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Educating future nursing scientists: Recommendations for Integrating omics content in PhD programs

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Abstract

Preparing the next generation of nursing scientists to conduct high-impact, competitive, sustainable, innovative, and interdisciplinary programs of research requires that the curricula for PhD programs keep pace with emerging areas of knowledge and health care/biomedical science. A field of inquiry that holds great potential to influence our understanding of the underlying biology and mechanisms of health and disease is omics. For the purpose of this article, omics refers to genomics, transcriptomics, proteomics, epigenomics, exposomics, microbiomics, and metabolomics. Traditionally, most PhD programs in schools of nursing do not incorporate this content into their core curricula. As part of the Council for the Advancement of Nursing Science's Idea Festival for Nursing Science Education, a work group charged with addressing omics preparation for the next generation of nursing scientists was convened. The purpose of this article

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is to describe key findings and recommendations from the work group that unanimously and enthusiastically support the incorporation of omics content into the curricula of PhD programs in nursing. The work group also calls to action faculty in schools of nursing to develop strategies to enable students needing immersion in omics science and methods to execute their research goals.

Keywords

Education; Genomics; Omics; PhD

Introduction

"The 21st centuiy is the century of biology" according to Dr. Francis Collins, the director of the National Institutes of Health (NIH; Collins, 2015). Current opportunities for the development of the biological branch of nursing science, from molecules to holistic humans, are unprecedented. Are nursing scientists prepared for this challenge or will they be bystanders in the research endeavors of the 21st century that will incorporate biological approaches to impact clinical practice? Educating and training the next generation of nursing scientists require that the cuniculum for PhD programs keeps pace with emerging knowledge in the life sciences. A field of inquiry that holds great potential to move nursing and other health sciences, including interdisciplinaiy efforts, forward is in the area of omics. Broadly defined omics includes genomics, transcriptomics, proteomics, epigenomics, exposomics, microbiomics, and metabolomics. Descriptions of these approaches can be found in Table 1. Taken together, the omics sciences link understanding of health, illness, and the environment across scales from molecules to cells to organisms to populations. Omics perspectives are applicable to the breadth of nursing science across populations from newborns to elders, from critical care to population health, and from prevention to treatment.

To address the incorporation of omics content in PhD programs in nursing, a work group of faculty experts from schools of nursing across the United States was convened to discuss opportunities and challenges of incorporating omics content into curricula. This work group was brought together as part of the Council for the Advancement of Nursing Science's Idea Festival for Nursing Science Education. The Idea Festival Advisory Committee was charged with inspiring dialogue about emerging areas of science (Henley et al., 2015b) and education of the next generation of nursing scientists (Henley et al., 2015a). The coauthors of this article represent the members of the omics work group and the Idea Festival Advisory Committee chair (SJH). Members were selected by the three cochairs of the working group (YPC, MH, DM) based on their incorporation of omics-based approaches into their research. Efforts were made to include scientists from across the United States who teach in PhD programs in nursing. The work group met over an 18-month period using web-based technology and phone conferences, conducted data collection from work group members using a survey of open-ended questions (results presented within this article), and conducted follow-up discussions about conclusions and recommendations via e-mail.

The authors of this article endorse the idea that all students in PhD programs in nursing should be able to demonstrate knowledge and an appreciation for how omics approaches

could inform nursing science and their future program of research. Without this foundational exposure, some students will miss opportunities to move their area of inquiry in new directions, increase their competitiveness to lead interdisciplinary teams as an independent investigator, and compete successfully for limited research resources. Additionally, we endorse the development of strategies to support students requiring immersion in omics science and methods to accomplish their dissertation and research goals.

