitology, Ethology, Ecology, Population dynamics, Limnology.
2. Biomathematics, Biochemistry, Biophysics, Biogeology, Biocybernetics, Biosociology.
3. Agricultural research and food production, Biotechnology, Medical research, Fishery research (as well as research in the Utilization of other natural resources), Environmental research (Health, Wildlife, Management).

5.3. Further training in teaching

The following statements about specialization for teaching are meant for teachers in the secondary schools at least from the age of about 12 to 18 years old. In this phase of specialization there should be included additional topics such as human biology, didactics of biology and general educational sciences.

Human biology
Structure, function and development of the human body, evolution of man, sex-, health- and environmental-education, psychological and ethological aspects of human life, human genetics including human races, man in the technical world.

Didactics of biology
Theory of educational objectives, methods of evaluation, psychology of learning and development, drafting a concept in biology, methods of biology teaching, media, role of the teacher, sociocultural factors of teaching, curriculum theory.

General educational sciences
Sociology of education, interaction research, pedagogical theories, pedagogical psychology, pedagogy of different school-types.

These topics of specialization should not be dealt with purely theoretically in the form of lectures; but should be offered in connection with seminars at the University as well as practical work at schools. The practice-oriented form implies that general education should for the greater part be linked to biology. So the proportion of didactics of biology to general educational sciences should be at least 3:1. Both together should cover about 2/3 of the specialization period in order to guarantee the minimum of time spent upon human biology.

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5.4. Further training in other professional fields (e.g. Industry, Public Services)

The increasing awareness that biological aspects play a major role in the decision-making process at the local, regional and governmental level, or in industry, leads to an increasing demand for biologists who have specialized towards the functioning in this process, during their university study. As the input of these biologists must be based upon a thorough knowledge of biology, the only appropriate entrance towards this specialization is formed by the central core-program in which only limited time will be available for acquiring skills and attitudes towards involvement in the decision-making process.
The inclusion of some rather limited courses in e.g. law and economics may give a first lead towards this specialization, but the biological subjects should be emphasized very clearly.

During the specialization towards a profession the following knowledge, skills and attitudes should be strengthened.

Knowledge
law, economics, business, administration, planning, sociology.

Skills
to be able to understand the 'language' of the major disciplines involved in the decision-making process (e.g. economics, politics) to be able to communicate (orally and in written reports) with non-biologists, in such a way that the bio-logical aspects that appear in the process are adequately `translated`.

Attitudes
Openness for co-operation and teamwork
Awareness of the possibilities and limitations in the application of biological knowledge in the various problems encountered in society.

These skills and attitudes can be strengthened during the specialization by means of research in one or a few projects (case-studies) which have a direct bearing on the involvement of biology in decision-making processes and which confront the student with the decision-making process as such. This research should be accompanied by theoretical courses given in close co-operation with the appropriate institutions outside biology (e.g. law, economy and certain aspects of sociology) and biology should be integrated with the non-biological disciplines involved.

6. Post-academic training

Based on the University study of biology it will be possible to build up an objective-directed system of post-academic training, which in turn can be part of a system of `permanent education'.

Opportunities should be given to teachers and all professional biologists to keep in contact with the advances in the biological sciences by organized refresher courses e.g. inservice training in universities or other research institutions. The importance of such post-academic courses lies in the necessity for all biologists (in teaching, research and other professional fields e.g._ industry, public services) to be made aware of the progress of new biological methods and theories and of the importance of applying these in the distinct fields of their daily work.

All biologists should regularly participate in post-academic training e.g. every second year.

Developing and implementing post-academic training is confronted with many problems e.g. motivation of the trainees, free time from school and other jobs, financing as well as the organization by the universities which are already over-burdened.

Organizing the participation in post-academic training on an European level could improve post-academic training as well as contribute to international exchange of biologists.

7. Recommendations and conclusions

- It is agreed that all biologists should have a common basic training period usually of 4 years, resulting in a level of knowledge, skills and attitudes comparable in all countries concerned.
  University training of biologists should be 5 years in total, allowing for a specialization into different fields of professions, based on the central core-program.

- The curriculum should allow the student to change his prospective field of specialization e.g. from teaching to research or vice versa.

