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Woods, Alison, Chandler, Colin, Connolly, Siobhan et al. (6 more authors) (2020) Designing and Developing Core Physiology Learning Outcomes for Pre-registration Nursing Education Curriculum. Advances in Physiology Education. pp. 464-474.

https://doi.org/10.1152/advan.00139.2019

Title

Designing and Developing Core Physiology Learning Outcomes for Pre-registration Nursing Education Curriculum

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Physiology learning outcomes for pre-registration nursing

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Abstract

Abstract

Physiology is a key element of ‘bioscience’ education within pre-registration nursing programmes, but there is a lack of clarity on what is included. Physiology and bioscience content and delivery is highly varied across both higher education institutions and the related programmes in the UK. Despite evidence highlighting concerns over nurses lack of bioscience knowledge and unsafe practice, there is no universally agreed curriculum with detailed outcomes of minimum levels of knowledge to support nurses in practice and patient care. This study aimed to inform the construction of discipline specific physiology learning outcomes to clarify relevant physiological topics required in pre-registration nursing. Initially, 360 learning outcomes were identified from various sources. Using a modified Delphi approach, an expert panel from the Bioscience in Nurse Education group reviewed and modified the list to 195 proposed outcomes. These were circulated to Universities in the UK who teach Nursing (n=65). Outcomes which had 80% consensus were automatically included to the next round with others recommended with modification (response rate 22%). The panel reviewed the modifications and 182 outcomes were circulated in the second questionnaire (response rate 23%) and further panel review resulting in 177 outcomes agreed. These learning outcomes do not suggest how they should be delivered but gives the basic level required for qualification as a nurse commensurate with the Nursing and Midwifery Council new standards for the 'future nurse'.

Keywords

Nurse Education

Curriculum Design

Nursing

Pre-registration

Delphi

Main Text

Introduction

Nursing is a diverse profession that attracts entrants with a wide range of prior educational experience. The challenge that educators face is to ensure that physiology and the other bioscience topics are engaging, support knowledge and skill development. They must show the relevance of the biosciences to the 'real world' clinical practice that is experienced by all students and practitioners. Patient and public safety require practice built on a sound foundation of knowledge. The purpose of this study was to provide guidance to educators, reduce variability, and set a benchmark in terms of level and breadth for the foundational physiological knowledge that supports professional development and safe patient care.

This project provides a clear definition of the relevant physiological knowledge that is required by nurses to support their clinical practice at registration. Consensus-driven, core learning outcomes were developed to define the key physiological concepts that nurses will build on throughout their future careers; supporting their lifelong learning, through ongoing reflective practice and continual professional development.

The UK shift in professional regulation to a competency based standards framework supports educators in developing an approach more aligned to student learning. Locating student learning across both university and practice-based environments supports the understanding of the skills they are developing, in relation to their subject learning (1). However, in terms of the subject knowledge to support practice, the standards based framework is less helpful requiring students to gain "*A comprehensive knowledge of the sciences on which general nursing is based, including sufficient understanding of the structure, physiological functions and behaviour of healthy and sick persons, and of the relationship between the state of health and the physical and social environment of the human being"* ((25), Standards Part 3, Annexe 1.6). The Bioscience in Nurse Education (BiNE) group is a specialist reference group of the Higher Education Academy consisting of academics with experience in pre and post registration nurse education (https://www.advance-he.ac.uk/knowledge-hub/bioscience-nurse-education-bine-special-interest-group). This group, established in 2012, developed the B-QAF learning outcomes (Table 1) to provide more guidance to educators, but this resource lacked specificity within the discrete subject areas (5).

Table 1: ***BiNE B-QAF, Learning outcomes.*** *These learning outcomes provide a high level overview of the combined disciplines comprising the Biosciences (2).*

1: Demonstrate knowledge, understanding and application of anatomical and scientific terminology
2: Demonstrate knowledge, understanding and application of the physiological principles of health
3: Demonstrate knowledge, understanding and application of the physiological basis for clinical observations & tests
4: Apply knowledge & understanding of physiology to health promotion & well-being
5: Demonstrate knowledge and understanding of pathophysiological processes
6: Apply knowledge of pathophysiological processes to conditions/diseases/illnesses relevant to field of practice
7: Apply and integrate knowledge and understanding of the pathophysiological processes to clinical decision-making
8: Apply and integrate knowledge of pathophysiological processes to promote patients/clients' understanding of their illness/condition/disease

9: Demonstrate knowledge, understanding and application of general pharmacological principles to clinical practice
10: Demonstrate knowledge, understanding and application of basic pharmacology to medicines administered
11: Apply knowledge and understanding of mechanisms of drug interactions and adverse drug reactions to medicines optimisation
12: Demonstrate an understanding of how individual variation can affect patients' responses to medicines

Genetics / genomics
1. Understand the different ways in which genomic information can influence patient care
2. Describe the structure and function of DNA, how it is organised to form the genome and how it is inherited
3. Explain how alterations to the genome can influence health and disease
4 Understand the importance of family history information
5. Understand the clinical indicators within an individual or family that may suggest a major genetic cause and act on these accordingly

The challenge, for educators, is to equip nurses and other health professionals for a diverse range of practice. The conceptual shift to defining the curriculum based on competency criteria rather than a traditional knowledge based curriculum design presupposes, in the case of nurses, an interdisciplinary bio-psycho-social knowledge base that supports and informs practice in partnership with the individual. It requires the ability to address the demands of real-world practice where each situation is unique and needs a high level of clinical decision making. Such decisions draw on appropriate up to date knowledge (10). Skills are developed through reflection on practice which further builds the professional knowledge base (26). In the UK all four fields of nursing practice: adult, mental health, learning disabilities and children's nursing require a common knowledge base to underpin their practice (25).