Omics-based research approaches are being supported by federal and private funding agencies and are encouraged through the development of major resources that facilitate using these approaches in research projects and training initiatives. The National Institute of Nursing Research's Strategic Plan (National Institute of Nursing Research [NINR], 2011), Implementing NINR's Strategic Plan: Key Themes (NINR 2014), and the Blueprint for Genomic Nursing Science (Genomic Nursing State of the Science Advisory et al., 2013) all support increased attention to omics-based approaches to research impacting nursing practice. Requests for applications (RFAs) and program announcements (PAs and PARs) issued through the National Institutes of Health increasingly mention that omics-based approaches are encouraged. Recent examples with the NINR as the sole participating institute are "Synergizing Omic and Symptom Science" (PA-13–264 and PA-13–265), "Genomic Underpinnings of Response to Rehabilitation Interventions" (PAR-14–0111 and PAR14-012), "Application of Genomic Advances to Wound Repair" (RFA-NR-12-002 and RFA-NR-12-003), and "Personalized Genomics for Symptom Management: Bridging the Gaps from Genomic Discovery to Improved Health Outcomes" (RFA-NR-11-003 and RFA-NR-004). Scientists across disciplines are encouraged to use publicly available omics-based resources such as those provided in Table 1. These funding opportunities and publicly available resources are relevant to nursing science research. The capacity for current and future nursing scientists to be responsive to funding opportunities, communicate in the language of their interdisciplinary colleagues, and use these available resources to propel their research trajectories requires appropriate education and training.

The adoption of omics content into PhD programs in nursing curricula lags behind practice-based nursing curricula. The need to incorporate genomics into nursing curricula across all levels of practice has been addressed in the literature over the past 10 years (Calzone & Jenkins, 2011; Calzone, Jenkins, Culp, Bonham, & Badzek, 2013; Jenkins & Calzone, 2014, 2012; Lea, Skirton, Read, & Williams, 2011), and competencies in genetics have been established for all levels of practicing nurses (Consensus Panel on Genetic/Genomic Nursing Competencies, 2008; Greco, Tinley, & Seibert, 2012). However, PhD curricula that prepare nursing scientists to conduct research and educate future generations of nurses have not received the same attention.

Calls for preparation of nursing scientists to address biological mechanisms in their programs of research are not new. Earlier reviews and position papers addressed the relevance of biological approaches to nursing science development (Bond & Heitkemper, 2001; Page, 2004; Rudy & Grady, 2005). Based on information posted on program websites in 2012, only 21.7% of PhD programs in the United States mentioned that physiology or other biology was a program element, only 15.0% mentioned biophysical measurement or instrumentation, and only 4.2% offered omics-related preparation (Wyman & Henly, 2015).

The applicability of omics approaches for research conducted by nursing scientists continues to increase as evidenced by the increasing number of funding awards and the increasing number of publications from nursing scientists that have incorporated omics approaches. However, based on current curricula, most students in PhD programs in nursing are not obtaining even a basic understanding of how and when to incorporate omics methods into their research. Therefore, it is appropriate to continue to focus on preparation of the next generation of nursing scientists and their ability to incorporate biological science and methods into their research trajectories.

The purpose of this article is to describe the discussions and the culminating recommendations from the work group. The intent is that these recommendations will inform curricula offered within PhD programs in nursing and call to action faculty in PhD programs in nursing to develop strategies to support students requiring immersion in omics science and methods to accomplish their dissertation and research goals.

Findings from the Work Group

Omics-related Emerging Directions and Implications for Nursing Science—The work group identified omics-related areas of inquiry that have implications for advancing nursing science and nursing practice by filling gaps in current knowledge and providing an opportunity for developing a truly integrated biopsychosocial science. Symptom science, the microbiome and metabolome in health and disease, the ability to self-manage interventions, the interaction between the genome and environment, and individualized health care are especially relevant to omics. As evidenced by examples in Table 2, faculty in schools of nursing are positioned exceptionally well to use advances in omics to address the development, progression, and management of symptoms; the variability in response and adherence to interventions including self-management strategies, particularly those that are noninvasive and non-pharmacologic; the variability in patient outcomes across the life span and within diverse settings; and the biological consequences of chronic stress and social disadvantage/discrimination. Details about these studies, where they are being conducted, and publications resulting from these studies can be found by using the grant numbers to search the NIH Reporter database (http://projectreporter.nih.gov/reporter.cfm). These examples illustrate a variety of omics methodologies and designs, including studies focused on DNA sequence variability, variation in DNA methylation, variation in gene expression levels, and variation in the microbiome. Exemplar designs and methods and their applications have been reviewed in the literature (Baumgartel et al., 2011; Conley et al., 2013; Foxman & Martin, 2015; Mischak et al., 2015; Nair, Pritchard, Tewari, & Ioannidis, 2014; Tzoulaki, Ebbels, Valdes, Elliott, & Ioannidis, 2014).

