I. Introduction  
A. Definition of the subspecialty or Section - The Neurogenetics Section was founded in 1999. The importance of inherited neurologic disorders became more recognized and moved from advances purely in the research arena to impacting neurologic diagnosis with significant implications for disease recurrence risk within families, and the promise of new therapies for these disorders based on new techniques and genetic pathway understanding. At the national level, policy decisions involving genetic and neurogenetic diseases have received input largely from the genetics community without much formal representation from the Academy. Despite the substantial presence within the Academy and the need for policy guidelines, neurogenetics had been conspicuous by its absence from the growing number of Academy sections.

B. General statement on conditions it covers and pertinent procedures (e.g. EMG, EEG) - Genetic susceptibility involves nearly every branch of neurology, including a wide range of condition ranging from multiple sclerosis, epilepsy, dementia, sleep, neuromuscular disease and movement disorders, to childhood disorders, such as autism, intellectual disability and language based learning disabilities. Genetic testing for "causal" genes as well as susceptibility genes is becoming more prevalent and there is a need for section engagement along multiple policy domains.

C. Overview of interaction with other specialties  
To be determined

D. Purpose of the document – Why is this needed? This document will assist future members and executive committee members of the Neurogenetics Section in understanding the roots of the section and create a visionary path of where the section is heading.

E. Overall mission statement – In broad terms, what is the sub-specialty trying to accomplish? The Neurogenetics Section furthers patient care, research, and teaching in the area of neurogenetics. This Section strives to increase the level of interest in neurogenetics and growing awareness of recent advances among AAN members. The Section on Neurogenetics will also serves as an important resource to the Academy by assisting in the development of practice guidelines and quality assurance parameters related to inherited neurologic diseases. Lastly, the section provides an avenue for interaction with the broader genetics community with regards to policy and decisions affecting a wide range of relevant issues, from insurance to patient care.
II. Background/History of Subspecialty or Section

A. Landmark early works/milestones - The neurogenetics section was founded in response to the need for clinical specialists experienced in the recognition of genetic disorders of the nervous system, their treatment and their diagnosis. These needs arose with the creation of new methods of diagnosis, and the general increase in the use of molecular biological approaches for understanding genetic and non-genetic disease.

The Neurogenetics section is still at an early stage in development. Initiated in 1999, the major efforts of the section have been directed toward defining the group as a subspecialty. Questions which have been approached are the need to develop ethical standards in genetic testing, the question of creating a supervising board and the proper mechanism for adequately training new specialists in neurogenetics.

B. Growth of the sub-specialty or Section to current status - The section has grown rapidly in the first few years. Initiated in 1999 with 27 members, the size quadrupled within 3 years and has now plateaued at about 180 members. The growth reflects the inclusion of new subgroups (neuromuscular, movement disorders, ataxias) in the group. The group will grow more with the specific development of training programs in neurogenetics.

C. Genesis of pertinent journals and societies (e.g. Neurology, Archives of Neurology, etc.). Neurogenetic articles now are prominent in all of the major neurology journals, and prominent in human genetic journal as well (such as Human Molecular Genetics). There are also 2 subspecialty journals titled: *The Journal of Neurogenetics* and *Neurogenetics*. *The Journal of Neurogenetics*, started in 1984, is published by Informa Health care, and is only recently becoming interested in clinically related approaches. Dr. David R Lynch, Councilor for the Neurogenetics sections, serves on it editorial board. *Neurogenetics* was first published in 1997. The journal presents research that contributes to better understanding of the genetic basis of normal and abnormal function of the nervous system. The current editors are Manuel B. Graeber, MD, Ulrich Müller, MD and James R. Lupski, MD. Several section members (including current section Chair Teepu Siddique, MD, and Dan Geschwind, MD PhD, chair elect) serve on the Editorial Board.

D. Current Board certification and other sub-specialty organizations/boards
Not applicable

E. Other professional and disease-related organizations relevant to the subspecialty.
There are other patient-advocate organizations, such as those focused on inherited ataxia, neuropathy, or Huntington’s disease. Although there are no formal relationships between these organizations and the AAN, potentially allied subspecialty professional organizations include the American College of Medical Genetics, American Board of Medical Genetics and the American Society of Human Genetics.
III. Current State of the Section

A. Patient care/practice. Neurogenetics is a rapidly expanding part of the clinical practice of neurology. Many neurologists, and particularly those who have been in practice for a long time, have limited formal training in the use and interpretation of genetic tests.

B. Research. This section has an active research portfolio and many members participate in either basic or clinical research.

