Supplemental Material

CBE-Life Sciences Education

Chen *et al.*

Nationwide survey
Survey distributed to neuroscience educators through professional societies, word-of-mouth and social media.

Note: primer used to explain what qualifies as a core concept is italicized in this printing of the survey.

Core concepts are overarching principles found across the subdisciplines of a field. While physics, microbiology and physiology have surveyed faculty and developed a consensus list of core concepts for their respective fields, neuroscience has not. This survey solicits your help in developing a list of core concepts for the neuroscience field and should take approximately 10-15 minutes to complete.

1. Please choose your role(s) related to neuroscience education (Select all that apply.) (Undergraduate Neuroscience Program Director (Major or minor), Graduate Neuroscience Program Director, Undergraduate neuroscience curriculum development, Graduate neuroscience curriculum development, Faculty teaching undergraduate neuroscience coursework, Faculty teaching graduate neuroscience coursework, Staff teaching neuroscience coursework, Pre-faculty teaching neuroscience coursework (e.g. postdoc), Research position)

2. What is your area of expertise in neuroscience?

3. At what institution do you currently work?

4. What type of institution is it? (For definitions according to Carnegie classifications, see http://carnegieclassifications.iu.edu/lookup/standard.php#standard_basic2005_list) (Doctoral or professional university, Master's college or university, Baccalaureate college, Associate's college, Tribal college, Other (Please specify.))

From Niemi and Phelan (2008), ***core concepts*** *are "organized around central concepts or principles, or 'big ideas.' The nature of these concepts differs from domain to domain, but in general they are* ***abstract principles that can be used to organize*** *broad areas of knowledge and make inferences in the domain, as well as determining strategies for solving a wide range of problems."*

According to Wiggins and McTighe (2005), core concepts are "transferable beyond the scope of a particular unit" and "they can be thought of as the ***meaningful patterns*** *that enable one to connect the dots of otherwise fragmented knowledge."*

Core concepts may be more clearly understood through example, in addition to the definitions above. A well-known list of core concepts for biological literacy was published by AAAS in 2011. During discussions supported by HHMI, NIH, NSF and AAAS, faculty and stakeholders agreed on five core concepts for general biology:

1. The diversity of life evolved over time by processes of mutation, selection, and genetic change.
2. Basic units of structure define the function of all living things.
3. The growth and behavior of organisms are activated through the expression of genetic

information in context. All students should understand that all levels of biological organization depend on specific interactions and information transfer. Information exchange forms the basis of cell recognition and differentiation, the organization of communities from microbial assemblages to tropical forests, and the mating behavior of animals.
4. Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics.
5. Living systems are interconnected and interacting.

For further unpacking of these core concepts, visit http://visionandchange.org/finalreport

Core concepts differ from fundamental facts, topical subdisciplines, and core competencies.

***- Fundamental facts** state basic information that is introduced to novices. For example, the statement "genetic information is coded as DNA" is a fundamental fact. Unlike core concepts, these basic facts do not explain phenomenon in multiple contexts.*

***- Topical subdisciplines** are a list of topics. For example, "linear acceleration," "relativity," and "magnetism" are subtopics in physics. Topical subdisciplines simply divide the field into small pieces but do not identify the organizing principles in the field.*

***- Core competencies** are skills which prepare students to be effective practitioners in the field. For example, "the ability to use quantitative reasoning" is a core competency in biology. Core competencies addresses skills rather than curricular content.*

5. Considering the examples and non-examples on the previous screens, please identify one (1) core concept for the neuroscience field. Recall that core concepts differ from fundamental facts, topical subdisciplines, and core competencies. Please also explain why you are suggesting this as a core concept.

6. Would you like to suggest another core concept? (Yes, No)

7. How many additional core concepts would you like to suggest?

8. Please identify your additional core concept for the neuroscience field. Please also explain why you are suggesting this as a core concept.

