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Running title: Reaching Australia-wide consensus on the Core Concepts of Physiology

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ABSTRACT

A set of core concepts ('big ideas') integral to the discipline of Physiology are important for students to understand and demonstrate their capacity to apply. We found poor alignment of learning outcomes in programs with physiology majors (or equivalent) from seventeen Australian universities and the fifteen core concepts developed by a team in the USA. The objective of this project was to reach Australia-wide consensus on a set of core concepts for physiology, which can be embedded in curricula across Australian universities.

A four-phase Delphi method was employed, starting with the assembling of a Task force from Physiology educators with extensive teaching and curriculum development expertise, from twenty-five Australian universities. Following two online meetings and a survey, the Task force reached agreement on seven core concepts of physiology and their descriptors, which were then sent out to the physiology educator community across Australia for agreement. The seven core concepts and their associated descriptions were endorsed through this process (n=151). In addition, embedding the core concepts across the curriculum was supported by both Task force members (85.7%) and educators (82.1%).

The seven adopted core concepts of Human Physiology were: *Cell Membrane, Cell-cell Communication, Movement of Substances, Structure and Function, Homeostasis, Integration* and *Physiological Adaptation*. The core concepts were subsequently unpacked into themes and sub-themes. If adopted, these core concepts will result in consistency across curricula in undergraduate Physiology programs and allow for future benchmarking.

New & Noteworthy: This is the first time Australia-wide agreement has been reached on the core concepts of physiology using the Delphi method. Embedding of the core concepts will result in consistency in physiology curricula, improvements to teaching and learning, and benchmarking across Australian universities.

Key Words: Core concepts, Physiology, Delphi method, curriculum, undergraduate education

INTRODUCTION

Over the past decade or so, there has been an increased awareness, and focus, on the need to teach and assess the core concepts in science, technology, engineering and mathematics (STEM) disciplines in higher education [1-3]. Although there are numerous ways in which to define a core concept, one accepted approach is to refer to a core concept as a 'big idea' that is central to a discipline [4]. A focus on teaching core concepts is beneficial as they provide a framework for teaching and learning, are applicable to many areas of a discipline, and can consolidate the content that students need to learn to have proficient knowledge in that discipline [4]. Indeed, core concepts have been developed and adopted in a variety of STEM disciplines including anatomy [5], biochemistry and molecular biology [6], pharmacology [7, 8] and physiology [9]. A set of fifteen core concepts in physiology were originally developed by a team in the USA [9] but were not meant to be the "final word" on the core concepts [10], with leading scholars anticipating that the core concepts, their conceptual frameworks, and conceptual assessments would be modified by the physiology educators who use them [10, 11].

A team of eight physiology educators from Australia conducted a preliminary study to determine the degree to which the set of core concepts of physiology derived by the leading USA team were aligned to Australian university curricula [12]. Both educator mapping and software analysis showed a general lack of alignment between the fifteen core concepts and the learning outcomes (LOs) for units (subjects) within physiology majors (normally 6-8 units/subjects) across undergraduate degree programs in 17 Australian universities. It also highlighted wide variability between academics' mapping of LOs to the same core concept, suggesting wide interpretation of the core concept titles and descriptors, and a lack of consistency between physiology majors, making benchmarking difficult. Thus, this analysis established that an agreed set of core concepts for physiology was needed across Australia.

There are established research approaches specifically for consensus development, with consensus techniques falling under the wide classification of action research approaches [13]. Consensus is regarded as a viewpoint that is acceptable to more than a simple majority of a group or individuals with influence [13]. The Delphi is a consensus method that establishes an opinion consensus amongst a group of experts. It requires anonymity of member opinions, iteration with controlled feedback, and a statistical group response [13-16]. The Delphi method is useful as it promotes achievement of consensus in situations where evidence is lacking or conflicting [13, 15, 16]. It is also a beneficial alternative to substitute committees, which may have the intrinsic disadvantages of dictatorial personalities, outspoken minorities, and unequal power relations [15, 16].