C. Education.
   a. Education about the appropriate use and interpretation of genetic tests is a critical part of neurology training, however not every program has the expertise to provide this. Continuum and AAN sponsored programs are helpful in this regard. We would benefit from additional interaction with other organizations such as the American Society of Human Genetics for education, economics issues, and legislative issues.
   b. There are neurogenetics fellowships offered at a small number of programs; not a certification program. Certification in medical genetics is done via the American Board of Medical Genetics.

D. Medical economics issues.
   a. Payment for genetic testing through 3rd party payers is a chronic problem, even when genetic diagnostic testing is the most cost effective and accurate approach to diagnosis. This is a problem across specialties.
   b. Payment for counseling and expertise in genetic disease?

E. Legislative issues.
   a. Congress recently passed Genetic Information Nondiscrimination Act (GINA). This is legislation that prevents discrimination on the basis of genetic test results, and also prevents insurance companies from denying coverage based on disease predisposition to a genetic condition. This legislation is designed to eliminate some of the barriers to free use of genetic testing.
   b. There continues to be great concern on the part of the section about the exclusive rights to genetic testing, resulting in limited access and high costs for many of the tests that we order as neurologists. This is an issue that extends beyond neurology, but affects us greatly in practice. Patent law as applied to genetic testing results in high costs, limited access, and lower quality.

IV. SWOT Analysis

A. Current strengths:
   Patient care—Technological advances in molecular genetics have increased the ability of neurogeneticists to make definitive diagnoses for many neurological disorders. A better understanding of the molecular basis of neurogenetic disorders is providing potential opportunities for therapeutic interventions. Thus, advances in molecular technologies and therapeutics will eventually lead to better patient care and treatments. The characterization of metabolic pathways and new genetic mechanisms is leading to the
development of novel targets for developing therapies. The field of pharmacogenomics is expected to change the prescribing patterns of neurologists based on genetic variations or polymorphisms in enzymes that metabolize medications. A smaller advance, although much more immediate, is the ability to stratify patients in therapeutic trials based on mutations in specific genes. This will reduce the heterogeneity of research subjects and provide better study designs for therapeutic trials. These advances across genetics will contribute to the development of more personalized medicine.

Research—Insights into molecular pathogenesis of neurogenetic disorders are revealing novel developmental and biological pathways. These research discoveries are providing a rich opportunity for scientific exploration. Advances in epigenetics, gene therapy, siRNA technologies, enzyme replacement, and stop codon “read-through” technologies, are expected to proceed at a rapid pace. Such work will have an increasing impact on our ability to better diagnose and treat patients.

Education—The explosion of the field of human neurogenetics and the myriad discoveries of genes and pathways relevant to disease diagnosis, prognosis, drug response, and gene delivery systems, provides a tremendous need for the continuing education of medical students, neurology residents, neurologists, and other health care providers.

Economics—The slow but increasing translation of basic science discoveries to better treatments puts research and clinical investigators in a stronger position for research dollars to study therapeutic modalities. The progress in understanding the molecular basis of neurological disorders places adult and pediatric neurogeneticists in a position to expand their scope of clinical practice.

Legislative—The passage of the “Genetic Non-discrimination Bill” on May 21st, 2008 (GINA) (HR 493) may alleviate some of the regulatory hurdles to increasing use of diagnostic genetics.

B. Weaknesses in the five areas:

Patient care—Many physicians are not adequately equipped to make thoughtful decisions regarding genetic diagnosis because of an insufficient knowledge and understanding of basic and molecular genetics. Diagnostic companies often ‘bundle’ many tests at high costs when thoughtful clinical evaluation in many cases allows for a clear hierarchical approach to genetic testing that can be significantly less expensive. The increasing pressure to see patients in shorter periods of time forces practicing neurologists to order a ‘Panel’ instead of a single genetic test that is likely to confirm the diagnosis. This approach coined “Panelopathies” by Anthony Amato, will increase the cost of laboratory testing for neurogenetic disorders. A major weakness in the delivery of patient care is the lack of sufficient numbers of board-certified adult and pediatric neurogenetic subspecialists in the United States.

Research—The growing burden of bureaucracy standing in the way of accomplishing both basic and clinical research has lead an inability to conduct longitudinal genetic
studies. The process of protecting research patients slows down the translation of discoveries form the “bench to the bedside”. It also increases the cost of research by mandating complex study designs to protect the privacy of human research subjects. The guidelines to remove all personal identifiers from genetic samples have made longitudinal genetic studies in adults and children with developmental disorders impossible to conduct. Navigating the privacy mandates recommended by the federal and state governments as well as the policies of Universities and other Institutions have hindered progress in neurogenetics.