9. We are interested in broadening the scope of survey participants. If you would like to refer us to a colleague who may be interested, please provide us with their name and contact information.

Thank you for taking the time to help establish the core concepts for neuroscience. If you would like to be informed of the progress on this project, please leave us your name and e-mail address in this separate link.

Pre-working session survey
Asynchronous assessment of proposed core concepts sent to working session registrants the week preceding the working session.

Core concepts are overarching principles found across the subdisciplines of a field. While physics, microbiology and physiology have surveyed faculty and developed a consensus list of core concepts for their respective fields, neuroscience has not. This questionnaire solicits your feedback on a preliminary list of core concepts for the neuroscience field and should take approximately 30 minutes to complete.

1. Please choose your role(s) related to neuroscience education (Select all that apply.) (Undergraduate Neuroscience Program Director (Major or minor), Graduate Neuroscience Program Director, Undergraduate neuroscience curriculum development, Graduate neuroscience curriculum development, Faculty teaching undergraduate neuroscience coursework, Faculty teaching graduate neuroscience coursework, Staff teaching neuroscience coursework, Pre-faculty teaching neuroscience coursework (e.g. postdoc), Research position)

2. Neuroscience area(s) of expertise (Choose all that apply.) (Behavioral, Cellular and molecular, Clinical, Cognitive, Computational, Developmental, Systems, Neuroscience education research, Other)

3. [if 'Other' chosen] Please enter other area of expertise.

4. At what type of institution do you currently work? (For definitions according to Carnegie classifications, see http://carnegieclassifications.iu.edu/lookup/standard.php#standard_basic2005_list) (Doctoral or professional university, Master's college or university, Baccalaurate college, Associate's college, Tribal college, Other (Please specify.)

Core concepts are overarching principles that organize knowledge and can be applied to all sub-disciplines in neuroscience.

A survey was sent to neuroscience faculty in Spring 2020 to solicit core concepts for the neuroscience field. 119 faculty responded with 195 suggested core concepts. We generated a preliminary list of core concepts from these data using the following criteria:
1) Applicable across subdisciplines of neuroscience
2) Simplest statement that conveys essential nature of the principle
3) Timeless
4) Important
5) Applicable across all species with nervous systems
6) Broader than a fact (unpackable)
7) Not a competency

Core concepts differ from fundamental facts, topical subdisciplines, and core competencies.

- **Core concepts** are overarching principles that organize knowledge and can be applied to all sub-disciplines in neuroscience.

- Fundamental facts state basic information that is introduced to novices. For example, the statement "genetic information is coded as DNA" is a fundamental fact. Unlike core concepts, these basic facts do not explain phenomena in multiple contexts.

- Topical subdisciplines are a list of topics. For example, "linear acceleration," "relativity," and "magnetism" are subtopics in physics. Topical subdisciplines simply divide the field into small pieces but do not identify the organizing principles in the field.

- Core competencies are skills which prepare students to be effective practitioners in the field. For example, "the ability to use quantitative reasoning" is a core competency in biology. Core competencies addresses skills rather than curricular content.

The preliminary list of core concepts has been provided to you via email. We recommend that you have that list available as you complete this questionnaire.

For the **Communication Modalities** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed core concept: ***Nervous systems encode and transmit information in various modalities.***
Nervous systems use genetic encoding, electrical signaling, chemical signaling, and activity patterns as communication modalities. The communication of information within cells, between cells, and across regions are essential for nervous system function. Neurons transmit information through the regulated movement of ions across their membranes, and electrical and chemical processes permit information transmission among neurons, glia, and non-neural tissues. Regulation of gene expression modifies information encoding, so that maintenance or alteration of genetic information affects nervous system structure and function. Information is also encoded and transmitted as timing, frequency, and patterns of neural activity. Various modalities enable communication to vary in speed and range.