There has been widespread use of the Delphi method for exploring policy issues, and for supporting decision making by business consortiums and government agencies [14]. The Delphi method has also been popular for making decisions related to health care [14], for example, to establish an operational definition of sarcopenia for use by clinicians in Australia and New Zealand [17]. Interestingly, the Delphi method has also been used as an approach for achieving consensus on curriculum requirements, and has been used extensively in nursing education [18], medicine [19, 20], pharmacy [21] and STEM [22]. Redman et. al [19] used the Delphi method to reach consensus on the core competencies of the practice of colposcopy, such that they could be used in a curriculum for national training programs across Europe. Similarly, Philips et. al. [20] used the Delphi method to identify and prioritize the key concepts on issues relating to women's health in order to develop a curriculum for medical students and resident physicians. Eriksson et. al. [21] used a modified Delphi method to identify core competencies for new pharmacy graduates and these formed the basis for the design of a new pharmacy degree. Likewise, Smith et. al. [22] used a modified Delphi method to seek consensus when revising the UK and Ireland's core syllabus for regional anatomy in undergraduate medicine.

The Delphi method is ideal for reaching consensus on the core concepts in a variety of STEM disciplines, including physiology. The aim of this project was to reach Australia-wide consensus among physiology educators on a set of core concepts for human physiology using the Delphi method.

METHOD

A four-phase modified Delphi method was used to achieve consensus amongst Task force members and physiology educators across Australia on the core concepts of physiology (Figure 1). The project was approved by the Victoria University Human Research Ethics Committee (HRE20-164).

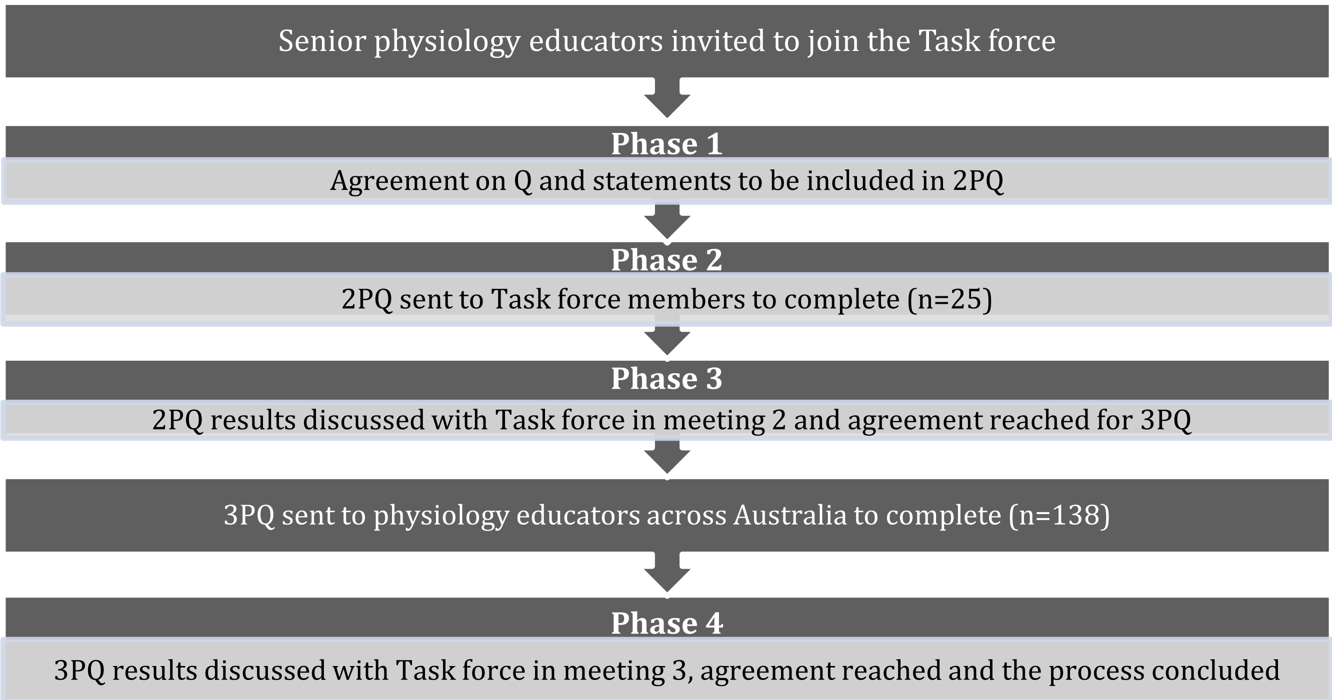

Figure 1: Schematic diagram of the 4-phase modified Delphi method. 2PQ – Second phase questionnaire; 3PQ – Third phase questionnaire; n=number of questionnaire respondents.

