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Subject-Specific Criteria for Bioscience Study Programmes[1]

Resolution passed in the Conference of Biological Faculties (KBF) of the German universities May 24, 2013, and referring to the "Subject-specific Criteria Life Sciences" of ASIIN.

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[1] Common publication by the Konferenz Biologischer Fachbereiche (KBF) and VBIO e.V., the major German society in the field of Biosciences in accordance with major societies of both entrepreneurs and employees.

Subject-Specific Criteria Biology

Recommendations on the Contents of Bioscience Bachelor Programmes

(KBF-Resolution passed May 24, 2013)

Preamble

Biology represents a set of specific and dynamic scientific disciplines. It has been an ongoing challenge to keep the current knowledge continuously at a state of the art level as well as to ascertain intellectual integrity, abilities of critical discussion, innovation and employability upon graduation. The vocational qualification of the graduates in Biology is critically dependent on an internalized comprehension of the fundamentals and principles in natural sciences as well as knowledge and skills in special biological areas. Graduates should be able to use these acquired competencies for innovation both on their own and in working groups. They should also be able to critically reflect their own and the activities of others with respect to their responsibility to both society and environment.

It is the primary responsibility of university faculties (including universities for applied sciences) to warrant subject-specific standards in Higher Education (HE) training towards students, bioscience community and society. In order to ascertain the achievement of subject-specific competencies sufficiently, the faculties declare the essential need of freedom to design the modules with regard to module size and structure, modes to verify learning outcomes, obligatory presence of students, required parts as prerequisites to pass modules, or, in other words, the essential need to adapt the regional, national and international framework to the subject specific requirements.

In many systems, quality assurance strategies do not sufficiently focus on comparable subject contents at different locations and reduces its activities on formal-administrative criteria. The authors of the Subject Specific Criteria Life Sciences underline the outstanding importance of comparable subject contents as essential criteria for quality management in life sciences.

The current paper represents a consensus among professors, students, societies of particular disciplines as well as those of employers and employees. The point of view paper is focusing on the generally accepted basics in biosciences and does not refer to particular specializing aspects during advanced studies. The paper lists a series of subject specific competences that should be gained during the bachelor phase in order to ascertain transition to subsequent bioscience master programmes in various fields.

By specifying subject specific criteria for the basic Biology study programmes, both comparability and compatibility of various curricula will be increased and significantly facilitate student mobility, mutual recognition of courses raising both transparency and reliability for all stake holders involved.

Aims and Goals of the Subject Specific Criteria:

The requirements formulated in this document are intended to

- Assure transparency for study programme selection by comparable designation of study programmes,

- Establish a system warranting comparable basic competences in general natural and biological fields
- Assure decent education in general natural sciences
- Optimize teaching formats by adapting teaching and learning formats to the subject specific requirements
- Gaining the basic competence to understand and develop novel complex subjects and knowledges in particular scientific areas
- Ascertain horizontal and vertical mobility of students by straightforward recognition of competences gained at partnering universities or other learning locations.
- Acquire subject specific, methodical, personal and social competencies,
- Achieve comparable qualifications for consecutive bioscience master programmes,
- Ascertain employability

The expectations to define the intended learning outcomes including subject-specific knowledge, skills and competencies are not to be considered static. They are subjected to continuous revision by the bio-scientific community consisting of the conference of the bio-scientific faculties, student representatives, bio-scientific communities, societies, associations of employers, employees and students. Therefore, the subject specific criteria defined in this document may help to define the aspects of "Good Practices" in subject-specific higher education.

Biology and Sciences

Biology requires basic competencies in natural and and mathematics. Knowledge and skills in chemistry, physics informatics, mathematics, statistical analysis are prerequisites to understand the principles of life.

Life sciences including interdisciplinary areas have been developed dynamically in the recent past. There is no clear-cut definition to distinguish among the closely related disciplines including biochemistry, biophysics, biomedicine, biotechnology, environmental sciences and bioinformatics. Therefore, a variety of particular study programmes has been developed more or less focusing on bioscience topics.

During the setup of bioscience study programmes, special care must be taken to balance general basics in the natural sciences with bioscience aspects.

Types of Study Programmes

To allow varying competence profiles in Biology as well as in interdisciplinary subjects three types of curricula have been distinguished, depending on their relative content in bioscience topics.