Knowledge discovery in these areas is needed to advance nursing practice. These emerging areas of inquiry are consistent with, for example, the NINR's Strategic Plan (NINR, 2011), Implementing NINR's Strategic Plan: Key Themes (NINR, 2014), the National Institutes of Health's Common Fund Metabolomics Program (http://commonfund.nih.gov/metabolomics/index), and the Blueprint for Genomic Nursing Science (Genomic Nursing State of the Science Advisory et al., 2013).

Strengths of Current Nursing PhD Programs to Address Omics—Themes that emerged from the collective dialogue of the work group that support the necessity of incorporating omics content into nursing curricula include (a) the unique position of nurses to conduct biobehavioral research and (b) the pool of applicants for the PhD in nursing who are increasingly more omics savvy.

Our work group identified the strong history of nursing in the areas of clinical care, risk assessment, and health promotion as a significant strength when interfacing biology and behavior in a program of research. Findings from basic omics sciences can be leveraged with the collaboration of nursing scientists who are uniquely well positioned to execute research advancing clinical translation of omics-based research findings. Because of their knowledge of human behavior in both health and disease states, nursing scientists can add context to what is learned at the bench via omics methods to interpret findings and successfully develop interventions that may influence human health.

Work group discussions also identified the changing applicant pool to bachelor of science in nursing, advanced practice, and PhD programs, including students with prior degrees in science, technology, engineering, or math enrolling in second-degree nursing programs. With increasing emphasis on science, technology, engineering, and math at all levels of education (Committee on Highly Successful Schools or Programs for K-12 Education, 2011; Gonzalez & Kuenzi, 2012), high school students have exposure to omics (National Human Genome Research Institute, 2006), especially in advanced placement courses (College Board, 2013). Genomics competencies have been established for all levels of practicing nurses (Consensus Panel on Genetic/Genomic Nursing Competencies, 2008; Greco et al., 2012), further adding to the omics knowledge base for many incoming PhD students. Although omics content may be unfamiliar to many faculty teaching in PhD programs, this is increasingly not the case for incoming PhD students. In many schools of nursing with PhD programs, it is indeed the students in the program who are driving the momentum to incorporate omics content into their education and training. To take advantage of these assets will mean that changes in PhD curricula are needed. This stance is supported by both the Council for the Advancement of Nursing Science Idea Festival Advisory Committee (Council for the Advancement of Nursing Science, 2014) and the American Association of Colleges of Nursing (2010).

Weaknesses of Current Nursing PhD Programs to Address Omics—Three themes emerged as weaknesses of current PhD programs in nursing to address omics content. These themes focused on the topics of (a) curricula, (b) faculty, and (c) environment/resources.

Our work group voiced concerns that the curriculum of most schools of nursing with PhD programs does not have substantive content in biology, biochemistry, physiology, microbiology, or omics and, most importantly, how these sciences link with human behavior and health outcomes. This gap in curricular content produces graduates who, through a lack of exposure during their education and training, cannot read and critique contemporary literature in the health sciences where omics perspectives are pervasive and who do not recognize opportunities to use omics approaches in their research. This also does not allow

the faculty to shepherd the next generation of nursing scientists in conduct of cutting-edge biobehavioral research.

Another concern of the work group was the current capacity of faculty who are teaching in PhD in programs in nursing to educate and mentor students in using omics approaches. Most schools of nursing with PhD programs do not have sufficient numbers of faculty conducting research using omics approaches who can educate and mentor students in omics content and methods (Williams et al., 2011).

Finally, an additional concern of our work group centered around the resources and environment to support omics research in most schools of nursing. Conducting omics-based research often requires access to data collection platforms that are usually not housed in individual laboratories but are found within core facilities of research-intensive universities. This is an issue for the conduct of omics research across all disciplines and is not limited to nursing scientists. This issue highlights the need for access to these facilities if faculty and students are to be successful conducting omics-based research. However, having access to these core facilities does not remove the need for in-house resources such as a wet laboratory for processing of biospecimens, basic data collection, and sample storage capacity, which many schools of nursing currently lack. Multiple members of the work group also raised concerns regarding the lack of bioinformatics support and computational infrastructure for statistical analyses of omics data that are vital to the successful completion of omics-based projects.

