



American College of Medical Genetics

Medical Genetics: Translating Genes Into Health®

Competencies for the Physician Medical Geneticist in the 21st Century

Report of a Working Group of the American College of Medical Genetics

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Introduction

Certification for physician medical geneticists has been offered by the American Board of Medical Genetics since 1982 and has been recognized by the American Board of Medical Specialties since 1991. Since this time, major advances have been made in genetics and genomics that greatly increase the impact of the discipline in all areas of medicine. New opportunities include treatment of both rare and common genetic disorders, expanded newborn screening and carrier screening programs, testing for risk of cancer and other adult-onset disorders, pharmacogenetic testing, and genomic analysis, including whole exome or genome sequencing. In spite of these advances, the number of physicians who complete medical genetics training and achieve ABMG certification has remained flat in recent years (Figure 1). In part, this may be due to national trends, fueled by the high debt of graduating medical students and a consequent tendency of medical students to train in high-paying specialties. In part it may be due to a relative lack of visibility of medical genetics to students at a time when they are making career decisions.

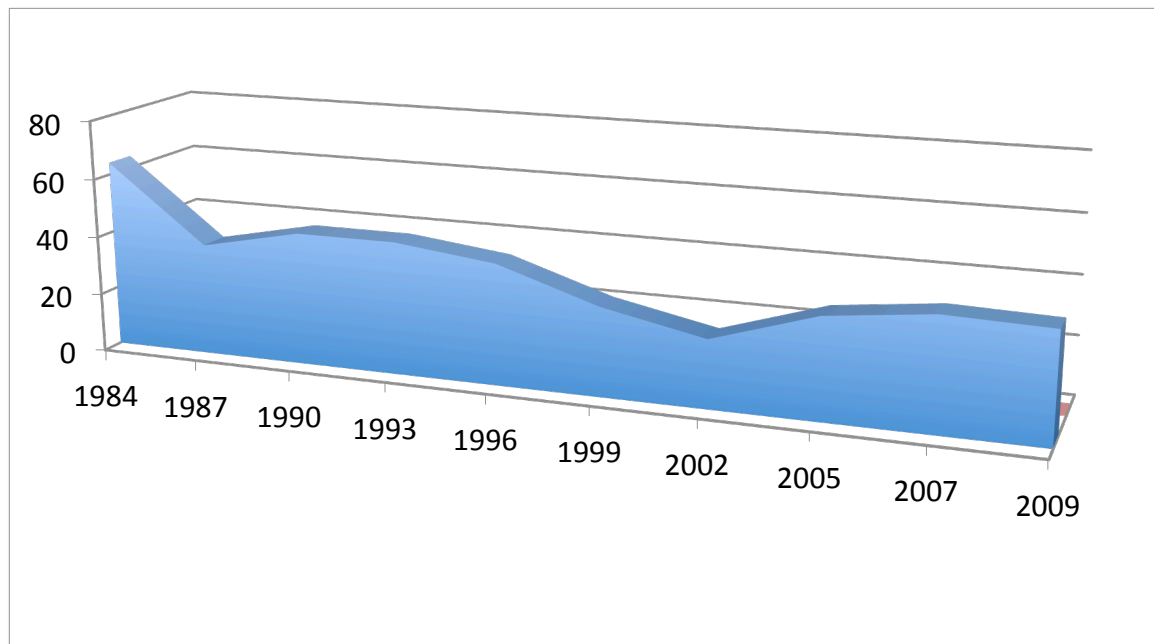


Figure 1 Average number of new ABMG diplomates in clinical genetics by year; the dip from 1996 - 2002 is attributable to the change in residency accreditation from ABMG to ACGME, with a temporary decline in the number of accredited programs.

The medical genetics community has organized a set of meetings to discuss ways to increase the “pipeline” of medical genetics trainees. The first, held at the Banbury Conference Center in 2004 (Korf et al. 2005), proposed expansion of the scope of medical genetics training to encompass new areas of practice. The second, held at the Banbury Center in 2006 (Korf et al. 2008), considered the scope of practice of medical

genetics given new advances in genetics and genomics. The latter meeting concluded with the suggestion that the medical genetics curriculum for training and maintenance of certification should be updated.

The present document provides a set of competencies and learning objectives for physician medical genetics training and lifelong learning, produced by a working group of the American College of Medical Genetics. Invited participants (Appendix A) met February 19-22, 2010, at Stone Mountain Conference Center, Atlanta, GA. Participants were asked to prepare a brief document outlining major areas of knowledge expected of the medical geneticist in a variety of topic areas, as well as the ten most common clinical presentations that might be seen by a medical geneticist. The group then used this material to compile the competencies and learning objectives, including overarching competencies and those specific to a given topic area.

The decision to focus on competencies rather than to produce a detailed list of knowledge, skills, and attitudes was made for several reasons. First, a comprehensive listing would be unwieldy and inevitably would be incomplete. Second, such a list would likely go out of date quickly. Third, it would appear prescriptive and might limit learning decisions made by faculty and trainees. Finally, formulation of competencies and learning objectives makes it clear not only what the medical geneticist should *know*, but also what he or she should be able to *do*. This can be critical in a discipline that spans all of medicine and in which medical geneticists must interact with colleagues in other medical specialties.