Type 1 Curricula with bioscience contents of 2/3 of total or higher (Biology, Biosciences, Life Sciences)

Type 2 Curricula with approx. half of bioscience contents (e.g. Biochemistry, Biophysics, Biotechnology)

Type 3 Interdisciplinary curricula with containing less than ½ of bioscience topics (e.g. Bioinformatics, Bioprocessing technology)

The learning outcomes in the type 3 curricula may vary with regard to focus and "deepness" whereas those of type 1 follow optimally the common canon of subjects in a comprehensive fashion.

Bachelor curricula in Biology (only Type 1)

A successfully accomplished Bachelor program should

1. provide the basis for a consecutive science oriented master program,
2. enable for further study programmes, which are not science oriented, or
3. provide employability.

The degree holders have acquired subject specific knowledges and methodic competences according to the communiqué of Bukarest in 2012 (EHEA Ministerial Conference 2012).

Subject specific competences:

Biology represents an empirism based research field using both correlation based and manipulative studies (pilot studies, field studies, laboratory experiments) and frequently also using experimental approaches. To develop particular subject related competencies, both theoretical knowledge and practical methodological and psychomotoric skills are required.

Intended learning outcomes of bioscience bachelor programs:

Bachelor degree holders

- have acquired solid basics in the natural sciences including chemistry, physics and mathematics

- know and understand basic principles of evolutionary processes

- understand the principles of statistics and can apply statistical methods

- know and understand the basic principles of Molecular, Cellular and Organismic Biology

- can apply state of the art bioscience methodology including appropriate experimental control. In addition, they are able to transfer the accomplished skills to new, as yet unresolved, scientific problems

- are able to work independently either in the laboratory or in the field and are able to handle living material properly

- know, understand and follow relevant Bio-Safety, Bio-Security and environmental issues including legislative basics

- are able to discuss bioscience issues in a differentiated way, argue based on scientific findings or knowledge and are also able to evaluate biological issues. Furthermore, they are able to include ethical, economic and legal consideration in their evaluation

- have acquired advanced subject specific knowledge and skills in at least one particular bioscience topic

- are able to solve bioscience problems and to present scientific data appropriately

- are able to accumulate knowledge from differing fields and transfer these into a wider context

- are able to relate results of scientific work to the theoretical background including state of the art knowledge in the field

- are able to discuss and evaluate scientific issues in a differentiated fashion

Personal and social competencies, methodical skills.

Bachelor degree holders in Biology:

- have acquired and trained conceptionally, analytic-synthetically, logical critically and problem solving oriented thinking

- have been critically dealing with societal, ethical and environmental consequences of their activities

- have acquired communication skills in general and are able to explain scientific information to people with and without bioscience background

- have acquainted knowledge and strategies to further develop subject related and transferable skills to continuously stay up to date in a particular field of interest

- are able to understand novel bioscience topics by self-learning

Required topics that Biology Bachelor study programmes (Typ 1-3) should cover

- Solid general knowledges and skills in the natural sciences are essential for all study programs in the field.

- With a general understanding of the principles in the natural sciences, the students should learn basic biological principles and skills, which are subsequently summarized in “Core Section Biology”.

- A high proportion of experimental and practical work: 50% or more of the workload is contributed by experimental laboratory courses, excursions, field studies and project work including the thesis. A typical feature of study programs in the biosciences is the high proportion of experimental approaches and training including the achievement of solid methodological skills.

- At a later phase of the study program, students should specialize in a selected field and develop advanced knowledge and understanding in this particular field which enables them to accomplish a scientific thesis at “State of the Art” level.

- Extended experimental laboratory and/or field work but also theoretical approaches including state of the art methods and technologies enables students for employment in various fields.

- Programs as well as the recognition of credits acquired at foreign HEI or elsewhere according to the Lisbon convention.

- Transferable skills (self and social competences, methodical skills) acquired and/or trained preferentially in bio-scientific contexts.#

Organization and structural elements for bachelor programs in Biology

The Subject Specific Criteria in Biology can only roughly give an overview about essential and desirable topics at levels that are appropriate for the bachelor level. Variations in realizing particular programs are attributed to particular expected learning outcomes.

Basic competences

- Common Topics in the Natural Sciences comprise the understanding and ability to apply the basic principles and methodologies in general, inorganic and organic chemistry, in physics, mathematics and statistics. These are all considered essential for the understanding of biological systems and should be acquired at deepness according to the bachelor level. The detailed formulation of study programs will strongly depend on the intended learning outcomes.