Opportunities Related to Incorporating Omics into PhD Programs in Nursing—The work group identified opportunities for schools of nursing to incorporate omics content into their PhD curriculum and felt that incorporating omics content could in turn provide benefits to PhD programs. Multiple members independently identified the opportunity to promote and expand interdisciplinary partnerships for both education and training as well as research opportunities. Interdisciplinary research teams are required to tackle today’s complex health-related problems using state-of-the-science approaches. Although most research-intensive schools of nursing have embraced the idea of interdisciplinary research and team science, opportunities to further expand interdisciplinary relationships should not be overlooked. Incorporating omics into the PhD curriculum in schools of nursing presents an opportunity to implement interdisciplinary partnerships including course sharing and cross-disciplinary research laboratory experiences. The work group believed that non-nursing disciplines that are involved with these partnerships would ultimately benefit from their exposure to nursing perspectives as well. For example, basic scientists who collaborate with nursing scientists will have expanded opportunities to conduct scientific investigations explicating the behavioral nuances of health and disease.

Another opportunity identified multiple times by work group members related to the promotion of nursing’s standing in the scientific community. Adding omics methods to the toolbox used by nursing scientists increases their potential to contribute to science, expands their networks of collaborations, and increases venues to disseminate their work, all leading to increased appreciation and dissemination into practice for the research that nursing scientists conduct.

Implications for Faculty of PhD Programs in Nursing—Work group members also discussed the potential implications of increased omics content in PhD programs in nursing with regard to (a) the need for increasing faculty expertise in omics and (b) financially supporting omics-based research in schools of nursing.

The need to incorporate genomics into nursing curricula and the lack of faculty training and expertise with genomics have been addressed in the literature over the past 10 years; however, the major focus has been on nursing practice (Calzone & Jenkins, 2011; Calzone et al., 2013; Jenkins & Calzone, 2012, 2014; Lea et al., 2011). Our work group advocates for the incorporation of omics content into the PhD curricula and an increase in faculty expertise in omics science and methods in order to educate the next generation of nursing scientists. On a positive note, resources are available to facilitate the incorporation of genomics into nursing curricula (Calzone, Jenkins, & Rust, 2007; Calzone et al., 2011; Daack-Hirsch et al., 2013; G2C2, 2015; National Human Genome Research Institute, 2013; Quevedo Garcia, Greco, & Loescher, 2011). Several schools have successfully integrated genomic content into their curricula by using a consultative process facilitated by a local change agent. In this process, a faculty member was identified as a change agent for his or her institution. The change agent worked with a consultant who is a nurse and expert in genomics. The process began with faculty conducting a self-study that included an assessment of their genetic literacy and current level and quality of genomics in the curriculum. The self-study was followed up with a 1-day, on-site consultation by the nurse expert who provided background and significance for the need to integrate genomics into the curriculum, examples of how and where to place genomics into the curriculum based on the self-study, and teaching and learning resources for faculty (Daack-Hirsch et al., 2013). This process can be used at the undergraduate and graduate levels and lead to threading omics across the curriculum, addressing it in a series of courses, developing a specific course, or a combination of these approaches (Daack-Hirsch, Dieter, & Quinn Griffin, 2011; Daack-Hirsch et al., 2013). Additionally, some schools of nursing do currently have training programs for PhD students in the omics. Examples include the University of Pittsburgh, which has an NIH-funded training program titled “Targeted Research and Academic Training of Nurses in Genomics” (T32NR0097509); the University of Iowa offers training opportunities in clinical genomics and genomic health research; and Clemson University offers a PhD in Healthcare Genetics.

The work group advocated for increasing the number of faculty incorporating omics into their research trajectory. This could be facilitated by providing in-depth training for faculty to increase their knowledge of omics, expanding their interdisciplinary collaborations, and increasing faculty awareness of opportunities that would support these endeavors. Resources for the education of nursing faculty continue to grow (NINR, 2015; Williams et al., 2011). The International Society of Nurses in Genetics (www.isong.org) continues to be a resource for education, practice, and research for nurses. Additionally, the NINR supports several intramural training experiences that are open to extramural faculty and students focusing on education in omics, including the Summer Genetics Institute and Methodologies Bootcamps (https://www.ninr.nih.gov/training/trainingopportunitiesintramural).

Implications for PhD Students in Nursing—Work group members also addressed foundational knowledge in omics that should be acquired by all students in PhD programs as

well as implications for the student that would require immersion in omics science and methods to address their dissertation project.