The diversity of prior-educational experience of entrants to nursing programmes, presents a challenge to educators of large student cohorts. Some will have studied biological sciences in considerable depth whilst others will have scant knowledge of basic scientific principles and language. For all students there will be areas of their learning which present conceptual barriers to their understanding involving a learning journey through a series of 'threshold concepts' (20). These steps relate to both knowledge components and their application, and will lead to the development of the skills and behaviours in practice (26). The learning outcomes developed in this project aim to facilitate this journey through the threshold concepts in physiology pertinent to nursing knowledge and practice. It has been widely reported over recent decades that pre-registration nursing students find the biosciences difficult (21) (12, 19).

Further challenges to educators in the biosciences have come from three areas. The first challenge was the move in the later part of the last century towards a more social model and the decreased emphasis of the medical model in nursing which led to a marked reduction in time allocated to the biosciences in the UK curriculum (18). This generated variance in programme delivery between UK higher education institutions (28). Secondly, the rapid expansion of the physiology knowledge base into a number of sub-specialities requires nursing practice and therefore nurse education to also rapidly adapt in order to develop nurses fit for 21st Century practice. Establishing the scope and depth of such subjects that are relevant to nursing practice is required. Thirdly, widening access to nursing presents difficulties for recruitment, student learning and educational provision. The profile of students recruited is influenced by funding, educational diversity, age, gender, and demography.

In addition there is the diversity within and between programmes and internationally there are differences in educational requirements to obtain nurse registration. Across all these routes of entry in the varying countries and contexts, the level of basic science education is highly variable and the educator may well be faced with a class where some students have little or very basic science knowledge and others will have degree or higher degree level science.

The demand for nurses and other healthcare professionals worldwide underpins the laudable aim of 'Health for All' which is enshrined within current development policies and practice such as the Sustainable Development goals (SDG) (29). Achieving universal health coverage will rely on substantial development of both health personnel and the way they work in society. Currently there is a worldwide deficit in the healthcare workforce which is set to increase over the coming years unless major steps are taken to recruit, train and retain staff (1). The nature of healthcare is also changing as it adapts to a relative reduction in infectious disease morbidity and mortality and with a growing global epidemic of non-communicable diseases (11). Recent experiences with Covid-19 required the redeployment of nurses and other healthcare staff into acute care areas. This action illustrated the need for all nurses to have a consistent underpinning of bioscience knowledge to support them in any area of practice.

This COVID-19 pandemic will change the future health care environment and true advances towards the SDGs require community based patient centred care delivered with an interdisciplinary focus, addressing social, political, environmental and economic factors over and above the traditional biomedical approaches (13). Within this context nurses are pivotal, because patient centred care is central to nursing practice and they form the majority of the health care workforce. The International Council of Nurses (ICN) definition of nursing states, 'Nursing *encompasses autonomous and collaborative care of individuals of all ages, families, groups and communities, sick or well and in all settings. Nursing includes the promotion of health, prevention of illness, and care of ill, disabled and dying people. Advocacy, promotion of a safe environment, research, participation in shaping health policy, and in patient and health systems management, and education are also key nursing roles*.' (14). '*In many parts of the world, nurses are the first, and sometimes the only, health professional that patients see*' (8) and are increasingly influential in healthcare provision. Nurse education must respond and adapt to changing expectations placed on the profession to equip the nurse at the point of registration with fundamental conceptual knowledge appropriate to their future practice in any clinical context.

This project aimed to develop a set of Core Physiology Learning Outcomes with a specific nursing focus. This will assist educators to meet the requirements of the nursing role, nursing students and professional regulators so students are equiped with the knowledge to support their future role as a nurse in practice to safeguard patient care.

Materials and Methods

A modified Delphi process was used to facilitate the aims of this project (16, 17). The Delphi approach allowed for consensus to be gained through a structured process (27), where group opinion from expert members was then circulated anonymously for comment to interested relevant parties who met the inclusion criteria (Tables 2 and 3).

Table 2: Inclusion and exclusion criteria for expert panellists

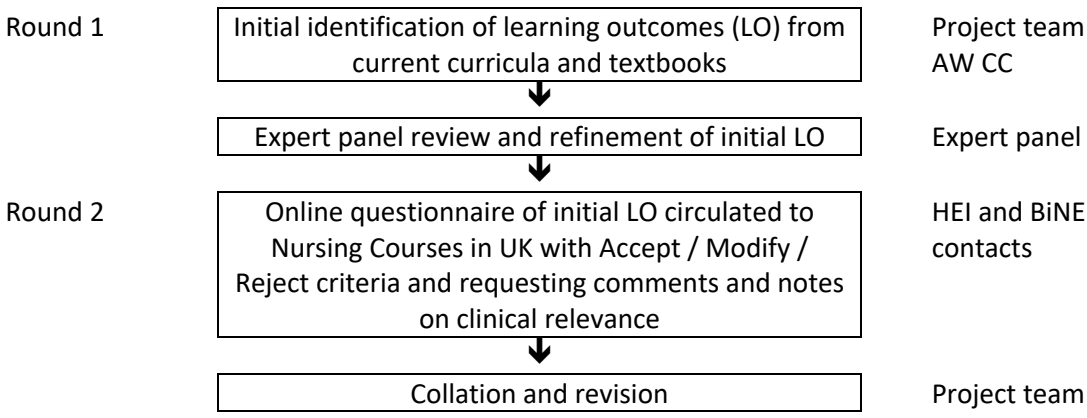
Inclusion Criteria	Exclusion Criteria
10 years or more experience teaching, organising and evaluating physiology modules for undergraduate nurses. Hold a BMedSci/Physiology degree and/or a nursing qualification with 10 years plus physiology teaching experience. (However it is acknowledged that all panellists were not exclusively providing physiology education, but were also engaged in anatomy pathophysiology, prescribing, clinical skills and other health care related topics.)	No experience in the teaching, organisation or evaluation of physiology in undergraduate nursing.

