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# Biology Standards Statement

Pauline Ross, Charlotte Taylor,  
Elizabeth Johnson and Susan M. Jones

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Office for Learning and Teaching  
Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education

GPO Box 9880,  
Location code N255EL10  
Sydney NSW 2001

<[learningandteaching@deewr.gov.au](mailto:learningandteaching@deewr.gov.au)>

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# Learning and Teaching Academic Standards Statement for Biology

This Biology Standards Statement is modelled upon the Science Standards Statement (Jones, Yates and Kelder, 2011)<sup>1</sup>. It includes a description of the nature and extent of biology, a statement of the Biology Standards expressed as threshold learning outcomes (TLOs), and accompanying notes that provide a framework for understanding, interpreting and applying the Biology Threshold Learning Outcomes (BTLOs).

The BTLOs strongly reference the Science TLOs (Jones et al., 2011) that were the core output of the ALTC Learning and Teaching Standards project for science. The Science TLOs have been endorsed by the Australian Council of Deans of Science as “a generic high-level statement of Bachelor of Science threshold learning outcomes” (Jones et al., 2011: p. 2), and map to the Australian Qualifications Framework (AQF) specification for the bachelor degree.

The BTLOs represent a consensus view of the biology professionals consulted (via workshops and an online survey) during the Discipline Network Project *Vision and Innovation in Biology Education* (VIBE) funded by the Office for Learning and Teaching (OLT). The Biology TLOs therefore represent the current (2013) nationally agreed standards of attainment for biology graduates in science.

Biology graduates may have studied biology (or a specific component of biology: e.g. biomolecular science, zoology or ecology) as a major within a generalist degree such as the Bachelor of Science (BSc). However, many students of biology will study biology only at first year (introductory) level as a foundation for later more specialised studies in, for example, medical or paramedical fields. For all such students and for the academics designing curricula for them, the BTLOs and their accompanying notes provide an essential guide to the core knowledge and skills expected of any student who studies biology at tertiary level. These include an understanding of evolution, cell theory, and how living things, in all their diversity, are systematically classified. In particular, students will understand how biological knowledge is acquired through the scientific method. Although such students will not be expected to meet the BTLOs, which are defined at graduate level, they will have had relevant foundational learning experiences in biology at introductory level.

This Standards Statement for Biology therefore provides a foundation for the evaluation of current biology degree programs, and for future curriculum development.

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<sup>1</sup> Jones, S. M., Yates, B. F. and J.-A.Kelder (2011). *Learning and Teaching Academic Standards Project: Science Learning and Teaching Academic Standards Statement*. Sydney: Australian Learning and Teaching Council (<[www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011](http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011)> or <[disciplinestandards.pbworks.com/w/page/52657697/FrontPage](http://disciplinestandards.pbworks.com/w/page/52657697/FrontPage)>).

## 1. Nature and extent of biology

Biology is the study of living organisms, whether single-celled or multi-cellular, as individuals or in groups, and their interaction with their environment and with each other. Biologists seek to understand the structure and function of the living world. Biologists investigate how organisms, access and use energy and the processes by which they develop and replicate. Evolution provides an overarching framework for understanding changes that have occurred in groups of organisms over time.

As a branch of science, biology is characterised by its complexity and diversity. The many sub-disciplines of biology are distinguished by:

- their subject matter
- the scale of the subject matter
- the suite of tools used for investigation.

Biology is a particularly dynamic discipline. Compared to the history of other areas of science, key areas of rigorous study in biology (e.g. genetics and molecular biology) have developed relatively recently. Biology is now moving into a phase of rapid expansion and discovery that places biologists at the forefront of current scientific research. Today's biologists face novel ethical challenges and need to develop innovative ways to work with living organisms. This requires them to develop, monitor, and practice ethical procedures, and to champion this approach in the public arena as the ethical questions facing society become increasingly more complex and challenging.

*"...biology is poised to help answer many of the pressing problems of the 21<sup>st</sup> century as related to food, ecosystem sustainability, development of alternatives to fossil fuel, and health-related issues."*<sup>2</sup>

Biology sits within the philosophical and operational framework of science. Working as a biologist requires immersion in the basic concepts that underpin thinking and practising in all the sciences. The discipline of biology itself requires an understanding of all aspects of life and thus it encompasses an extraordinary range of sub-disciplines such as taxonomy, ecology, physiology, phylogenetics, cytology, microbiology and molecular biology. These areas are closely connected by a common intellectual approach that guides the ways of thinking and experimentation that advance our understanding of living organisms. Natural systems exhibit complexity and dynamism at scales from the global ecosystem, to individual organisms and to the cellular and molecular level. A commonality in structures and processes characterises all these systems, and an ability to move conceptually between these scales is a key requirement for biological thinking and reasoning.