The work group overwhelmingly supports exposure to omics content for all students in PhD programs. It would mean that all students have exposure to omics methodologies, the types of research questions that can be addressed and hypotheses that can be tested using these methodologies, and research designs that incorporate omics approaches. This would allow all students to gain an appreciation for how omics can contribute to their area of inquiry, including biological and social determinants of health across the life span. Such exposure could be embedded into existing courses within the curriculum, through the development of new courses and electives, and through external workshops and summer institutes like those mentioned previously for faculty education.

The work group also overwhelmingly supported that PhD students with a passion for incorporating omics science and methods in their research should have opportunities in wet laboratories and experience with omics data management and relevant computational techniques including Big Data from omics data sets. In order to become competitive, independent investigators, students should understand science underlying omics approaches as well as process and research design, appreciate ethical concerns when conducting some types of omics studies, and complete a postdoctoral fellowship in an omics-related area.

Conclusions and Recommendations

The following are recommendations to obtain these experiences during doctoral study:

1. Nursing scientists appreciate the interplay between biology, behavior, environment, and health, a unique view that differs from other scientific investigators. Omics approaches are relevant to research conducted by nursing scientists and provide an opportunity for translational research.
2. All students in PhD programs in nursing need exposure to basic omics content in their core curriculum. Students often transform their ideas about their projects and future trajectory of research after instruction in new topical areas. That instruction impacts the student’s thought process, giving them tools to address their research.
3. This work group calls to action faculty in schools of nursing to develop strategies for students needing immersion in omics to successfully execute their dissertation research. The work group endorses the need for exposure of all students to omics science and methods; however, this will not be sufficient for students pursuing an omics-based dissertation project. These students will need immersion experiences that may not be available at all schools of nursing. The work group suggest the following:
    a. Prospective applicants to PhD programs with an interest in omics-based research should be advised to apply to a school of nursing that has faculty and the infrastructure aligned with their research interests.

b. A multi-institutional approach to educating the next generation of nursing scientists should be considered. Increased collaboration could provide a solution, especially for those schools that do not have the faculty expertise relevant to omics research and education. PhD students who are interested in omics-based research may be unable to relocate or may decide to attend a school of nursing without a strong omics program because it offers strength in another area that is important to their training. Those students may still be able to attain the education and training in omics as well as in-laboratory data collection and new statistical approaches by spending part of their training and education with a mentor from another school of nursing or elsewhere in their university who has a strong omics program of research.

c. The Graduate Partnership Program at the NIH should be considered (https://www.ninr.nih.gov/training/trainingopportunitiesintramural/graduate-partnership-program) to support a student's omics-based dissertation project. This project would be conducted through a collaboration of mentoring by NIH intramural scientists and faculty at the student's home university.

d. Courses taught by omics experts could be delivered to students using web-based or distance education. This would allow for the scientific and theoretical content to be delivered to trainees across institutions; they would connect with other resources for their laboratory and data analysis training. The Nursing Education Exchange (www.winnexus.org) could serve as a model for this approach. To facilitate this approach, the development of a genomics education consortium could be developed.

4. Current and future nursing scientists need to consider the relevance of omics research approaches to their research. When omics methodologies have the ability to move an area of inquiry in new directions, this work group would advocate that nursing scientists have a responsibility to use omics to address that topic, lest the fields of inquiry important to nursing will lag behind or other scientists will move those fields forward for them.

Omics science and methods offer powerful tools to broaden our understanding of health and disease, including interventions for disease prevention, health protection, health promotion, and self-management. Including omics content in the training and education of future nursing scientists through formal curricula and PhD program planning is an essential component of the preparation of future nursing scientists. The work group hopes that these recommendations will prove useful to PhD programs in nursing as they evaluate their curricula and training plans and respond to emerging areas of knowledge and science.