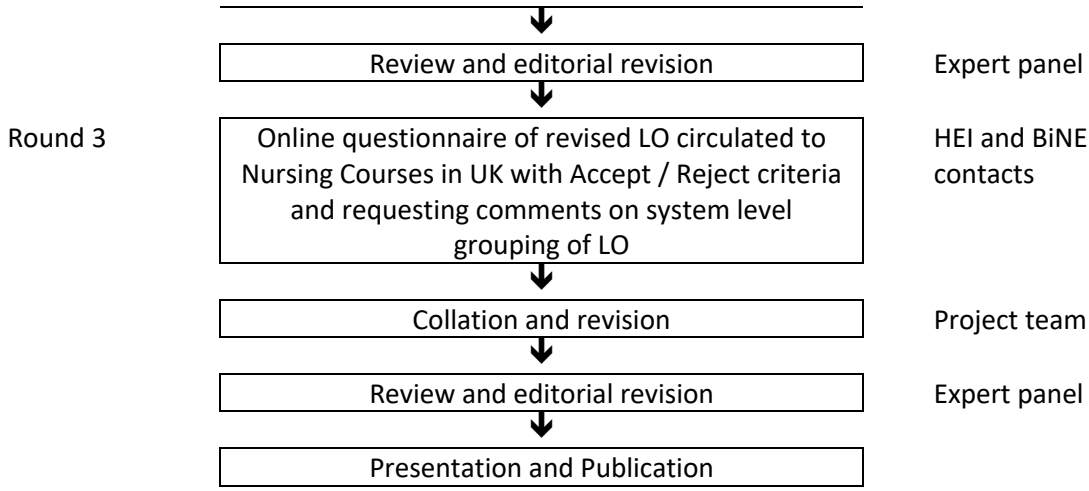
Table 3: Inclusion and exclusion criteria for the national online consensus survey

Inclusion Criteria	Exclusion Criteria
A minimum of 3 years plus teaching experience in physiology for undergraduate nurses Actively employed at a nursing school Teaches on the nursing common foundation programme and applied pathophysiology programmes at undergraduate level.	Advanced Nurse Practitioners Specialist Nurses Postgraduate programmes No physiology teaching experience Physiology teaching experience of 1-3 years Expert panellist members

The modified Delphi approach began in round 1 with initial identification and revision by the expert panel of the set of learning outcomes. Rounds 2 and 3 were online email questionnaires in line with the classical Delphi approach and expert panel review for typographical changes. The project outline is shown in Figure 1.

Figure 1 Project outline





Round 1

Within UK Nursing higher education there is no shared physiology curriculum to follow or assess, unlike other professions or subject areas. The study by (5) used an existing anatomy syllabus as the starting point from another profession. Whilst physiology learning outcomes in science and medicine exist (4), none were available specific to nursing. Here a similar topic identification approach to (23) was used in the modified Delphi approach. The project leads (AW and CC) defined the initial set of learning outcomes derived from existing curricula, textbooks and online resources[1]. This provided the starting point of the core curriculum with 360 learning outcomes focused on topic rather than the taxonomy. This focus on detailed outcomes was to avoid a 'broad brush' approach which is already covered within the BiNE framework.

Expert panel discussion reduced and modified the learning outcomes. The expert panel were recruited by invitations to the membership of the BiNE network and comprised of 8 physiologists and nurses with extensive experience (10 years plus) of teaching, organising and evaluating physiology modules in pre-registration nurse education. They discussed the initial set of 360 learning outcomes considering them from both a conceptual and systems based approach at their meeting. The initial 360 learning outcomes were refined and organised with a systems based approach as this provided a clear structure and related well to the majority of textbooks and other available resources. The learning outcomes were also revised in line with Bloom's taxonomy to ensure academic level consistent with the requirements of university graduate nurses. These refinements resulted in 195 outcomes for inclusion in the round 2 survey.

[1] List of textbooks and other sources:
Anatomy.TV by Primal Pictures online source
Barrett KE, Barman SM, Boitano S, Brooks H (2016) Ganong's Review of Medical Physiology (25th Ed). New York, N.Y.: McGraw-Hill Education LLC.
Boron WF, Boulpaep EL, (2017) Medical physiology (Third edition). Philadelphia, PA: Elsevier
Hall JE, Guyton AC (2016) Guyton and Hall textbook of medical physiology (13th Ed). Philadelphia, PA: Elsevier
Kibble J D, Halsey Colby R., (2009) Medical Physiology: The Big Picture. Lange
Michael J, Cliff W, McFarland J, Modell H, Wright A (2017) The Core Concepts of Physiology - A New Paradigm for Teaching Physiology
Scanlon VC., Sanders T (2015) Essentials of anatomy and physiology (7th Ed). Philadelphia, PA: F. A. Davis
Tortora, GJ.; Derrickson, B. (2011) Principles of Anatomy and Physiology (13th Ed) Wiley
Waugh A, Grant A (2014) Ross and Wilson Anatomy and Physiology in Health and Illness (12th Ed) – Elsevier. Churchill Livingstone

Round 2

This first online questionnaire was circulated as part of the modification phase. Participants were introduced to the survey via an email sent to all university departments in the UK who provided pre-registration nurse education identified through an online search. The BiNE network was also used for dissemination of the survey. The following questions introduced the survey '*Have you considered if pre-registration nursing students are learning enough physiology for qualification?*' and '*Would you like to share your views on what physiology nursing students should know by their graduation?*' With the invitation *'we would like to invite you to help and share your views to produce a set of learning outcomes for pre-registration nursing students related to physiology*'. The anonymised questionnaire allowed participants to state their experience and disciplinary background. The survey contained the 195 intended learning outcomes from the Delphi expert panel. Participants were asked to accept, reject, modify and/or comment on each outcome.