Selection of Task force

A senior physiology educator at each Australian university with a physiology major (or equivalent) within an undergraduate degree was identified by the project lead (KT) and emailed an invitation to join a Task force to reach consensus on the core concepts of physiology in the Australian Higher Education context, along with Information to Participants and a Participant Consent form. Return of the signed Consent form was taken as acceptance to join.

Phase 1

Twenty-five Task force members were present at the first online video conference (Zoom) meeting at which the project leads (KT & AH) delivered a presentation outlining the background and aims of the project and the agenda for the meeting. Task force members were then shown pre-prepared questions and statements and asked to vote on their inclusion in a Second Phase Questionnaire (2PQ) using the Zoom polling function. Comments or suggested changes to questions and statements were made verbally or using the Zoom chat function before voting. Consistent with previous investigations using the Delphi method [17] consensus was pre-set at greater than 80%, that is, greater than 80% of respondents either 'Agreed' or 'Strongly Agreed' with the statement. Items obtaining at least 75% were slated for further discussion.

Phase 2

The 2PQ (https://figshare.com/s/2e3058a7f2dd910f5b0b) was sent to all Task force members to complete. A total of twenty-four questions were included in the 2PQ, which included eighteen demographics questions, three questions focusing on the need for a list of Australian-derived core concepts, three key questions asking Task force members to rate their level of agreement on a 7-point Likert scale (Strongly Agree – Strongly Disagree) about the fifteen core concepts of physiology and their descriptors taken from Michael et al. (2011) and two open ended questions.

Phase 3

The results and comments from the 2PQ were analyzed and reported to the Task force in a second online video conference (Zoom) meeting. Items reaching >80% agreement were adopted. Comments raised in the open ended-questions in 2PQ were thematically analyzed for common words/phrases, and these informed the wording for consideration by Task force members for potential inclusion in 3PQ. More specific comments about what should be included within a core concept were passed on to team members tasked with unpacking each core concept (a process separate to the Delphi method that occurred after its conclusion). Any potentially missing core concepts, or any other comments or suggestions made verbally or using the chat function, were discussed, and if required, modifications or new questions put forward. Following discussion and amendments, the Task force members voted anonymously on the questions to be included in the Third Phase Questionnaire (3PQ) using the poll function on zoom. The 3PQ (https://figshare.com/s/b9d517573740e2fb6dac) had a total of thirty questions: nineteen demographic, three on the need for a list of Australian-derived core concepts, one key question asking respondents to rate their level of agreement, on a 7-point Likert scale (Strongly Agree – Strongly Disagree) about the seven core concepts of physiology agreed on by the Task force, two open-ended questions on missing core concepts or alternative wording, and five questions on embedding and assessing the core concepts across the curriculum.

Phase 4

The 3PQ was distributed to members of The Australian Physiological Society, the Task force and by Task force members to physiology educators within their universities. The 3PQ was open for three weeks, after which the results were analyzed and presented to the Task force in a third and final online video conferencing (Zoom) meeting. Findings and survey comments were discussed, and final amendments made to the descriptors before Task force members voted anonymously using the online polling tool for the final time before the process was concluded.

RESULTS

Task force Demographic

A total of twenty-five Task force members from twenty-five separate Australian universities across all six States and one of two Territories (Australian Capital Territory) in Australia participated in the 2PQ. Australia has thirty-eight public and four private universities. The core business of Australian universities is a mix of teaching and research, with some including both higher education and vocational education training. Over 90% of Task force members identified themselves as physiologists, with all currently teaching, across a range of degree programs (typically 3-4 years for undergraduate degrees and 1-2 years for postgraduate), and the full range of year levels (1-3) and teaching modes (lectures, workshops, tutorials). All Task force members had been involved in curriculum development. The demographic details of participating Task force members are illustrated in Table 1.