- Chance should be given to all professional biologists to have ample opportunity to stay in close contact with new developments in biological sciences, relevant to their field of profession by refresher courses through inservice training at the University.

- Some of the accepted recommendations have a bearing upon the co-operation between Universities on an European level. They implicate that during the last year of the central core-program measures should be devised to stimulate exchange of biology students in order to facilitate individual choice of specialization in the 5th year.

This exchange will broaden the students horizon in the different fields of the bio-logical sciences. It will also allow the student to get acquainted with methods developed elsewhere in European biological laboratories.
It takes also into consideration that it is not possible for each university to deal adequately with all different types of specialization within its biological department.
The implementing of these recommendations will be greatly facilitated by inter-european recognition of formal qualifications at the various levels.

Annex 1. Aims of ECBA

1. To represent the professional interests of biologists to the European Communities,
2. To ensure the professional competence of biologists within the European Communities.
3. To facilitate the exchange of information on professional matters relating to the work of biologists within the European Communities.
4. To facilitate free movement of biologists within the European Communities.
5. To promote exchange of those teaching biology in all classes of educational establishment.
6. To promote co-operation and exchange of information between the national biological societies about their activities throughout Europe.

Annex 2. Training of biologists in European countries (1976)

Question	Belgium	Denmark	France	Fed. Rep. Germany	Italy	Netherlands	Norway	Sweden	United Kingdom
Usual age of leaving school and entry to university	18	18 - 20	17 - 18	19	18	18 - 19	19 - 20	18 - 19	18
Years of study in science-subjects before entering university:									
Biology	3-6	6	5	6-9	3	2-4	3-5	3-4	7
Mathematics	6	6	7	8-9	3	6	5-6	6	7
Physics	5	3-6	5	3-6	3	5	2-5	4-5	7
Chemistry	4	3-6	5	2-5	3	4	2-4	4-5	7
Title(s) of final exam(s) and years of study) set by:									
a. University	Licence (4)	Candidatus Scientiarum (6-7)	Licence es Science (4)	Diplom-examen (5)	Laurea(5)	Doctoraal (6)	Candidatus magisterii (3½) Candidatus realium (2-3 y additional to Cand.Mag)	Filosofie Kandidat (3)	Bachelor of Science(4)[1]
b. State	—	—	—	Staats-examen(5)	State exam for O.N.B.	State exam for teachers (4)	Cand.Mag. (3½) Cand.Real. (2-3) additional to Cand.Mag)	State exam for teachers (4)	State exam for teachers (5)[1]
c. other body	—	—	—	—	—	—	—	—	Member Institute Biology (4)[1]
Further qualification(s) taken after normal leaving examination (name and additional years of study)	Doctorate(4-5) Agregation a l'Enseignement Superieur (4-6)	Lie. Scient. (2-3) Dr. Phil(6-10)[2]	D. ès Science (D en Med., D en Pharma- cie) (3)	Doctor rer.nat. (2-4 after Diplom- oder Staats-exam) Dr. habil (4-6 after Dr. rer.Nat.)[3]	Perfectioning (2) Specialization(3)	Doctor (3-6)	Doctor (3-7)	Ph.D. (3-6)	M.Sc. (1-2) Ph.D. (3)
Requirements (and years of study) hat qualify a person to									
a. do research	Licence (4)	Cand.Sc. (7)	D. es Science/ Med/Pharm. (7)	Dipl.ex (5)	Laurea + State exam	Doctoraal(6)	Cand.Real. (5½-6½)	F.K. (3)	B.Sc. or M.I. Biol (4)[1]
b. teach at high school	Licence (4) Agregation a l'Enseignement Secondaire (1	Cand.Sc. (6-7)	Licence + C.A.P.E.S (5)	1st Staats-ex. (Scientif. 4-5) + 2nd Staats-ex. Pedagogy 1½)	Laurea + special exam	Doctoraal + teachers cer- tificate (5-6) or State exam for teachers (4)	Cand.Real + Pedag.semi- nar (½) or Cand.Mag. + Pedag.Seminar(½)	F.K. + 1 year at teacher trai- ning college (4)	B.Sc. or M.I. Biol. + teachers certificate (5)[1]

[1] often with first year exemption

[2] will be changed in near future in: Dr. Scient.

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