Biologists work within an established framework of scientific methodologies, employing observation, measurement, and classification, to conduct experiments and test hypotheses. This structured approach is particularly pertinent to the dynamic nature of living systems, which are characterised by complexity, variability, and unpredictable outcomes. This

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<sup>2</sup> Holm et al. (2011). Vision and change in biology undergraduate education. BaMBEd 39(2) 87-90.

provides a particularly challenging framework, and biologists must therefore acknowledge the role of probability in the interpretation and communication of their findings.

Biologists share a focus on making careful observations of phenomena in field or laboratory environments, a rigorous approach to asking questions and developing hypotheses, and the selection of appropriate experimental methods with which to test their predictions. Through the application of the scientific method, biology graduates will understand how biological knowledge is generated and that such knowledge is both testable and contestable.

## 2. Australian graduates in biology

The career destinations of Australian graduates with biology degrees are many and varied, reflecting the very broad scope of the discipline and the diversity of degree offerings at Australian institutions of higher education. A national survey of employment outcomes for science graduates over the period 1990-2000<sup>3</sup> found that graduates in the Life Sciences reported a much wider range of professional employment compared to other areas of science, encompassing technical, managerial and professional levels.

Depending on the nature of their degree studies, biology graduates may find employment with a range of organisations, including, for example, pathology or biotechnology laboratories, environmental agencies, state or federal government agencies, such as Parks and Wildlife Services. Some may also find employment in technical work in the laboratory or hands-on research in the field, and may be required to provide analysis, synthesis, recommendations or policy advice based on scientific knowledge generated by others. Biology graduates are needed as teachers in primary or secondary schools to improve the scientific and biological literacy of the community.

In all of these scenarios, biology graduates require good critical thinking and communication skills, and the ability to work independently and in teams in a disciplinary or interdisciplinary context.

*“..... you are expected to read and write well, to talk coherently and intelligibly and to develop a sense of style. There is a tolerance of divergent values. A biological training also offers a grounding in manipulative skill, a capacity for reasoning and an ability to cope with complexity”<sup>4</sup>*

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<sup>3</sup> [What Did You Do With Your Science Degree?](#) A national study of employment outcomes for Science degree holders 1990-2000, prepared for the Australian Council of Deans of Science (ACDS) by Craig McInnis, Robyn Hartley and Malcolm Anderson, Centre for the Study of Higher Education, University of Melbourne

<sup>4</sup> Becher and Trowler (2001). *Academic Tribes and Territories: intellectual enquiry and the cultures of disciplines*. Open University Press, Philadelphia, USA

### 3. Biology Threshold Learning Outcomes (BTLOs)

	<b>Upon completion of a bachelor degree or major in biology, graduates will:</b>
<b>Understanding biology</b>	<p>1.1 Demonstrate a coherent understanding of biology by articulating the methods of biology, and explaining why current biological knowledge is both contestable and testable through further inquiry.</p> <p>1.2 Demonstrate a coherent understanding of biology by explaining the role and relevance of biology in society.</p> <p>1.3 Recognise that biological knowledge has been acquired by curiosity and creativity, and demonstrate creativity in thinking and problem solving.</p> <p>1.4 Recognise and appreciate the significant role of biodiversity in sustaining life on our planet.</p>
<b>Biological knowledge</b>	<p>2.1 Exhibit depth and breadth of biological knowledge by demonstrating well-developed understanding of identified core concepts in biology.</p> <p>2.2 Exhibit depth and breadth of biological knowledge by demonstrating that these 'core concepts' have interdisciplinary connections with other disciplines.</p>
<b>Inquiry and problem solving</b>	<p>3.1 Gather, synthesise and critically evaluate information about biological phenomena from a range of sources.</p> <p>3.2 Critically analyse observations of biological phenomena by creating and developing models and/or proposing and testing hypotheses.</p> <p>3.3 Design and conduct field, laboratory based, or virtual biological experiments.</p> <p>3.4 Select and apply practical and/or theoretical techniques.</p> <p>3.5 Collect, accurately record, interpret, analyse, and draw conclusions from biological data.</p>
<b>Communication</b>	<p>4. Effectively synthesise and communicate biological results using a range of modes (including oral, written, and visual) for a variety of purposes and audiences.</p>
<b>Personal and professional responsibility</b>	<p>5.1 Be accountable for their own learning and biological work by being independent and self-directed learners.</p> <p>5.2 Work effectively, responsibly and safely in individual and peer or team contexts.</p> <p>5.3 Demonstrate knowledge of the regulatory frameworks and ethical principles relevant to their sub-disciplinary area within biology, and apply these in practice.</p>