Round 3

The second online questionnaire was circulated to the identified HEIs and again also through the BiNE network. Participants were asked to accept or reject the 182 modified list of outcomes with comments requested on each system which could include typographical modifications or suggestions. All outcomes with 80% or more consensus were automatically included, and any with less than 80% were rejected.

Ethical approval for this study was obtained through Edinburgh Napier University and informed consent was obtained from the members of the expert panel. The project and use of the data were explained clearly on the first pages of the questionnaire alongside instructions for completing and submitting the responses. Simple demographic information was requested in the early section of the form to establish respondents met the eligibility criteria for the survey, but no specific personal data were collected. Respondents confirmed their consent to participate at the start of the questionnaire and reconfirmed it at the point of submission. The survey system used (Novi Survey) ensured that data were held securely on the University server.

Results

The progressive development and refinement process of the Learning outcomes was shown above in the methods section.

Round 1

The expert panel discussion confirmed the approach based on learning outcomes as one which would allow a definition of topic and level to be achieved at the point of registration regardless of the educational model and delivery pattern. This also raised the issue of the level of knowledge that students could be expected to have on entry to a programme, hence although some learning outcomes were seen as too basic, they were retained from the expert panel discussions to be tested in the Delphi survey rounds. The decision to follow a systems based approach for the learning outcomes was debated within the expert panel and drew more on the traditional structures of existing physiology curricula whilst equally able to support curricula based on integrated systems biology, applied, clinical or life course approaches.

Round 2

Fourteen full responses were received from the 65 UK HEI's contacted (22% response rate). With a consensus of at least 80% agreement for the proposed LOs for inclusion; 11 learning outcomes were identified for rejection; 3 were identified as duplicates, and 32 were flagged for modification. The rejected outcomes were either seen as too basic; not clinically relevant; or suitable at post registration level. One outcome was added following the comments from the questionnaire and panel review leaving 182 outcomes to be circulated in Round 3, the second online questionnaire.

The majority of learning outcomes were retained, but those rejected were judged to be either too basic or too advanced (Table 4). For example some were seen as too basic: '*Distinguish between atoms, elements, molecules, and compounds'* and '*Distinguish between ionic, covalent, and hydrogen bonds.'* and raised concern within the expert panel as without these fundamental concepts a student may lack the scientific literacy to engage with many of the other learning outcomes. These entry level threshold concepts may be an obstacle to understanding physiology for some students who lacked sufficient science background in this interdisciplinary profession. Those learning outcomes seen as too advanced could be reviewed in future work to support the career development of registered nurses. The issue of overlap between the disciplines within the biosciences was raised in some of the comments for example:

> "*I think this is a good example of the disadvantages of separating the anatomy and physiology learning outcomes as the functions of the musculoskeletal system are much better taught with the structures …. nurses not being able to identify major bones or muscle groups rings so many bells!!!".*

This shows a distinction between anatomy and physiology, also some comments suggested the exclusion of pathology. In both these areas the clear need to integrate the bioscience learning is evident and suggests that further work is needed in bringing learning outcomes from the different bioscience disciplines together.

Table 4: Rejections from the round 2 online questionnaire

Learning outcome	Rationale for rejection
Distinguish between atoms, elements, molecules, and compounds.	*lack of clinical context and relevance; Students need to be able to relate the physiological changes which occur due to illness to their findings and underpin their care with their understanding*
Distinguish between ionic, covalent, and hydrogen bonds.	*Lack of clinical context and relevance; Students need to be able to understand homeostatic balance of ions such as an understanding would underpin their management of issues such as acid-base imbalance. Evidence supports raising the profile of genetics in pre-registration nursing programmes. The structure of DNA is important to this.*
Explain the concept of physiological buffering	*I would not deem this necessary at the point of registration, although clearly this may become an integral part of specific clinical practice at some point to some nurses. Clinical Relevance: blood gases*

Describe the respiratory and renal regulation of the CO2/HCO3 buffer system, which allows the maintenance of the normal plasma pH of 7.4.	
Distinguish between CO2-derived (volatile acid) and non-volatile acid, the relative amounts produced each day through dietary intake and cellular metabolism, and the normal routes of loss from the body.	*I do not think there is a need to distinguish between volatile and non-volatile acid*
Differentiate respiratory compensation from renal compensation and describe the signs and symptoms of alterations in pH	*in my view and experience delivered in specific post- registration education*
Define VO2MAX and identify situations in which it is limited by cardiac output, pulmonary gas exchange, skeletal muscle blood flow and oxygen uptake	*Too ambitious or aspirational, only relevant to specialist roles. Clinically more relevant to cardio/respiratory physiologists not nurses, possibly post registration*
Discuss the importance of the hypothalamic pituitary axis in neuroendocrine regulation	*Unsure of the clinical relevance for point of registration*
Compare and contrast the consequences of infarction of the anterior, middle, and posterior cerebral arteries	*Possibly post registration*
Draw a flow diagram for the brain regions involved in planning, initiating, and executing skilled voluntary movements	*Not sure clinically relevant*
Describe how respiration, cardiovascular, renal, gastrointestinal, eye movement, muscle, and endocrine function change from wake to NREM and REM states	*Suggest to detailed, add to existing outcome on sleep.*

Round 3

This second circulation of the Delphi survey confirmed and refined the learning outcomes. This round received 15 full responses from the 65 UK HEIs (23% response rate), with 178 outcomes at or above the 80% consensus automatically included. However, minor typographical modifications were made to 17 outcomes following commentary and review by the project team and expert panel. The majority, 106 of these 178 outcomes reached 100% consensus from both the expert panel and the second round Delphi survey. One outcome was removed by the panel due to repetition within another agreed outcome, and 4 were automatically rejected as they fell below the 80% consensus (Table 5). This resulted in consensus on the 177 learning outcomes grouped within a systems approach (See Appendix).