- **Subject specific contents**

- Genetics, evolution and systematics, physiology and biogeography of microorganisms including viruses, fungi, plants, animals and humans
- Basic understanding how pro- and eukaryotic cells work with regard to cellular biology, biochemistry, biophysics and molecular biology; including subcellular and molecular levels.
- Structure, function, development and behaviour of mono-, multicellular and societal organisms
- Basics in neurobiology
- Ecology, ecosystem analysis
- Aspects of applied biology
- General principles of thinking and working approaches in both the natural sciences in general and the bioscience field including the critical discussion of scientific results and their impact on society
- Legal framework and additional regulations for working in biosciences; bioethical aspects

- Transferable skills

- Scientific thinking and working, critical analysis, synthesis and interpretation as well as documentation of acquired data
- Good Scientific Practice, scientific writing, presentation of data including the generation of figures, critical discussion of obtained results, intellectual property rights
- Good Laboratory Practice, Due diligence, occupational safety requirements and further organizational obligations
- Personal competence (self, social), communication skills

Recommended Contents for Biology Bachelor Programs

The subsequent catalogue lists elementary contents in Biology which should be reflected in the study programs. Neither the chapters as summarized herein nor the relative proportion of the parts to each other may be derived from this list; both the structure of study programs and the formulation of particular modules may thus vary. Again, the level of communicating these topics will correlate with the educational level of a bachelor degree. Nevertheless, in case that a study program defies markedly from the recommendations given herein this should be indicated to ascertain the required transparency.

1. **Core Section Biology**
   Depending on the type of study program, this section may represent the major, an equal or a minor proportion of the whole program. Depending on varying goals of particular programs, the professors arrange how to include most/if not all of the subsequent topics.

   1a. Common Biology, evolution, genetics

   - History of Biology
   - Basics of inheritance, regulation of developmental processes, genetic control of environmental adaption
   - Adaptive mechanisms in evolution: genetic drift, selection and proof of "strategies" that are stable during evolution, frequency dependent evolution
   - Synthetic theory of evolution
   - Performing of genetic experiments including genetic modification of organisms
   - Acquisition of data in molecular biology, phylogenetics
   - Basics in bioinformatics, genome annotation, genomics, transcriptomics, proteomics, metabolomics, high throughput sequencing
   - Classical genetics (Mendel rules, breeding)
   - Molecular genetics (mutagenesis, transformation, genetic model systems)
   - Developmental genetics and population genetics
   - Principles of species and their generation including critical discussion on current and previous concepts
   - Critical discussion of non-evolution-based ideas

   1b. Biochemistry, Biophysics, Physiology

   - Structure and function of biomolecules (proteins, nucleic acids, carbohydrates, lipids, co-factors)
   - Fundamentals in biochemistry and biochemical pathways (glycolysis, gluco-neogenesis, citrate cycle, fatty acid oxidation and synthesis, nitrogen homeostasis, urea cycle, amino acid metabolism, biological membranes, electron transport systems, respiratory chain, ATP synthesis, photosynthesis, animal and plant hormones
   - Principles of transport and transfer of information
   - Metabolism of nucleotides and nucleic acids
   - Structure and inheritance of genetic information
   - Regulation of transcription and posttranscriptional modification
   - Regulation of protein synthesis, folding, assembly, transport and degradation

- Protein interactions and protein cascades
- Macroscopic physiology of organisms (transport mechanisms, gas exchange)
- Hormones and endocrinology

1c Cellular and Developmental Biology

- Cellular and intracellular organization of cells as basic units of life
- Structure and biogenesis of biological membranes, compartments and organelles
- Functional elements in cells; comparing prokaryotic, eukaryotic, animal fungal and plant cells
- Intermediary filament network and cytoskeleton
- Developmental Biology of selected model organisms
- Selected examples of molecular regulation of differentiation and determination
- Establishment of axonal systems
- Histology and Cytology
- Selected examples of morphology and organogenesis
- Correlations of ontogenesis and evolution
- Stem cells and cellular differentiation

1d Zoology

- Phylogeny, Structure and Function of relevant animal groups
- Taxonomy (methods/theories), brief characteristics of animal tribes
- Knowledge of species and determination of both in the field and the laboratory
- Structure of animal organs and tissues, reproduction, ontogenesis, skeletal systems, integument, respiration, circulation, digestion and secretion, sensory organs, communication systems
- Neurobiology (neuronal systems, origin, evolution and diversity of neuronal systems, neuronal regulation of behaviour)
- Sensoric and motoric principles
- Basics in zoogeography and the evolution of animals
- Basics behavioural biology of animals (animal behaviour at proximate and ultimate levels, ontogeny of behaviour and mechanisms of learning, modes of communication, social behaviour)
- Basics in immunology and infection biology