## 4. Notes on the Biology Threshold Learning Outcomes (BTLOs)

These notes are intended to offer guidance on interpreting the Biology Threshold Learning Outcome (BTLO) statements. The notes and the BTLOs should be considered in the context of the statement of the 'nature and extent of biology' contained in this booklet, and the *Vision and Innovation Statement* produced by VIBEnet as a separate publication.

The BTLOs describe the threshold learning outcomes of a pass level graduate from a bachelor level degree program in biology or biology major within a bachelor degree. A *bachelor degree* is defined according to the Australian Qualifications Framework, within which it represents a level 7 qualification. A *threshold learning outcome* (TLO) is defined as the “minimum discipline knowledge, discipline-specific skills and professional capabilities including values and behaviours that are expected of a graduate of a specified level of program in a specified disciplinary area” (Jones et al., 2011: p. 3).

The BTLOs are not intended to be weighted equally across the major or degree program, nor does the numbering imply a hierarchical order of importance. However, the numbering may be used to provide easy reference to a specific BTLO.

The notes on the BTLOs presented here draw upon the notes on the Science TLOs provided in the Science Standards Statement, but are written in the context of the discipline of biology, with the intention of supporting biology teaching academics in curriculum review and renewal.

The **Good Practice Guides for the five Science Threshold Learning Outcomes** should be consulted for further elaborations of these notes. Each Good Practice Guide provides a succinct literature review of current research, exemplars of good practice, and a suite of web and print based resources relevant to that TLO. The theoretical concepts and practical ideas in the Science Good Practice Guides will be directly applicable to undergraduate teaching in biology.

### BTLO 1 Understanding biology

#### BTLO 1.1

*A coherent understanding:* Graduates need an appreciation of biology as the study of all aspects of living things and their interactions with the environment. Biology is a broad and ever-expanding discipline with many sub-disciplines. It is too broad a discipline for biology graduates to understand all the sub-disciplines in detail, but graduates should understand how the sub-disciplines interact to describe living organisms and the processes of metabolism. The theory of evolution is a unifying principle for the discipline.

*The methods of biology:* Biology graduates will understand that biological knowledge is created through the process of research and inquiry. Creating new knowledge in biology involves observations of biological phenomena and design of hypotheses that are testable through systematic and logical inquiry. Biology graduates will be able to recognise the limitations of the methods of biology as well as their strengths, and understand that sometimes serendipity is involved in making new discoveries.

*Contestable:* A biology graduate will have an appreciation and understanding that biological knowledge and existing understandings are based on the best evidence at the time, but are open to uncertainty, contestability and further inquiry which may depend on the constraints of currently available technology.

*Testable:* All biological knowledge is, in principle, testable. A biology graduate will understand that many biological 'facts' have already been tested (and can be replicated), while other biological knowledge awaits testing and re-testing (i.e. is contestable) by experiment.

## **BTLO 1.2**

*Role and relevance:* Biology graduates will understand that biological knowledge creates both challenges and opportunities for individuals and society at local and global levels. Biological knowledge allows decision making about individual and global human health, the maintenance of biodiversity and the sustainability of ecosystems.

*Society:* Biology graduates will understand that there are complex societal issues that have solutions in biology. These include improving human health, population growth, food sustainability and security, genetic and medical technologies and the sustainability of biodiversity and ecosystems.

## **BTLO 1.3**

*Curiosity and Creativity:* Biology graduates will understand that the creation of biological knowledge is often the consequence of curiosity and innovation. Biology graduates need opportunities to be creative and curious in conducting experiments and research during their undergraduate studies. This means that undergraduate learning experiences should include opportunities for discovery, for exploration and for making novel connections.

## **BTLO 1.4**

*Sustainability of life:* Biology graduates need to appreciate that biological knowledge has a significant role in ensuring sustainability of biodiversity and life on our planet.