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Table 1 –

Definitions of a variety of Omes and Omics

Ome/Omic	Definition	Example Resources
Genome/genomics	The genome is the complete set of DNA in a cell. DNA carries the instructions for building all of the proteins that make each living creature unique. The human genome comprises approximately 21,000 genes. Genomics is the study of the sequence variability or gene functions within the genome, whereas genetics is the study of a particular gene.	Database of Genotypes and Phenotypes (dbGaP): www.ncbi.nlm.nih.gov/gap Cancer Genome Atlas: cancergenome.nih.gov Sequence Read Archive (SRA): www.ncbi.nlm.nih.gov/sra
Transcriptome/ transcriptomics	For the instructions in DNA to be carried out, first DNA must be transcribed into corresponding molecules of RNA, referred to as transcripts. The collection of transcripts from active genes can vary among cell or tissue type and is called the transcriptome. Transcriptomics is the study of the transcriptome.	Gene Expression Omnibus: www.ncbi.nlm.gov/geo
Proteome/ proteomics	The proteome consists of the collection of proteins expressed from the genes, which can vary among cell or tissue types. Proteomics is the study of the proteome.	Protein database: www.ncbi.nlm.nih.gov/protein Reactome database: www.reactome.org
Epigenome/ epigenomics	Derived from the Greek, epigenome means “above the genome.” The epigenome consists of marks on the genome (e.g., methylation of the DNA) that impacts when and where a gene will be active, often in response to the endogenous and exogenous environment. The marks, which are not part of the DNA itself and can vary among cell or tissue types, can be passed on from cell to cell as cells divide and from one generation to the next. Epigenomics is the study of the epigenome.	Human Epigenome Project: www.epigenome.org
Exposome/ exposomics	The exposome is the measure of all the exposures of an individual in a lifetime and how those exposures relate to health. It complements the other omics by characterizing the environment, which is important to interpreting other omics data. Exposomics is the study of the exposome.	Toxic Exposome Database: www.t3db.ca
Metabolome/ metabolomics	The complete collection of all small molecules in a biological sample, which can originate from the endogenous or exogenous environment, is called the metabolome. The collection of molecules can vary among cell and tissue types. Metabolomics is the study of the metabolome.	Metabolomics Workbench: www.metabolomicsworkbench.org
Microbiome/ micorbiomics	The collection of genetic material from microscopic organisms, such as bacteria, fungi, and viruses that live on and in our body, chiefly in the gut and on our skin, is called the microbiome. There are 10 times more microbial cells than human cells in a human being. Microbiomics is the study of the microbiome.	Human Microbiome Project: commonfund.nih.gov/hmp/index

“Omes” (e.g., genomes, proteomes, and microbiomes) are the objects of study, whereas “omics” (e.g., genomics, proteornics, and rnicrobiomics) are fields of study. Brief definitions of a variety of omes and omics are provided. Definitions were adapted from those provided by the National Institutes of Health National Human Genome Research Institute, the Centers for Disease Control, and omics.org.

Table 2 –

Examples of Omics-based National Institutes of Health–funded Research Being Conducted by Faculty at Schools of Nursing