1e Botany

- Phylogeny, taxonomy and systematics of fungi and plants
- Morphology of plant organisms
- Structure of plant organs, tissues and cells
- Structure and functional principles of selected plants and fungi including developmental circuits
- Physiology of plants (photosynthesis, molecular mechanisms of environmental adaption)
- Knowledge of the most relevant indigenous and non-European plant families

- Acquisition of practical skills to determine plant species and establish preparations of plant objects
- Basics of phytogeography and evolution of plants

1f Microbiology

- Phylogeny, taxonomy and systematics of pro- and eukaryotic microorganisms
- Cell Biology, physiology, regulation and signal transduction mechanisms in pro- and eukaryotic microorganisms
- Microbial energy metabolism
- Basics in molecular genetics of microorganisms
- Relevance of microorganisms in global metabolic circles, microbiomes
- Application of microorganisms in environmental microbiology and biotechnology
- Understanding of important pathogenicity mechanisms of microorganisms
- Knowledge and safe use of biological agents including risk assessment and attribution of safety levels

1g Ecology

- Analysis and energy balance of the biosphere, biogeochemical circles
- Basic knowledge of the interaction of organisms including the interactions of organisms with both abiotic and biotic environment (dependence on ecological niches, adaption, symbiosis, commensalism, parasitism)
- Ecophysiology and environmental adaption at metabolic level
- Bio-Indication
- Understanding ecological correlations and models of current environmental issues
- Fundamental concepts: ecological niche, population growth, competition, predator-bait-dynamics
- Basics of structure and function of ecosystems
- Applied ecology (biodiversity research, anthropogenic consequences, economic aspects)

2. Fundamentals in the Natural Sciences

For a deeper understanding of biology it is essential to acquire basic competences in natural sciences and mathematics.

2a General and Inorganic Chemistry

- Physicochemical basics: Atoms, molecules, ions, salts, molar entities, stoichiometry, periodicity, chemical binding, energy balance, chemical reaction, chemical equilibrium, precipitation reactions, acids and bases, redox reactions, electrochemical potential and reactions, typical compounds of major group elements, minor group elements, complexes, metals in living organisms
- Qualitative and quantitative analysis (titration, instrument based analysis), standard reactions (test tube reactions)

2b Organic Chemistry

- Basic knowledge of organic chemistry, organic compounds (e.g. carbohydrates, functional groups, carbonyl compounds, polysaccharides, amino acids, peptides, heterocycles, nucleic acids), reaction mechanisms (e.g. radical, nucleophile, electrophile substitution, polarized binding, elimination, reactions of carbonyl groups, reactions at CC double and triple bindings, oxidation and reduction)
- Understanding the correlation of molecular and macroscopic structure , binding forces, substance specific properties and reactivity, reaction types, groups of organic compounds and their technical synthesis, natural compounds and their relevance

2c Physics and Physical Chemistry

- Bioscience relevant topics in experimental physics: mechanics and thermodynamics (binding equilibrium), ideal and real gases, aggregate phases and phase transitions, solution and mixed phases, mixtures and separation procedures
- Electricity and electromagnetism, oscillations and waves, optics
- Calculating with physical terms and dimensions
- Kinetics (phenomenological, experimental approaches, chemical reactions), electrochemistry (electrolytes, electrodes and electrochemical processes, ion-equilibria)
- Atomic and nuclear physics, radioactivity and ionizing radiation

2d Mathematics, Statistics and Informatics

- Functional correlations, differentiation and integration of functions with one or more variables, curve discussion, power series, common differential equations, linear equation systems, basics in statistics, mean value and distribution, regression, classification and testing biological models, biological explorative statistics, parametric and non-parametric tests, dimensions and correlation of quantities in Biology, mathematical description of dynamic processes

3. Transferable Skills

- Regulatory framework for activities in the bioscience field (GMO-regulations, ionizing radiation, animal protection, Natural and environmental protection, biological substances, working materials)
- Common Codex of Good Scientific Practice including due diligence and occupational safety requirements and further organizational obligations (risk assessment, (bio)safety considerations and the implementation of safety procedures for activities in the laboratory, safety instructions, safety aspects of instruments and equipment)
- Expertise according to regulatory standards (Bio-Substances Act etc.)
- Personal competence (self, social, communicative, intercultural), skills in project management, independence, ability to learn
- Writing scientific articles with respect to critical discussion of own and other´s data and proper citation