Table 5: Final rejections from round 3 online questionnaire

Learning outcome	Rationale for rejection
Distinguish between local and humoral control of tissue blood flow	Not specifically related to a relevant clinical application
Describe the regulation and different stages of labour	Applicable to midwives rather than pre-registration nursing students
Outline the process, regulation and benefits of lactation.	Applicable to midwives rather than pre-registration nursing students

Describe the structure, normal stimulus, and function of the semi-circular canals and otolith organs and outline the equilibrium pathways.	Too specific, combined with a more general outcome of vestibulo-cochlear function

Discussion

The decision to present the learning outcomes in a systems based approach drew more on the traditional structures of existing physiology curricula. Whilst it may provide a logical framework for learning, it could equally support curricula based on integrated systems biology, applied, clinical or life course approaches, and may be integrated into nursing modules where the assessments may not specifically test the physiology component. For example, using an integrated approach to the body's response to exercise could draw on elements of all the systems listed and be part of a clinically relevant package of teaching around obesity or extreme weight loss. However, from an educational point of view this could be overwhelming for the student early in their learning journey but could help senior students and qualified staff to draw these topics into their practice relevance. This integration to support nursing practice is known to be valued by students (6). Considering the applied nature of some learning outcomes to clinical practice helps students see the relevance; for example, highlighting the learning outcome of bone formation to understand healing and repair for patients with fractures indicates the necessity and importance of this topic. Similarly, in phlebotomy knowledge about the clotting process explains the need on removing the needle to press on the site so that patients do not bleed and this directly applies to the development of practical skills.

It was noted that whilst these learning outcomes provide a structured list, they do not imply the structure of delivery and may be interpreted quite differently depending on the nursing programme within which they are delivered. Within the UK, they should be integrated into clinically relevant programmes supporting and meeting the requirements of the NMC standards expressed as skills and proficiencies (25). Thus, providing the physiological backdrop across the life course to support experience in specific areas of care (e.g. maternity, child, psychiatric and care of the older person) as required by the EU directives (9). The shift to competency based standards places practice at the forefront and these learning outcomes can be used to reduce variability, improve understanding and support the application of science to healthcare, where technology demands more of health workers, especially nurses.

The overall aim of the nursing curriculum must be to underpin the competent practice of the newly qualified nurse. However, bioscience is perceived to be a difficult subject within a pre-registration nursing course (7) with physiological concepts known as challenging to students and a particular cause of anxiety to them (22). Sound knowledge of anatomy and physiology can be an indicator of success in both pre-registration courses (3) and post qualification support for patient care and safety (15). These learning outcomes define the range of physiological knowledge that can support clinical decision making and ongoing learning.

Understanding key concepts of the body's functions equips practitioners in their reflective learning and ongoing development throughout their careers. Such concepts can be seen as thresholds to fuller understanding and better situational decision making in practice. Some students at the start of their nursing studies may not be equipped with the language and basic scientific concepts to engage with this area of study. This was reflected in the Round 2 rejection of some of the fundamental

learning outcomes around the structure of atoms and molecules, the nature of chemical bonds and chemical reactions. These were seen as too basic to be included, though for some students support may be needed with these fundamental threshold concepts.

In other proposed learning outcomes, the overlap with related disciplines was evident, in particular anatomy and pathology. These could represent false divisions to nursing students who are seeking to understand the integrated nature of the human body with all its changes over a lifetime, through normal development and ageing with the overlay of degenerative, infective or non-communicable diseases. These learning outcomes present a core level of physiological knowledge for all fields of practice in nursing at the point of registration, which will also provide a starting point for advanced professional practice. Combining learning outcomes from the different bioscience disciplines represents the next step in supporting nurse education by joining up the subjects to facilitate the interdisciplinary profession of nursing. A strong bioscience background is needed to support further post-graduate study and role development in relation to independent prescribing, advanced clinical examination and diagnosis, and expanding nursing roles as they develop across the world. In this context, these learning outcomes underpin safe practice and patient care congruent with licencing approaches in other countries.

Nursing is fundamentally interdisciplinary, and as such may suffer from the challenges of language and conceptual differences between the individual disciplines (24). The majority of nurse educators that the students encounter, both in academia and clinical practice will not be bioscience specialists hence learning outcomes need to be sufficiently explicit, accessible and clinically relevant to support student learning and staff engagement. In summary, these learning outcomes, constructed by a panel of experienced physiologists and nurse educators, aim to support the education of the current and future pre-registration nursing students by identifying the core foundational knowledge essential for delivery of safe patient-centred care and future nursing practice.

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Figure

Figure 1 Project outline

Appendix

Physiology Learning Outcomes- 177 learning outcomes

At the point of registration, the registered nurse will be able to:

A: Foundations of Physiology

Science of Life

1.	Define the terms acids, bases, and salts
2.	Apply the terms mixture, solution, solute, solvent, colloid, and suspension, for example in relation to blood and body fluids.
3.	Understand how the structure of carbohydrates, proteins, lipids, and nucleic acids contributes to function in cellular control, metabolism and nutrition.

4.	Explain how energy is acquired, transformed and transferred to maintain life-heat transfer, metabolic rate, redox environment, ATP and enzymes by: a. Identifying and explaining the factors that can affect the rate of chemical reactions. b. Identifying the structural features of an enzyme and their relationship to enzyme function. c. Identifying the properties of ATP and its role in energy transfer.
5.	Describe systems of control and give examples of: a. Feedback (cell to cell and to systems) b. Adaptation and compensation c. Dysregulation.