**Education**—There is a tremendous need for the education of medical students, neurology residents, neurologists, and other health care providers in the basic principles of neurogenetics. Most training programs stress patient care and leave little time for didactic teaching in neurogenetics. Given the relatively small number of adult and pediatric neurogenetic subspecialists, it will be impossible to educate all neurologists without innovative approaches.

**Economics**—Decreasing research monies from NIH have put increasing pressure and obstacles for those pursuing basic research in neurogenetics. The diminishing reimbursement rates and a lack of a timely board certification process for clinical neurogenetic subspecialists will lead to a decline in the number of individuals pursuing this new field at a time when the need will increase. In the rapidly evolving genetic testing environment, the reimbursement structure needs to be redesigned to account for genetic counseling. Clinicians do not have the time to appropriately explain the risks and benefits of genetic testing since it reduces the rate at which they can see patients and, therefore lowers their practice revenue. However, the high cost of genetic testing and the continued development of new therapies is expected to increase the coffers of industry and contribute to the rising cost of health care in the United States.

**Legislative**—The passage of GINA will potentially permit reductions in the regulatory hurdles to increase the use of diagnostic genetic tests and to do basic human genetic research. However, this will not happen immediately and there will still be some who have been so sensitized to this perceived risk that it may take a long time to overcome this hurdle. Legislative and ethical guidelines are needed to proactively curb the increase in claims of ‘wrongful birth’ and ‘wrongful life’.

**C. Opportunities for growth in each area:**

**Patient care**—The fields of adult and pediatric neurogenetics will grow if the board certification process was shortened and included as a certification issued by the American Academy of Neurology. Training genetic counselors in neurogenetics and issuing licenses to genetic counselors so they can receive direct payment for their services will enhance the delivery of patient care.

**Research**—Recruiting physician-scientists into the field of neurogenetics will help sustain continued growth. Strategies and training programs are needed to recruit and train more individuals in the emerging fields of neurogene therapy and developmental molecular neurobiology.
**Education**—The scarcity of formal courses in clinical adult and pediatric neurogenetics in medical schools and residency training programs provides an opportunity to develop curricula to educate the next generation of neurogeneticists.

**Economics**—The emergence of new genetic diagnostic technologies, pharmacogenetic tests, and novel therapies creates an opportunity for neurogenetic subspecialists to expand their scope of practice. Subspecialty board certification in clinical and laboratory neurogenetics will help qualified individuals to generate sustainable practice revenue to provide clinical care, diagnostic testing, and genetic counseling. The development of Current Procedural Terminology (CPT) codes specifically for neurogenetic subspecialists, neurogenetic testing, and genetic treatment interventions will help to clarify the financial feasibility of practicing neurogenetics as a primary subspecialty.

**Legislative**—Neurogenetic subspecialists are in a unique position to shape the legal and ethical implications of advances in the field.

**D. Threats to achieving goals in each area:**

**Patient care**—The lack of a trained pool of adult and pediatric neurogeneticists threatens to hinder the quality of care to patients with genetic disorders of the nervous system. Poor reimbursement rates by third-party payers are a threat to the sustainability of neurogenetics and genetic counseling as specialties.

**Research**—The lack of availability of research funding will hinder progress in neurogenetics and slow the development of future treatments.

**Education**—The lack of institutional support in most medical schools and hospitals for adult and pediatric neurogenetics is a direct threat to improve the education of medical students, residents, neurologists, and other health providers.

**Economics**—The costs of new treatments for neurogenetic disorders will create novel ethical, legal, and economic situations especially in an age where many Americans do not have health insurance. The economic impact of costly burgeoning technologies will threaten or challenge their rapid implementation.

**Legislative**—Legislative naivety regarding genetic therapies may threaten to hinder progress in the field of neurogenetics.

**E. Current status of AAN input to each area (we interpret this to mean input from AAN as an organization rather than individual AAN members):**

**Patient care**—the committee is not aware of any particular efforts that AAN has made in this regard. Dr. Mathews had discussed the prohibitively high cost of genetic testing due to exclusive intellectual property issues with someone involved in AAN lobbying efforts. While he found this an interesting topic and sympathized with the issue, he felt it was not ‘big enough’ to warrant commitment from AAN as a lobbying priority.
Research—the committee is not aware of any particular efforts that AAN has made in this regard.

Education— AAN Foundation Fellowship (Raymond Adams). Continuum publishes an occasional issue on topics in Neurogenetics. Neurogenetics courses at the Annual Meeting have included basic and clinical (including genetic testing).

Economics—the committee is not aware of any particular efforts that AAN has made in this regard.

Legislative— the committee is not aware of any particular efforts that AAN has made in this regard.