Recall fundamental facts state basic information that is introduced to novices and core competencies are skills which prepare students to be effective practitioners in the field, while core concepts are overarching principles that organize knowledge and can be applied to all sub-disciplines in neuroscience. Below are the criteria we used to develop the core concepts.

1) Applicable across subdisciplines of neuroscience
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5. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

6. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

7. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Structure-Function Relationship** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed Core Concept: *Structure permits and constrains nervous system function, and function shapes structure.*
Nervous system structures and functions bi-directionally inform each other at all levels of organization. For example, structural properties of proteins enable proteins to function effectively. Neurons and glia have protein compositions and essential morphological specializations that differentiate them from other cells and determine their functional properties. The architecture of the connections between neurons and glia in circuits and networks underlies and is constrained by requirements for efficient information flow that produce specific behaviors. Conversely, activity levels and functional demands of nervous systems can stimulate alterations of circuit connectivity, cell morphology and protein expression.

Recall fundamental facts state basic information that is introduced to novices and core competencies are skills which prepare students to be effective practitioners in the field, while core concepts are overarching principles that organize knowledge and can be applied to all sub-disciplines in neuroscience. Below are the criteria we used to develop the core concepts.
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7) Not a competency

8. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

9. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

10. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Information Integration** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed Core Concept: *The output of a unit in the nervous system is dependent upon the inputs it receives and processes.*
Nervous systems compute appropriate responses to external and internal conditions. Inputs to a unit in the nervous system are integrated to determine the probability of an output. The integration and output are influenced by the current state of the unit. Information processing within a unit of the nervous system follows statistical, mathematical, engineering, and physical principles and allows the nervous system to coordinate its own functions as well as functions of other body systems.

Recall fundamental facts state basic information that is introduced to novices and core competencies are skills which prepare students to be effective practitioners in the field, while

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11. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

12. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

13. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Plasticity** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed Core Concept: *Nervous systems adapt to experiences.*
The nervous system is malleable. From early developmental stages and throughout life, the nervous system strengthens and weakens components in response to experience. This modulation, or plasticity, occurs in response to intrinsic and extrinsic influences, including activity, injury, disease, and usage. Nervous system plasticity is a dynamic process that allows the nervous system to flexibly meet functional needs, including homeostasis and information storage.

Recall fundamental facts state basic information that is introduced to novices and core competencies are skills which prepare students to be effective practitioners in the field, while core concepts are overarching principles that organize knowledge and can be applied to all sub-disciplines in neuroscience. Below are the criteria we used to develop the core concepts.
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7) Not a competency

14. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

15. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

16. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Emergence** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed core concept: ***Nervous system functions are constructed from the combined interactions of more granular units within the nervous system.***
Unique nervous system functions emerge at higher organizational levels through the interaction of smaller, autonomous biological units. The mechanisms and interactions of more granular levels of nervous systems are the substrate by which higher order function emerges. Neuronal and glial behavior arises from the function of individual organelles and proteins. Complex nervous system functions such as cognition, behavior, perception, and emotion are the outcome of interactions between many smaller, simpler units.

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17. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

18. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

19. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Function** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed core concept: ***Nervous systems function to coordinate survival responses to the environment and to permit behavior.***
Nervous systems detect and monitor external and internal environmental conditions, in conjunction with utilizing stored information, to mount an appropriate and optimal response. Homeostatic regulation of neural function and other body systems requires the nervous system to integrate many inputs. Although functions of nervous systems vary across species, all nervous systems permit behavior. When normal function is disrupted in the nervous system, disease symptoms and functional deficits can arise.

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20. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

21. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

22. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Evolution** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed Core Concept: *Evolutionary processes produce shared functions and homologous nervous system structures, as well as adaptations that generate differences between organisms.*
Nervous systems are subject to evolutionary forces and therefore must be understood within the phylogenetic history and ecological context of an organism. Similarities in neural mechanisms between species may be due to inheritance from a common ancestor or convergent evolution. Differences in behavior between species may be due to selection for differences in neural mechanisms or genetic drift. Genetic changes and developmental mechanisms generate differences between species that can inform our understanding of the neural basis of behavior.