Table 1: Demographics of Task force Members (n=25)

Demographic	**N (% of 25) or Data mean ± SD**
Identify as a Physiologist	24 (92%)
Teach Physiology	25 (100%)
Teaching Experience (years)	16.8 ± 7.1
Role in curriculum development	25 (100%)
Institutions Taught at (number)	2.4 ± 1
Teaching Workload (% of total)	53.3 ± 21.7% (range 10% - 100%)

Phase 2

The initial questions of i) whether core concepts in physiology should be taught, and ii) whether there should be Australian-derived core concepts, were both accepted at a level of agreement greater than 80% (both items had 92% agreement). The fifteen core concepts were initially listed by name only, and then with description provided. This was important because 92% of the Task force agreed to the statement ‘Do you believe the title of each core concept should be self-explanatory?’

Task force member views of the core concepts are shown in Table 2. Only five of the core concepts listed obtained greater than 80% agreement and were automatically adopted: *Cell-Cell Communication* (92%), *Cell membrane* (85%), *Flow down gradients* (85%), *Homeostasis* (100%) *and Structure/Function* (100%). In cases where agreement was initially below 60%, including the description increased the level of agreement, but they were still well below the 80% agreement required, and were thus not adopted. Most commonly, items were not adopted as they were not thought to be specific to physiology, but instead belonged to other disciplines, such as *Physics/Chemistry* (an obvious one), *Cell Theory* and *Genes to Proteins* (molecular biology) and *Evolution* (biology). Indeed, for most items with between 60 and 80% agreement (except for *Interdependence*) including the description lowered the level of agreement, confirming the content was not physiology discipline specific. As such, none of these were adopted. *Scientific reasoning* (which was greater than 75% agreement), and *Interdependence* (which increased from 61.5% to 79.2% agreement with the description) were identified for Task force discussion prior to the 3PQ finalization.

Table 2: Task force level (%) of Agreement with the initial set of fifteen core concepts

	List	Description
Causality	69.2	60.0
Cell-Cell Communication	**92.3**	**92.0**
Cell Membrane	**84.6**	**96.0**
Cell Theory	73.1	72.0
Energy	65.4	64.0
Evolution	23.1	40.0
Flow down Gradients	**84.6**	**88.0**
Genes to proteins	50.0	60.0

Homeostasis	**100.0**	**96.0**
Interdependence	61.5	79.2
Levels of Organization	73.1	68.0
Mass Balance	30.8	36.0
Physics/Chemistry	34.6	48.0
Scientific Reasoning	76.9	76.0
Structure/Function	**100.0**	**100.0**

Data is percentage of Task force that Strongly Agree or Agree
***Bold text**: adopted as >80% agreement*

Phase 3

The Task force met in a second meeting to endorse the five adopted core concepts and associated descriptions, and to discuss those concepts reaching greater than 75% agreement and aspects raised in the open-ended comments, as to whether core concepts were missing or any other suggestions. Prior to the meeting, each adopted core concept was presented, and requests for alternative wording requested. The core concepts with alternatives were presented at the meeting, where the final core concept and wording was agreed upon (achieved using online anonymous polling, again requiring 80% agreement). Four of the five original core concepts that reached 80% were adopted 'as is', with agreement to change *Flow Down Gradients* to *Movement of Substances*. *Scientific Reasoning* was discussed as it reached >75% agreement in 2PQ. While it was widely agreed that the concept was important, it was felt to be a core scientific skill across any science discipline, and not specific to physiology. As such, *Scientific Reasoning* as a core concept did not reach agreement for inclusion in 3PQ. *Interdependence* was discussed due to obtaining only 61.5% by word alone, which increased to the almost required 80% (79.2%) when the description was added. Taskforce members agreed that a concept with the descriptor '*Cells, tissues, organs, and organ systems interact with one another (are dependent on the function of one another) to sustain life*' was worthy of being included. As such, this was specifically discussed with the wording of the concept being the issue. This resulted in an alternative title of *Integration* suggested and agreed upon, which ended up having a very similar description (see Table 3) as the original description listed above and as described by Michael and McFarland [9]. Finally, any missing core concepts that were suggested in the open-ended questions were discussed. Several suggestions relating to disease processes were made, including *disturbance of homeostasis leads to disease/damage/disorder; disease processes or aspects of immunology* and *physiological basis for disease processes*. Discussion went beyond disease, considering how the body changes throughout the lifespan, and how the body adapts to external stimuli. These related to two other comments relating to: *Sensory perception: Perceiving and responding to changes in the internal and external environments;* and *physiological adaptation to the environment (e.g. living at altitude or in hot environments).* Ensuing discussion centered around the ability to change in response to the internal and external environment in the short term, which relates to homeostasis, but also in the longer term in response to growth, development and aging, and things such as exercise, nutrition, extreme environments and disease. Based on further comments and discussion of this idea, a final core concept named *Physiological Adaptation* was suggested and agreed upon.