# **BTLO 2 Biological knowledge**

## **BTLO 2.1**

*Depth and breadth:* Biology graduates will have depth of knowledge of the core concepts in biology, which are further articulated in the *Vision and Innovation Statement* for undergraduate biology education. Graduates will have gained a *depth* of knowledge through the study of a specific sub-discipline of biology at an advanced level. Their advanced level studies will build on the *breadth* of introductory and intermediate level studies.

*Biological knowledge:* This is the currently accepted body of facts, unifying theories and explanations from investigations of the natural world.

*Core concepts:* Biology graduates will understand the unifying theories, organising principles and core concepts of the biology discipline.

## **BTLO 2.2**

*Interdisciplinary connections:* Biology graduates will understand how concepts in biology relate to other sub-disciplines in biology and disciplines of science. Solving 21<sup>st</sup> century biological problems will require the integration of biological knowledge with other disciplines. Biology graduates will need to think and contribute outside their immediate disciplinary boundaries, and be prepared to work in interdisciplinary teams to provide informed solutions about the complex problems facing the world.

*Sub-disciplines:* This term is used in this document to describe a sub-discipline of biology, such as molecular biology, genetics, ecology, plant or animal science, or biochemistry.

## **BTLO 3 Inquiry and problem solving**

### **BTLO 3.1**

*Critically evaluate information:* Biology graduates should be able to assess the validity of information by reference to the author credentials, the publisher, intended audience, relevance and/or critical analysis that may include aspects of the experimental design and the conclusions reached.

*Range of sources:* Sources will include books, book chapters, academic and biological journals (refereed and non-refereed), government reports and other 'grey' (i.e. non-refereed) literature, and online or other electronic information. Biology graduates will be able to critically evaluate science-based material in the media and other public forums. They will be able to determine the credibility of the evidence, assumptions and potential fallacies in arguments.

### **BTLO 3.2**

*Critically analyse observations of biological phenomena:* Biology is primarily an observational and experimental discipline. Using critical thinking skills, biology graduates will observe similarities and differences in phenomena, and detection of and departure from biological patterns. They will create explanations/models to account for these observations and identify implicit and explicit assumptions in these explanations/models, while understanding that multiple working hypotheses may be reasonable. Graduates will be able to critically analyse and explain the arguments underlying the creation of these explanations/models that support their understanding and explanations of biological phenomena.

*Proposing and testing hypotheses:* Biology graduates will be able to construct testable hypotheses and null hypotheses from explanations/models. Biology graduates will understand that hypotheses cannot be 'proven', but that the null hypothesis can be rejected through statistical analysis and this provides a tool for justification to support the hypothesis and model.

### **BTLO 3.3**

*Design and conduct field, laboratory-based or virtual biological experiments:* Biology graduates will be able to design and carry out an experiment that effectively tests a hypothesis. Biology graduates will be able to design an experiment identifying the main variables (which may interact), controls and replication.

### **BTLO 3.4**

*Select and apply practical and/or theoretical techniques:* Biology graduates will have an understanding of a range of practical techniques in the laboratory or the field (as appropriate) including microscopy, molecular and cell biology techniques, whole organism experimentation, population and ecological analysis and modelling of biological data. Graduates will be able to use practical techniques appropriate to their chosen sub-discipline of biology and have an appreciation/basic understanding of techniques used in other areas of science that complement biological inquiry.

### **BTLO 3.5**

*Collect, accurately record, interpret and draw conclusions from quantitative data:* Biology graduates will be able to collect, collate and organise data from experiments and other sources. Data in biology may be quantitative (numerical measurement) or qualitative such as images, video or sound recordings. Experimental results can be collected in a variety of forms, usually involving multiple measurements that are consolidated into datasets. Biology graduates will be able to recognise patterns and describe trends and relationships in the data using statistics as appropriate. They will have the capacity to develop arguments and draw valid conclusions based on their interpretation of the data and statistical analyses. Their conclusions may lead them to reject and re-cast a working hypothesis or explanation. Each of these steps requires the critical thinking processes of analysis, inference, interpretation and deductive reasoning. Biology graduates will be able to explain the significance of random sampling, reproducibility and uncertainty in experimental design and analysis. In addition, qualitative evidence, such as descriptive observation, may be used to inform scientific judgements.