The Cell – The Fundamental Unit of Life

6.	Describe the structure and function of the components of the cell a. Plasma membrane and membrane proteins and carbohydrates in relation to excitability, active and passive transport, cell recognition and receptors. b. Nucleus and the nuclear membrane. c. Cell organelles d. Cytosol constituents.
7.	Explain how changes of tonicity of body fluids (diffusion, osmosis, active transport) can alter fluid balance and may lead to various disease states.
8.	Describe intracellular processes involved with the metabolic control of cell function and second messenger systems in health and disease.
9.	Describe the cell cycle and the factors that influence cell growth, development, ageing and death in nuclear and cell division.
10.	Engage with contemporary knowledge of the contribution of genetics and genomics to health and disease by explaining in relation to the cell cycle: a. The significance of chromosomes in heredity and genomics b. The difference between mitosis and meiosis and their purpose in the body. c. The processes of DNA replication, gene expression and protein synthesis d. Adaptation to cellular stress (e.g. hypertrophy, hyperplasia, neoplasia) e. Cell death (e.g. apoptosis, necrosis, senescence).

The Body Fluid Compartments: Extracellular and Intracellular Fluids, Homeostasis

11.	Compare the distribution and composition of fluid compartments in the body and the importance of maintaining them within tight controls (electrolyte/ionic, pH, temperature, volume).
12.	Identify the causes and types of oedema and the factors involved in its formation.

Tissues

13.	Identify the function of the basic tissue types: a. Epithelia b. Connective tissue c. Muscle d. Nerve.

Integumentary

14.	Discuss the following functions of the skin and its appendages: a. Thermoregulation b. Protection (physical, chemical, immunological, microbiological, sunlight) c. Sensation d. Synthesis of vitamin D e. Excretion f. Indicator of health and ageing g. Pigmentation and responses (sunlight, shock / pallor, emotion, psychology, culture).
15.	Discuss the response of the skin to injury and wound healing.

Musculoskeletal Physiology and Movement

16.	Identify the functions of the musculoskeletal system.
17.	Compare and contrast the properties and function of skeletal muscle with cardiac and smooth muscle and outline the mechanism of contraction and its control.
18.	Define the term motor unit and describe the function of the neuromuscular junction.
19.	Explain the processes of bone formation, remodelling and repair and describe the differences across the life course.
20.	Identify the role of joints in facilitation of movement.
21.	Discuss the changes in the musculoskeletal system a. across the life course b. through use and disuse.
22.	Explain the hormonal and nutritional factors that affect the musculoskeletal system.

B: Immunology

23.	Discuss the components of innate immunity: a. Physical defences (e.g. mucous membranes) b. Chemical (e.g. lysozymes) c. Cellular (e.g. phagocytes) d. Mechanical (e.g. vomiting) e. Microbiological (e.g. gut microbiota)
24.	Explain the role and process of inflammation and identify the chemical mediators involved.
25.	Discuss the development and significance of fever/pyrexia.
26.	Discuss the components of adaptive immunity: a. humoral responses b. cell-mediated responses.
27.	Discuss the antibody mediated response including immunoglobulin isotypes and their functions.
28.	Discuss the significance of immunological memory and acquired immunity.
29.	Explain the concept of self-recognition and tolerance.
30.	Identify the characteristics of the primary and secondary immune responses.
31.	Distinguish between active and passive immunity

32.	Discuss the role of vaccination programmes and herd immunity in public health.
33.	Explain the role of the lymphatic system in immunity.
34.	Discuss immune responses and altered health status in: a. Hypersensitivity b. Autoimmunity c. Immunosuppression.
35.	Discuss the impact of the interactions between the nervous and immune systems on health (psychoneuroimmunology), in particular how responses to stress can affect health.

Microbiome

36.	Describe the human microbiome and the interaction of microbiota with body systems in health and disease across the life course.

C: Cardiovascular Physiology

The Heart

37.	Relate the structure of the heart to its function.
38.	Describe the conducting system of the heart.
39.	Explain the events of the cardiac cycle, the pressure changes, blood flow, and the state of the valves during each stage.
40.	Relate the standard electrocardiogram to the cardiac cycle and explain the alteration in conduction responsible for common arrhythmias.
41.	Discuss cardiac output and its relationship to stroke volume and heart rate.

The Circulation

42.	Distinguish the functional differences between the different types of blood vessels with regard to their structure.
43.	Discuss tissue perfusion and its relationship to cardiac output, blood pressure, flow and peripheral resistance.
44.	Discuss the regional distribution of blood to organs and systems within the body.
45.	Explain the factors that influence exchange between the blood, lymph and interstitial fluid.
46.	Explain the importance of coronary perfusion to heart function.
47.	Discuss the importance of venous return to cardiovascular function and control.

CVS Control

48.	Discuss the neural and hormonal regulation of heart rate and contractility.
49.	Describe the baroreceptor reflex and its role in blood pressure control.
50.	Describe the renin-angiotensin-aldosterone system (RAAS) in the control of arterial blood pressure.
51.	Explain how blood flow and cardiac output changes during exercise in response to the metabolic requirements of muscle cells.
52.	Recognise the systemic compensatory mechanisms during challenged cardiovascular function (e.g. shock).
53.	Discuss the changes to cardiovascular function across the life course.

Blood

54.	List the basic functions of whole blood.
55.	Identify the cellular and non-cellular components of blood and state their functions.
56.	Outline the stages of haematopoiesis.
57.	Discuss the potential for stem cell research to improve health.
58.	Identify the characteristics of the red blood cell in relation to its function.
59.	Describe the ways in which oxygen is transported in blood, the structure of haemoglobin and the factors that influencing the binding of these.
60.	Describe the ways in which carbon dioxide is transported in blood.
61.	Describe the life cycle of the red blood cell and explain the recycling of the haemoglobin molecule.
62.	Distinguish between the ABO blood groups and the Rh factor and their significance to safe transfusion practice.
63.	Recognise and interpret blood profiles (venous and arterial) as indicators of health status.
64.	Discuss the factors that influence blood coagulation.
65.	Explain the sequence of events and factors that influence haemostasis and blood clotting.