The final seven core concepts agreed to by the Task force are shown in Table 3 and were included in 3PQ, which was sent to the Task force members. Fourteen out of the twenty-five Task force members responded to the survey, with full agreement for all core concepts to be adopted (see Figure 2).

The 3PQ was also sent to the wider physiology educator community across Australia predominantly through the Australian Physiological Society and Task force distribution.

Table 3: Adopted Core Concepts and their descriptors

Core Concept	Description
CELL-CELL COMMUNICATION	The function of the organism requires that cells pass information to one another to coordinate their activities

CELL MEMBRANE	Cell membranes determine what substances enter or leave the cell and its organelles. They are essential for cell signaling, transport and other cellular functions
MOVEMENT OF SUBSTANCES	The movement of substances (ions, molecules, fluids, and gases) is a central process at all levels of organization in the organism
HOMEOSTASIS	The internal environment of the organism is actively regulated by the responses of cells, tissues and organs through feedback systems
STRUCTURE AND FUNCTION	Structure and function are intrinsically related at all levels of the organism
INTEGRATION	Cells, tissues, organs, and organ systems interact to create and sustain life
PHYSIOLOGICAL ADAPTATION	Organisms adjust and adapt to acute and chronic changes in the internal and external environments across the lifespan

Phase 4

One hundred and thirty-seven educators completed the Phase 3 survey, with 91% of respondents agreeing that core concepts should be taught. Table 4 provides details for educator demographics, with 76% considering themselves physiologists (the remaining identified with Biomedical Sciences disciplines), 93% teaching physiology and 71% involved in curriculum design. There was a good range of years spent teaching, higher education institutions represented and the proportion of their workload teaching (average 55%), providing confidence that those surveyed are representative of physiology educators across Australia. While the need for Australian core concepts did not reach consensus amongst the educators, reaching only moderate agreement (75%), many respondents were ambivalent (20% neither agreeing nor disagreeing), meaning that less than 5% disagreed with the statement.

All 7 core concepts were adopted, reaching greater than 80% agreement (see Figure 3) with less than 3% disagreeing across all concepts. The level of agreement was *Cell-Cell Communication* (92%), *Cell Membrane* (92%), *Movement of Substances* (93%), *Structure and Function* (92%), *Homeostasis* (92%), *Integration* (90%) and *Physiological Adaptation* (86%). Any missing core concepts that were suggested in the open-ended questions were considered and discussed by the Task force in a third meeting. Comments included the inclusion/consideration of pathophysiology, reproduction and changes over the lifespan, changes in health with exercise, obesity and starvation, and disease-related changes, all of which the Task force discussed and considered to be part of *Physiological Adaptation*. As such, the 7 core concepts were adopted. All suggestions for wording changes were passed on to the Task force subgroups to consider when unpacking the core concepts.

Embedding the core concepts across the curriculum was supported by both Task force members and educators (86% and 82% agreement, respectively), with *standardization and benchmarking across universities*, and *consistent approach to the design and delivery of physiology curricula,* the most commonly chosen reasons for doing so. However, there was not strong agreement to specifically assess all the core concepts summatively, reaching only moderate agreement amongst educators (73%) and even less amongst the task force (69%).

Table 4: Demographics of Educators

Demographic	**Category**	**N**
Physiologist	No	30
	Yes	94
Teach Physiology	No	9
	Yes	112
Teaching Experience (Years)	<5	15
	5-10	36
	11-15	25
	16-20	16
	21-25	11
	>25	18
Location of Current Institution	ACT (1)	3
	NSW (4)	14
	Qld (7)	21
	SA (3)	16
	Tas (1)	3
	Vic (8)	46
	WA (4)	17
Number of Institutions taught at (over career)	1	39
	2	49
	3	26
	4	4
	5	2

	>5	2
% time spent teaching (of workload)	10%	9
	20%	5
	30%	8
	40%	24
	50%	13
	60%	17
	70%	11
	80%	11
	90%	5
	100%	12
Involved in curriculum design	No	35
	Yes	86