## **BTLO 4 Communication**

*Effectively synthesise and communicate:* Biology graduates will be able to synthesise complex biological information and/or data and present it in an accessible way appropriate to a specific audience.

*A range of modes:* Biology graduates will be able to communicate experimental outcomes and information effectively using a range of modes (written, oral, visual) and formats (e.g. written scientific research report, poster, new media, webpage) using a variety of techniques (e.g. graphs, statistical tables, models and simulations).

*A variety of purposes and audiences:* Biology graduates will be able to communicate their findings in ways which reach and are understood by audiences of their peers, decision makers, the general public, school students and future biologists; they will be able to present biological information in both technical and non-technical ways.

## BTLO 5 Personal and professional responsibility

### BTLO 5.1

*Independent and self-directed:* Biology graduates will have learned to work autonomously within certain professional contexts, and will be able take responsibility for their own development as learners. They will know how to seek required information and be able to apply that information in novel settings. They will understand the limits of their own current learning, and know when to seek assistance.

### BTLO 5.2

*Work effectively, responsibly and safely:* Biology graduates will know the occupational health and safety requirements and risks of scientific work in the laboratory, field or office, as appropriate to their sub-discipline. They will take responsibility for themselves and for others working with them as team mates or volunteers. When working in teams, they will understand the need to negotiate and responsibly fulfil their role(s) in team projects.

### BTLO 5.3

*Regulatory frameworks:* Biology graduates will know the regulatory frameworks that apply to their sub-disciplinary area. These might include animal ethics legislation and procedures, federal and state government permit systems, Australian Quarantine regulations, guidelines from the Office of the Gene Technology Regulator, food standards and/or medical/human ethical standards. They will be prepared to abide by these regulatory frameworks as they move into professional employment, and will understand the consequences for themselves and others.

*Ethical principles:* During their undergraduate study, biology graduates will have demonstrated ethical behaviours specific to their biological context (e.g. animal care and handling or patient confidentiality). At the broader level, they will understand and demonstrate intellectual and scientific integrity, including accurate data recording and appropriate storage, proper referencing and plagiarism.

## Appendix 4 Interview with leading biology researchers

Leading biology researchers interviewed were:

Professor Maria Byrne (<http://sydney.edu.au/medicine/anatomy/research/labs/byrne/>),

Professor Stephen Simpson (<http://sydney.edu.au/science/people/stephen.simpson.php>)

Associate Professor Gareth Denyer

(<http://sydney.edu.au/medicine/people/academics/profiles/gareth.php>)

Professor Richard Kingsford (<http://www.bees.unsw.edu.au/richard-kingsford>)

Associate Professor Paul Adam (<http://www.bees.unsw.edu.au/paul-adam>)

Professor Emma Johnston (<http://www.bees.unsw.edu.au/emma-johnston>)

These videos were produced by Derek Muller and Andrew Bennett and are available on YouTube (see below).

**Leading Australian biology academics share their thoughts on what skills are important for biology graduates to have. The videos were produced by Derek Muller and Andrew Bennett.**

Video number	Question	Video location and Comments
1.	<b>What is Biology?</b>	<a href="http://www.youtube.com/watch?v=kvBQv0cs0Sw">http://www.youtube.com/watch?v=kvBQv0cs0Sw</a>
2.	<b>What skills should tertiary biology graduates have?</b>	They all stress the importance of developing research skills and agree that these are best taught in practical classes – both in the laboratory and in the field.  <a href="http://www.youtube.com/watch?v=Wur9tzJIA1c">http://www.youtube.com/watch?v=Wur9tzJIA1c</a>
3.	<b>What are the most effective strategies for teaching tertiary biology?</b>	They comment on the importance of innovation and communication with students.  <a href="http://www.youtube.com/watch?v=gXjoAzWXdA4">http://www.youtube.com/watch?v=gXjoAzWXdA4</a>
4.	<b>What content knowledge should tertiary biology graduates learn?</b>	They all agree that understanding evolution and evolutionary processes is key to understanding biology and biological processes.  <a href="http://www.youtube.com/watch?v=tJqjdldW2w">http://www.youtube.com/watch?v=tJqjdldW2w</a>
5.	<b>How should students' understanding of biology be assessed?</b>	Are exams ever the best option?  <a href="http://www.youtube.com/watch?v=97kf_Odn8Lo">http://www.youtube.com/watch?v=97kf_Odn8Lo</a>