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23. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

24. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

25. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

For the **Genetics** core concept listed below, please rate its importance in the neuroscience field and uniqueness relative to other proposed neuroscience core concepts.

Proposed Core Concept: *Unique patterns of gene expression underlie the organization and function of a nervous system.*
Genetic expression determines morphological and functional properties of nervous systems at all life stages and levels, from subcellular to single cells to networks. Nervous systems develop into an organized arrangement of functional regions as dictated by the expression of necessary and appropriate genes. Nervous system mechanisms that produce behavior, cognition, and physiological processes depend on gene expression patterns, which can be modulated by internal and external forces through molecular and epigenetic mechanisms.

Recall fundamental facts state basic information that is introduced to novices and core competencies are skills which prepare students to be effective practitioners in the field, while core concepts are overarching principles that organize knowledge and can be applied to all sub-disciplines in neuroscience. Below are the criteria we used to develop the core concepts.

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4) Important
5) Applicable across all species with nervous systems
6) Broader than a fact (unpackable)
7) Not a competency

26. Do you agree that this meets the criteria for a core concept? (Strongly Disagree, Moderately Disagree, Undecided, Moderately Agree, Strongly Agree)

27. How important is this core concept in neuroscience education? (Not Important At All, Moderately Important, Important, Absolutely Essential)

28. Is this core concept unique from the other seven proposed core concepts? (Definitely Not, Probably Not, Probably, Definitely)

29. Please rank the core concepts in order of importance for neuroscience education by dragging and dropping the statements below. 1 is most important; 8 is least important.

30. Are any core concepts missing? (Yes, No)

31. What core concept(s) is/are missing?

Thank you for taking the time to provide some initial feedback on the preliminary list of core concepts. We look forward to revising this list with you on July 30, 12pm - 3pm (Eastern Time).

Mid-session survey

Survey distributed to working session participants prior to small group discussion on assigned core concept.

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1. Please select the core concept for which you are providing feedback. (Communication modalities (Breakout groups #1-3), Emergence (Breakout groups #4-5), Evolution (Breakout groups #6-7), Function (Breakout groups #8-9), Genetics (Breakout groups #10-11), Information integration (Breakout groups #12-13), Plasticity (Breakout groups #14-15), Structure-function relationship (Breakout groups #16-17))

2. Does the core concept **statement** adequately encompass a fundamental nature of neuroscience? (Yes, No)

3. Is the explanatory paragraph accurate? (Yes, No)

4. Is the explanatory paragraph comprehensive? (Yes, No)

5. Please provide any suggestions you have regarding the core concept. For example, you may want to consider phrasing, content, scope, etc.

Post-session debrief survey

Asynchronous survey sent to working session participants

Thank you for taking time to help develop core concepts for the neuroscience field. Your contributions will check that the finalized list of core concepts are relevant and important in your neuroscience subdiscipline. This work can advise existing and new neuroscience programs on curriculum development and assessment and provide a framework to be used in neuroscience education research.

1. Neuroscience area(s) of expertise (Choose all that apply.) (Behavioral, Cellular and molecular, Clinical, Cognitive, Computational, Developmental, Systems, Neuroscience education research, Other)

2. [If 'Other' was selected] Please enter other area of expertise.

3. For each proposed core concept, select whether it should be eliminated, modified or kept as is. (Eliminate, Keep with modifications, Keep as is)

4. What core concept(s) need to be added? Please explain why. In your explanation, please describe how it meets the criteria for a core concept (spans across subdisciplines of neuroscience, simplest statement to convey the essential nature of the concept, timeless, applicable across species with nervous systems, broader than a fact, and not a competency) and explain how it is distinct from the existing core concepts.

5. Any additional comments?

Thank you for your contributions to this project.