Number in brackets after each state indicates how many different universities were represented in the survey (total number = 28)

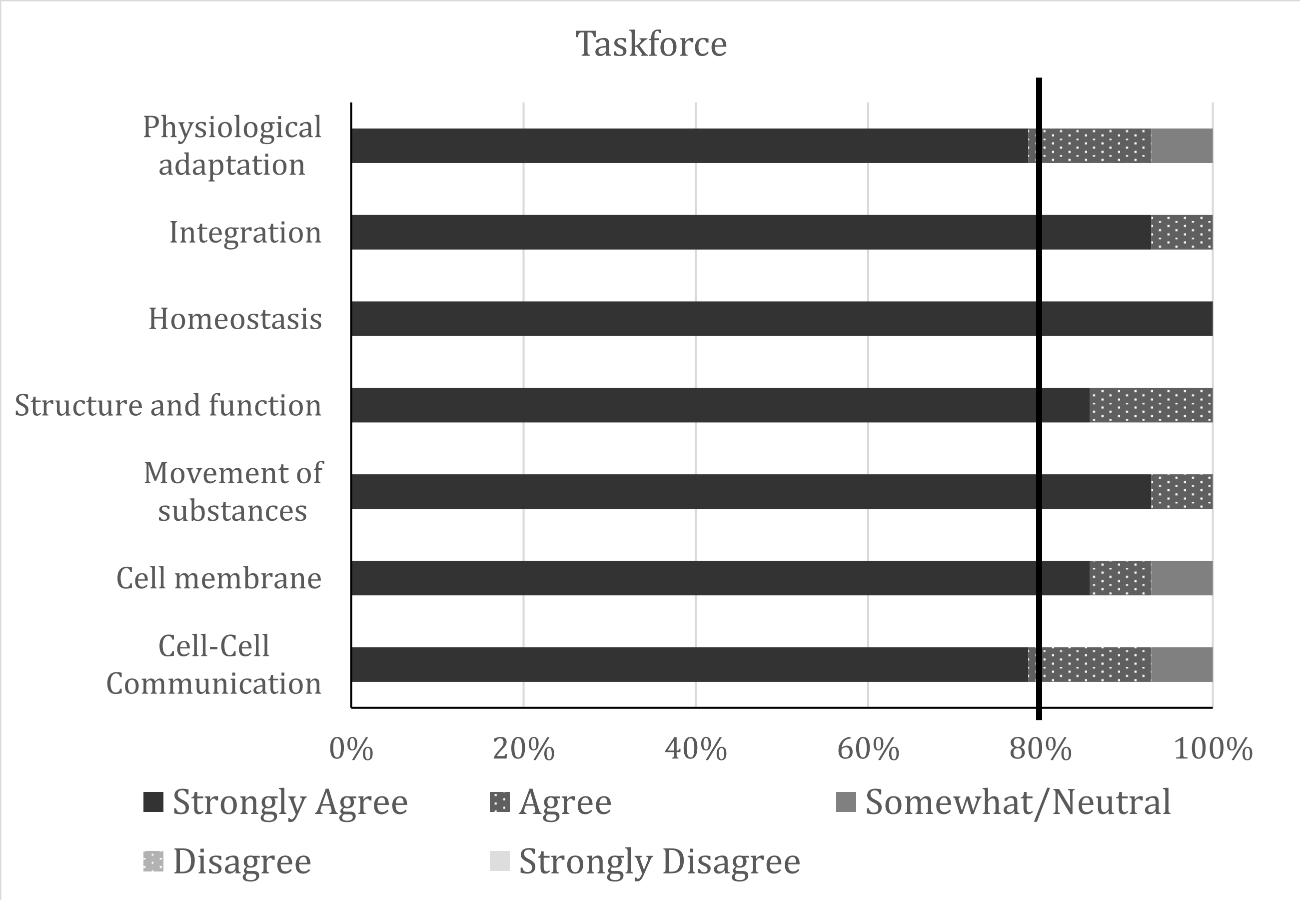

Figure 2: Task force level of agreement (%) with the seven core concepts developed by the Task force using the Delphi method (n-=14).