Acid-Base Regulation

66.	Identify the normal range of pH values and describe their significance in a variety of body fluids.
67.	Describe the role of buffers in maintaining pH and specifically the role of respiratory and renal regulation in maintaining plasma pH.

D: Respiratory Physiology

68.	Describe the functions of the respiratory system.
69.	Identify the structure-function relationships at all levels of the respiratory system, from the mouth and nose to the alveoli and its components.
70.	Define and compare the three factors that affect pulmonary ventilation: a. Airway resistance b. Lung compliance c. Surface tension.
71.	Explain how gas laws relate to intrapleural and alveolar pressures and volumes during ventilation.
72.	Define and distinguish between various pulmonary volumes and capacities and how they are measured.
73.	Describe the gaseous exchange of oxygen and carbon dioxide between the alveolus, blood, and body cells.
74.	Explain the control of ventilation and the factors that influence the rate of pulmonary ventilation including: a. Chemoreceptors b. Stretch receptors c. Proprioceptors.
75.	Identify the location and state the functions of the regulatory respiratory centres.
76.	Describe the function of the muscles of ventilation and recognise signs of respiratory compensation.

77.	Relate normal and abnormal breath sounds to the quality of ventilation and the processes causing these changes.
78.	Describe the factors affecting pulmonary ventilation and outline how these may give rise to alterations in alveolar ventilation in disease states.
79.	Describe the changes during the life course and the effect of environment (air quality, altitude, diving) on respiratory function.

E: Exercise Physiology.

80.	Explain the control mechanisms responsible for increased ventilation and heart rate during exercise and how they can occur without any measurable change in arterial blood gas values.
81.	Discuss the effects of exercise training on the heart and coronary circulation.
82.	Describe the impact of exercise on the health of whole person and the individual body systems.

F: Gastrointestinal (GI) System Physiology.

83.	List and describe the functions of the gastrointestinal system and associated organs.
84.	Describe the movement of food through the digestive system (from entry to exit) and the changes that occur as food is digested and the nutrients absorbed.
85.	Identify the components and functions of gastric, hepatic, pancreatic, and duodenal secretions.
86.	Describe the cephalic, gastric and intestinal phases of digestion and explain the neural (central and enteric), endocrine and paracrine controls of: a. GIT movement b. Secretion.
87.	Explain the mechanism of control and phases of swallowing and identify situations in which it can become compromised.
88.	Distinguish between endocrine and exocrine functions of the pancreas.
89.	Describe the functions of the liver and gallbladder.
90.	Explain the role of the liver and gallbladder in carbohydrate, lipid and protein metabolism.
91.	Describe the digestion, assimilation and absorption of the major nutrients (fats, carbohydrates and proteins).
92.	Identify the sources and approximate requirements of fluid and nutrients entering and leaving the gastrointestinal tract daily for individuals at different stages of life.
93.	Describe the functions of the large intestine.
94.	Describe the sequence of events in the colon that contribute to the processes of compaction and movement of faecal matter for defecation.
95.	Differentiate between movements under voluntary and involuntary (autonomic and enteric) control throughout the small and large intestine and describe the defaecation reflex.

96.	Understand the characteristic differences in digestive function across the life course (specifically in babies and ageing individuals): a. Motility b. Absorption c. Secretion d. Sensitivity.
97.	Describe the alterations in motility that can lead to gastroparesis, achalasia, diarrhoea, constipation, megacolon and irritable bowel syndrome.

Metabolism and Nutrition

98.	Explain the importance of a healthy balanced diet for health, and in providing nutritional support across a range of clinical situations.
99.	Outline the metabolism of carbohydrates, lipids and proteins and their role in providing energy for growth, repair and reproduction.
100.	Explain how the metabolic rate of the body adapts to different metabolic demands e.g. exercise.
101.	Explain the importance of tailored diet, balance, nutrition and feeding in normal and altered health.
102.	Describe the role of the 7 components of a healthy diet (carbohydrates, proteins, fats, vitamins, minerals, fibre and water).

G: Endocrine Physiology

103.	Explain the functional difference between endocrine and exocrine glands.
104.	Explain the principle of negative feedback, positive feedback and feed forward control of hormone secretion.
105.	Identify the different chemical classes of hormones (peptide, steroid and amines) and distinguish between their mechanisms and actions.
106.	Describe the mechanisms that regulate blood glucose concentration.
107.	Describe the mechanisms that regulate blood calcium levels and its storage
108.	Describe hormonal effects on energy metabolism and growth.
109.	Explain the role of the endocrine system in stress responses.

H: Reproductive physiology

110.	Outline the role of the hormones produced by the ovaries and pituitary gland in the development and maintenance of the female reproductive function.
111.	Describe the age-related changes in the hypothalamo-pituitary-gonadal axis that lead to puberty, reproductive maturity, and reproductive senescence (menopause) in the female.
112.	Describe the ovarian and menstrual cycles and how this impacts on fertility.
113.	Describe the process of fertilisation leading to implantation of a zygote.
114.	Describe the secondary sexual characteristics of the female body.
115.	Outline the processes of gestation and parturition.
116.	Identify the key developmental changes during embryonic and foetal development.
117.	Outline the hormonal and physical changes that occur during pregnancy.
118.	Describe the male secondary sexual characteristics and the physiological functions of the major components of the male reproductive tract.
119.	In males, explain the age related hormonal changes that lead to puberty, reproductive maturity, and reproductive senescence (andropause).