V. Vision

A) Short Term Goals

1) Promoting cost-effective genetic testing. One of the greatest advances in diagnostic testing for neurologists in the past decade has been the development and availability of testing to confirm the presence of genetic disorders, “genetic testing”. This advance has allowed us to confirm previously uncertain diagnosis as well as to appreciate that many genetic disorders have a broader presentation than initially thought. The main drawback to this testing is cost with many individual tests costing in the thousands of dollars. Unfortunately, many of these tests are marketed in screening panels, and this is not cost-effective in most circumstances. By promoting cost-effective genetic testing, we hope to minimize overall costs to a patient for their health care while allowing for implementation of new advances and subsequent improved health care for the individual patient. Additionally, cost-effective genetic testing would allow for more patients to be assessed with the same amount of health-care dollars.

2) Promote education on appropriate initial and subsequent genetic testing for investigating neurogenetic disorders. This goal is linked to #1 above. Such education would include a) if testing is even indicated, b) what order of testing should be done (assess most common causes first), c) how to interpret the results, and d) what counseling is needed. The issues mentioned in #2 will be addressed by continuing to provide lecture series at the AAN national meetings. The section also hopes to begin development of guideline for genetic testing for common conditions. The education provided would be subject to review by the full neurogenetics section and modified by feedback provided by the full AAN membership.
The AAN is a vital resource in promoting these goals. Its national meetings provide a venue for the educational courses. Also, they provide a forum to disseminate information and receive feedback.

3) Support of infrastructure or systems that facilitate central sample repositories and databases for some of relatively rare conditions treated by those in neurogenetics. This would provide long term benefit to patients and in the short term promote needed research.

B) Long term goals.

1) Develop educational and communication programs dealing with complex genetic risk. Since most neurologic conditions are not due to single mendelian mutations, but arise out of the interaction of common, or rare polymorphisms with other factors (complex genetics), there is a growing need to educate practitioners, even those currently in the discipline of neurogenetics. Communication of the concepts of disease risk, the role of genetic biomarkers, and genetic modifiers will frequently be necessary. For example in the future, with the increasing role of complex genetics in diseases, dementia or autism referrals to the neurogenetics clinic could be envisioned. The $10,000 genome is in the near future and thus these complex issues will become central in many neurologic disciplines and specifically, neurogenetics.

2) Work towards a subspecialty certification in neurogenetics. This may be in conjunction with other boards that have ongoing programs and should also include genetic counselors.

3) Facilitate the integration of neurogenetics with other neurologic disciplines. Since most forms of neurologic disease involve genetic risk, nearly all other sections of the AAN have overlap with neurogenetics. This is not surprising, as neurogenetics is not a specific category of illness, such as epilepsy, stroke or headache, but more like a set of methods and approaches to these diseases, similar to outcomes research for example. As genetic knowledge with regards to etiology and treatment response explodes, there will be a need for expertise in complex genetics in many other AAN sections and sub-disciplines of neurology.

4) Promote guidelines and provide support for the dissemination of genetic information in the electronic medical record, along with other clinical information. Electronic medical records provide great opportunity for biomedical research, including population based studies of genetic and environmental risk that were previously not feasible. This is further accelerated by the rapidly diminishing cost of genetic analysis at the population level. De-identified records that can be connected to genetic information will be invaluable for not only understanding disease risk and mechanism, but for understanding a particular patient’s liability for adverse treatment outcomes or drug reactions. These efforts can be greatly facilitated by support from the relevant professional societies.
Summary

Genetics is likely to play a significant role in nearly every neurologic sub-discipline in future clinical practice. Therefore, the strategic goals outlined in this neurogenetics plan need to be thoughtfully integrated across many AAN section topics, both from a research and clinical standpoint. This includes, but is not limited to issues related to genetic testing, education at all levels of pre and post residency training, and the need for ample biomaterials and data repositories to promote patient oriented translational research. Advances in genetic technologies and our knowledge pertaining to the genetic basis of common neurologic disease necessitates dealing with these issues now. However, few resources are currently available to facilitate the achievement of the short or long-term goals. Therefore, a key current challenge is to garner the resources and support from other sections to develop and implement these goals, at the same time that the details of these goals are being filled in.

Contributors: Dominic Fee, MD, Daniel Geschwind, MD, PhD, Joseph Higgins, MD, FAAN, David Lynch, MD, PhD, Katherine Mathews, MD, Massimo Pandolfo, MD, Susan Perlman, MD, Louis Ptacek, MD, FAAN, Teepu Siddique, MD, FAAN, Shoji Tsuji, MD, PhD