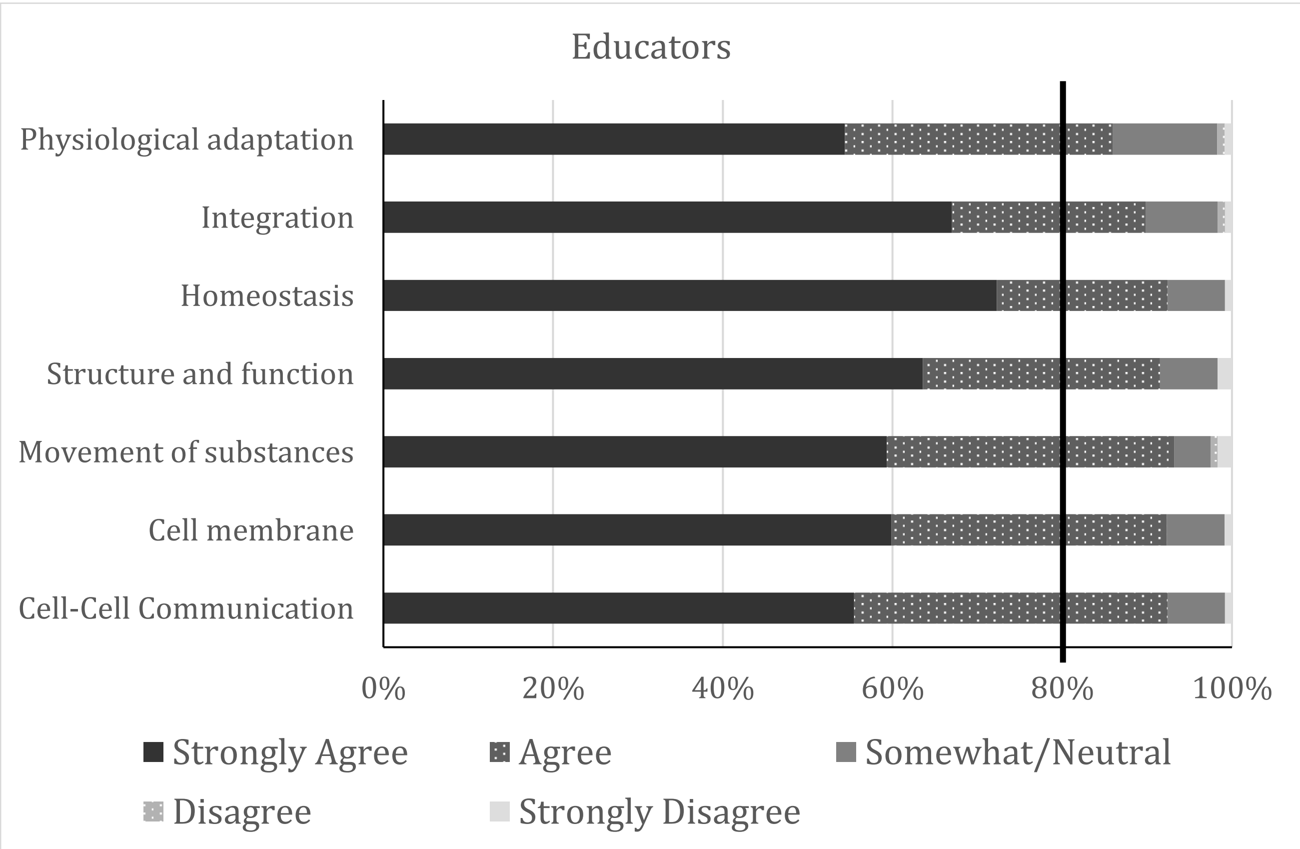

Figure 3: Educator level of agreement with the seven core concepts developed by the Task force using the Delphi method (n=137).

DISCUSSION

Adopting a set of core concepts ('big ideas') integral to a discipline can align teaching, aid in curriculum design, and focus assessment as well as student learning. This study identified and agreed by consensus, on seven core concepts and their descriptors for the discipline of Human Physiology in Australia: *Cell Membrane, Cell-cell Communication, Movement of Substances, Structure and Function, Homeostasis, Integration* and *Physiological Adaptation*.