I: Nervous system physiology

120.	Describe the properties of the neurone membrane that establish the resting membrane potential.
121.	Illustrate the relationship between resting membrane potential and cellular excitability.
122.	Describe the generation of an action potential in terms of the changes that occur to the membrane (including graded potential and all of none phenomenon).
123.	Describe the significance of the refractory period (absolute and relative) in nerve function.
124.	Explain the physiological significance of myelination in the nervous system.
125.	Describe the propagation of an action potential and factors which affect the speed of propagation.
126.	Explain the transmission of an action potential from one neuron to another in the synapse (chemical and electrical synapses) and their role in temporal and spatial summation.
127.	List the major groups of neurotransmitters and identify their actions and functions.
128.	Understand the relationship between sensory and motor functions in the nervous system.
129.	List the types of sensory receptors, based on location and stimulus modality.
130.	Describe the organisation of the nervous system in terms of functional significance of the central and peripheral nervous system (including autonomic and somatic components).
131.	Identify the functions of peripheral nerves (spinal nerves and the 12 cranial nerves), and relate these to their sensory and motor distributions.
132.	Differentiate between the sympathetic and parasympathetic nervous systems and explain how their structure supports their distinct functions.
133.	Discuss the neuroendocrine regulation by the hypothalamic pituitary axis as an essential regulator of homeostatic processes.
134.	Describe ways the autonomic nervous system (ANS) contributes to maintaining homeostasis.
135.	Relate the components of the brain stem to their functions.
136.	Identify the composition and function of cerebrospinal fluid.
137.	Outline the functions of the ascending and descending tracts.
138.	Describe the stretch, tendon, flexor, and extensor reflexes and their role in human health.

Special Senses

139.	Describe the function of the eye and outline the visual neural pathways
140.	Describe the function of the outer, middle, and inner ear structures (including vestibulo-cochlea) and outline the auditory and postural neural pathways.
141.	Discuss how taste and smell can influence perception and behaviour, such as appetite and disgust.

The Cerebellum and Basal Ganglia in Motor Control

142.	Outline the role of the cerebellum in the regulation of skilled movement and in motor learning.

143. Explain the neurological disturbances that can result from disease or damage in different regions of the cerebellum.
144. Outline the role of the basal ganglia in the initiation and control of movement and their links with the cerebellum and cerebral cortex.
145. Recognise the common physical signs associated with neurological disease; a. rigidity b. dyskinesia c. akinesia d. tremor e. spasticity

Cerebral Cortex

146. Discuss the vulnerability of brain tissue to different types of injury: a. Trauma b. Hypoxia c. Degenerative change d. Inflammation e. Demyelination f. Biochemical and Nutritional neurotoxins.
147. Understand the significance of neurological observation to determine brain function.
148. Describe the major areas of the cerebral cortex, their roles and connections for: a. Perception b. Movement control c. Vision d. Hearing e. Somatosensory f. Speech g. Emotion h. Executive function.
149. Describe the different types of memory and outline the ways in which they are formed and retained.
150. Describe the characteristics of common types of dementia.
151. Describe the consequences of damage to the corticospinal tract (CST) and contrast the effects of CST (pyramidal / upper motor neurone) lesions to lesions of the motor cortex.
152. Describe the cortical areas important for language and their functional interconnections.
153. Describe how ageing affects the brain and how emerging research might help to limit cognitive decline and promote cognitive function.

The Limbic System

154. Describe the main functions of the limbic system and relate how it works with other areas of the cerebral cortex to produce cognitive emotional behaviours.
155. Discuss how emotion and the reward systems interact with the limbic system and the ANS to influence homeostasis, with emphasis on addiction.

Sleep

156. Define sleep and discuss the importance of sleep to health.

Temperature

157.	Define the thermoregulatory set point and the negative feedback control of body core temperature, including the role of the hypothalamic set point.
158.	Contrast the stability of body core with that of skin temperature. Include the control and mechanisms of cutaneous blood flow and sweating on skin temperature.
159.	Discuss the thermoregulatory mechanisms which maintain a stable core temperature with changes in environmental conditions, exercise and infection.

J: Renal Physiology

160.	Outline the functions of the structures of the urinary system.
161.	Identify the structure of the kidneys in relation to function.
162.	Describe the relationship of a nephron and its surrounding structure to its three basic functions: glomerular filtration, tubular reabsorption (passive and selective) and tubular secretion.
163.	Explain glomerular filtration, how it is regulated and identify factors which influence glomerular filtration rate (GFR) e.g. pressure, charge, size.
164.	Contrast the contents of the filtrate with whole blood e.g. H_2O, Na^+, inulin, albumin, and red blood cells.
165.	Discuss how renal blood flow, renal plasma flow, glomerular filtration rate, and filtration fraction affect renal function.
166.	Explain the creatinine/inulin clearance principle to estimate the glomerular filtration rate, renal plasma flow, and renal blood flow and demonstrate its significance in assessing renal function.
167.	Describe the roles of the different areas of the nephron in water and electrolyte reabsorption, including the glucose threshold.
168.	Describe the roles of the different areas in the nephron in tubular secretion.
169.	Describe the role of the key hormones associated with the kidney, indicating their major stimuli, site of action, and effects. a. Renin and Angiotensin II b. Aldosterone c. Anti-diuretic hormone d. Atrial natriuretic peptide e. Parathyroid hormone f. Erythropoietin.
170.	Describe the mechanism and significance of the kidney's ability to produce either a dilute or a concentrated urine.
171.	Explain the role of the kidneys in the immediate and long-term control of arterial blood pressure.
172.	Contrast the male and female urinary systems.
173.	Explain the micturition reflex.
174.	Explain the impact of changes that occur over the life course on the urinary system.

Fluid balance

175.	Describe the significance of water to physiological processes in the body and identify its distribution in the fluid compartments of the body.
176.	Explain the regulation of water balance through intake, metabolism and excretion.
177.	Discuss the potential causes and effects of water imbalance.

Acknowledgments

This research was funded by the Physiological Society and supported by the Bioscience in Nursing Education (BiNE) group. AW and CC particularly thank the colleagues and panel members for their time and contribution to the work.