Title of Project	Description	Funding Source
Biobehavioral determinants of the microbiome and preterm birth in black women	The goals of this study are to elucidate the biobehavioral determinants that govern the structure and dynamics of the microbiome of black women during pregnancy and to investigate whether microbiome composition is associated with preterm birth	NINR: R01NR014800
Toxicity profiling: creating novel paradigms to personalize cancer treatment	The goals of this study are to develop a two-stage model that will ultimately use clinical factors to screen for patients at increased risk and then perform genetic testing only on those select patients to refine the risk assessment, thereby improving clinical utility and feasibility	NINR: R01NR013707
Pain sensitivity in low back pain	This study will investigate the role of enhanced pain sensitivity on the risk of persistent low back pain through characterization of pain sensitivity and pain sensitivity candidate gene profiling	NINR: R01NR013932
Epigenomics of patient outcomes after aneurysmal SAH	This project will characterize the methylome of daily cerebrospinal fluid samples representing the central nervous system environment post aSAH to clarify the pathophysiology associated with delayed cerebral ischemia and patient outcomes	NINR: R01NR013610
Genomic variability and symptomatology after traumatic brain injury	The overall objective of this project is to determine the extent that variability in genes involved in the mitochondrial oxidative phosphorylation (OXPHOS) pathway, responsible for cellular energy production, is responsible for variability in symptoms related to cognition, behavior, and emotion post-TBI.	NINR: R01NR013342
Transcriptional regulation in the spinal cord after spinal cord injury: role for trkB.Tl in spinal cord injury pain and locomotor dysfunction	The goal of this project is to understand how gene expression after spinal cord injury changes in the presence and absence of a truncated isoform of the brain-derived neurotrophic factor (Bdnf) receptor, trkB.Tl. We used microarray technology to examine gene expression changes across genotypes, injury status, and time	NINR: R01NR013601
What genes are differentially expressed in a mouse model of HIV treatment associated neuropathic pain?	The goal for this project was to examine differential gene expression in the spinal cord of mice treated with a component of highly active antiretroviral treatment compared with mice treated with a vehicle control. We identified several differentially expressed genes, including the giant axonal neuropathy (Gan) gene.	NINR: R01NR010207–02S1
Does the X-ROS signaling pathway play a role in human Duchenne Muscular Dystrophy (DMD)?	The goal of this project was to examine whether the X-ROS signaling pathway, which is dysregulated in a mouse model of DMD (the *mdx* mouse), is also dysregulated in human patients with DMD versus control patients. We used next-generation RNA sequencing to examine gene expression changes in the X-ROS signaling pathway from human muscle biopsy samples.	NINR RC2NR011968
Longitudinal analysis of the Premature Infant Intestinal Microbiome Prior to Necrotizing Enterocolitis: A Case-Control Study	This is a case control study of infants with NEC and their unaffected counterparts. We conducted longitudinal analysis of the 16S rRNA genes of 312 samples obtained from 12 NEC cases and 26 age-matched controls. From this, we characterized the community structure of the intestinal microbiome of all infants and identified novel differences in children with NEC and age-matched controls.	NINR: K23NR011320
The preterm infant microbiome: biological, behavioral and health outcomes at 2 and 4 years of age	The microbiomes of 78 very low birthweight infants will be investigated including while they were admitted to the neonatal intensive care unit and following them through 4 years of age, studying the succession of the microbiome and the relationships of microbiome to early and later health outcomes.	NINR: R01NR015446
Microbiome & Pain in IBS	The goal of this grant is to define microbiome composition and pathophysiological features tied to symptoms and likely etiology. The first aim is to compare GI microbiome, permeability, and cytokines in women with IBS versus healthy controls (HCs) without IBS. The second aim is to compare abdominal pain, other IBS symptoms, and psychosocial distress symptoms in those IBS subjects with abnormal versus normal GI biomarkers. In addition, we will explore patterns of associations among GI biomarkers and of GI biomarkers with abdominal pain and other symptoms. The goal is to identify possible IBS subgroups based on biomarkers.	NINR: R01NR014479
Unraveling the link of sleep to IBS: A Metabolomics Approach	The aims of this study are to (a) compare plasma metabolites gathered during the night in women with IBS plus poor sleep to women with IBS but no complaint of poor sleep and HCs who deny poor sleep; (b) correlate TRY metabolites and their ratios with sleep and GI symptoms across all three groups; and (c) explore patterns of associations among GI, sleep, and psychological distress symptoms, polysomnographic, heart rate variability, and genetic polymorphisms in TRY in women with IBS and HC.	NINR: R01NR015117

Title of Project	Description	Funding Source
Epigenetics and Psychoneurologic Symptoms in Women with Breast Cancer	2-year longitudinal biobehavioral cohort study examining levels of psychoneurological symptoms (cognitive dysfunction, depressive symptoms, anxiety, fatigue, sleep disturbances, and pain) and relationships to genomic/ epigenetic measures (DNA methylation, telomere length, micronuclei frequency) in women with early-stage breast cancer.	NINR: R01NR012667
Muscle function and depression-like behavior in a mouse model of cancer fatigue	The goal of this project is to understand the effects of cytokines on the molecular pathways causing depressed mood and skeletal muscle wasting and their interaction in an animal model of cancer related fatigue.	NINR: R01NR012618
Intergenerational Impact of Genetic and Psychological Factors on Blood Pressure	The overall goal of this project is to delineate the psychobiological (genetic and environmental) mechanisms through which AA mothers' perceived racial discrimination, mental health, and parenting behavior affect their own and their young children's blood pressure over time.	NINR: R01NR013520
Symptoms clusters in oncology patients receiving chemotherapy	This study will evaluate for the occurrence and changes in symptom clusters in patients receiving chemotherapy for breast, lung, colon, or ovarian cancer. In addition, we will attempt to identify genetic markers in patients with different symptom experiences.	NCI: R01CA134900

AA, African American; aSAH, aneurysmal subarachnoid hemorrhage; GI, gastrointestinal; HC, healthy controls; IBS, irritable bowel syndrome; NCI, National Cancer Institute; NEC, necrotizing enterocolitis; NINR, National Institute of Nursing Research; rRNA, ribosomal RNA; TBI, traumatic brain injury; TRY, tryptophan.