In a previous mapping study, we showed that the fifteen core concepts developed by a USA-led team mapped poorly to LOs from units (subjects) focused on physiology in seventeen undergraduate degrees in Australian universities [9]. We speculated that this could be due to the diversity in the Higher Education system in Australia and took on the advice of leading scholars to adapt the key core concepts they had derived to our context [10,11]. Using a four-phase Delphi protocol, a Task force comprising physiology educators from twenty-five Australian universities with extensive experience in teaching and curriculum development agreed on a set of seven core concepts and their descriptors specific to the discipline of Human Physiology. Notably, all but one (*Physiological Adaptation*), were adapted from the original core concepts developed by the team led by Michael and McFarland [9]. The core concepts were endorsed by educators, with varying teaching and curriculum experience, from twenty-eight universities across all Australian states and the Australian Capital Territory. Although we did not have representation from the only university in the Northern Territory, we were confident that there was wide representation of physiology expertise in the Task force members and the broader Australian educator community. Reaching national consensus by the team of Australian physiology educators involved in curriculum development could potentially result in improved integration of the agreed set of core concepts and a consistent approach to the design and delivery of physiology curricula across undergraduate courses in Australian universities. In the future this would allow for standardization and benchmarking, and provide a consistent knowledge base of graduates, making it easier to move into post-graduate courses across universities. In addition, it would also provide a guide for designing LOs, assessments and teaching practices and allow for internal auditing of existing curricula.

The core concepts in Physiology adopted were originally based on the fifteen core concepts proposed by our USA colleagues [9], which were used as the initial list of concepts for the Task force to review. Given the poor mapping of physiology subject LOs to these core concepts [12], the Task force adopted only four of the original core concepts: *Cell Membrane, Cell-cell Communication, Homeostasis,* and *Structure and Function*; with two more adopted with name changes: *Movement of Substances (flow down gradients)* and *Integration (interdependence)*. In what may reflect the difference in the degree program structure in Australia, the other initially listed core concepts were considered important, but more associated with other disciplines. For example, (cell) biology (*cell theory, evolution, genes to proteins, levels of organization*) and (bio)chemistry (*mass balance, physics/chemistry, energy*) are taught separately and considered different disciplines in Australia. Finally, along with *Integration* as a core concept to bring the other core concepts together, the (patho)physiological responses to acute and chronic stimuli and across the lifespan were captured in the core concept *Physiological Adaptation*. The adoption of the seven core concepts provides a framework for curriculum design, teaching and assessment, producing commonality in physiological graduate knowledge. The inclusive nature of the Delphi method across almost all Australian States and Territories, with more than half of all universities represented; confirmation for adoption by a wide range of physiological educators; and support from the Australian Physiological Society; provides confidence in their likely adoption and use Australia-wide.

Another important outcome from this exercise is the development of new teams of educators in a community of practice. The national community of practice of physiology educators have in teams unpacked each of the core concepts into themes and sub-themes and then validated the unpacked core concepts as a group. The unpacked core concepts are not finite but can provide a guide for educators to scaffold the learning and plan teaching activities. In the next phase, with the support of an assessment expert, the Task force members will collaboratively work together to produce concept inventories – higher-order assessments which assess student achievement of the core concepts at various degree levels [23]. Concept inventories have been developed in many science disciplines [23]. Additionally, the core concepts will be included in an Assessment Framework which allows mapping of summative assessments such as examinations, against a set of constructs to provide a holistic overview of the assessment and information on whether it is achieving what was intended. Our intent is that these resources will be shared with the international physiology community and contribute to broader collaborations as we all strive to improve student learning through improved curricula, assessments, and teaching.

The limitation in our study is that it was conducted in Australia, with primarily Australian academics and educators. As such, the survey only encompasses a small proportion of Physiology educators worldwide. Despite this, the strong agreement with the Australian derived core concepts among the survey respondents suggests that academics and educators in the field of physiology education, irrespective of the degree within which they teach, and their years of teaching, all strongly support the concepts proposed in this study.

In conclusion, this systematic study using a four-phase Delphi method provided a consensus for a set of seven core concepts in physiology in the Australian context: *Cell Membrane, Cell-cell Communication, Movement of Substances, Structure and Function, Homeostasis, Integration* and *Physiological Adaptation*. Critical to this work is unpacking of the concepts for educators, as well as the continued development of the community of practice to enable learning resources and approaches to teaching to be shared in the wider academic community.

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