The format of this document differs from the six core competencies used by the American Council of Graduate Medical Education to guide residency training (patient care, medical knowledge, practice-based learning and improvement, interpersonal communication skills, professionalism, and systems-based practice). It was felt the competencies expected of a medical geneticist would be clearer if organized according to the work activities specific to medical genetics. The competencies in this document can be mapped to the ACGME six core competencies, which would be helpful for medical genetics residency program directors.

This document is divided into two sections: overarching competencies and discipline-specific competencies. Medical genetics encompasses essentially all of medicine; the overarching competencies define the history-taking, risk assessment, physical examination, communication skills, *etc.*, that span all areas of medical genetics. The discipline-specific competencies are organized by body system for the most part and identify skills that are specific to that area. This is not to imply that a trainee in medical genetics only needs to acquire competency in specialty areas of interest. A medical geneticist is expected to acquire all these competencies; organization into discipline-specific areas provides an expedient way to organize a large volume of information. Most of the discipline-specific sections include three types of competencies. First are things a medical geneticist should be able to do when functioning as a consultant. This

includes things like providing a differential diagnosis of genetic disorders and organizing and interpreting genetic testing. It is presumed that, in most cases, the geneticist will not have primary responsibility for the care of the patient, but instead is helping to guide the genetic evaluation along with other providers. The second competency addresses disorders where the medical geneticist is likely to play a role in providing longitudinal management. The third competency addresses the interpretation of genomic tests for common disorders that fit within the discipline.

Overarching Competencies

Competency 1: Obtain and interpret medical, social, and family histories, as well as physical examination findings, necessary for the evaluation of patients with or at-risk for genetic disorders.

Learning Objectives:

Medical and Social History

1. Obtain and interpret all pertinent history in the evaluation of a patient with a suspected genetic condition.
2. Recognize deviations from normal growth and development throughout the life cycle.

Family History

1. Obtain a multi-generation pedigree appropriate to the clinical question.
2. Recognize the patterns of Mendelian inheritance or the occurrence of familial clustering in pedigrees.
3. Recognize the hallmarks of mitochondrial disorders, including maternal inheritance, heteroplasmy, and disease threshold.
4. Appreciate transmission patterns indicative of abnormalities of imprinting.
5. Recognize the inheritance patterns associated with disorders due to triplet repeat expansion.
6. Identify patterns indicative of germline or somatic mosaicism.

Physical Examination

1. Recognize and document pertinent normal, dysmorphic, and other physical features associated with disease-specific phenotypes.
2. Obtain and interpret anthropometric measurements required for a complete dysmorphology examination.

Competency 2: Order and interpret genetic tests and apply results to patient management and counseling.

Learning Objectives:

1. Recognize the indications for prenatal, carrier, diagnostic, presymptomatic, and predictive genetic tests.
2. Formulate a strategy for testing that integrates family history and dynamics, patient preference, clinical needs, and financial issues.
3. Apply the principles of analytical and clinical validity in selecting and ordering the appropriate test(s) at the right time.

4. Utilize evidence-based guidelines in genetic testing, where available.
5. Meet the pre-analytical requirements for genetic tests, such as sample requirements.
6. Recognize the capabilities and limitations of different technology platforms and how they apply to test selection.
7. Become informed about expectation of turn-around-time and cost and communicate these expectations to patients and health professionals.
8. Maintain clear communications with the testing laboratory, such as in the evaluation of challenging cases.
9. Recognize the distinction between clinical and research testing, and the need to verify research results for clinical use in a clinical laboratory.
10. Appreciate the implications of intellectual property and patent laws on access to genetic testing.
11. Interpret standard nomenclature used in reporting genetic test results.
12. Critically interpret genetic test results, recognizing the distinction between benign variants and clinically significant findings.
13. Participate in the collection of clinical and laboratory information for the improvement of the quality of patient care.
14. Incorporate the results of genetic tests into strategies for patient evaluation and management.
15. Use resources available for interpretation of genetic tests, such as genome and phenotypic databases and bioinformatic tools.

Competency 3: Integrate multiple sources of information, including family history, physical examination, genetic testing, and databases, to quantify genetic risks to an individual or to family members.

Learning Objectives:

1. Calculate risks utilizing principles of Mendelian transmission, population genetics, and using Bayesian approaches.
2. Appreciate how germline mosaicism affects recurrence risk counseling.
3. Recognize the clinical significance and reproductive implications of somatic mosaicism, uniparental disomy, and imprinting mutations.
4. Incorporate the results of genetic testing into risk assessment, taking into account the possibility of both false negative and false positive results.
5. Assess risks of multifactorial disorders based on empirical data, knowledge of environmental exposures, and results of genomic testing.

Competency 4: Apply the principles of effective communication in the care of patients with or at-risk for genetic conditions.**Learning Objectives:**

1. Communicate risk assessment, genetic test results, and options for care and courses of action in a clear, accurate, and balanced manner to patients and families.
2. Tailor information to the literacy level of the family, assessing comprehension during the process.
3. Demonstrate knowledge of and sensitivity to cultural values in communicating genetic information to individuals and families.
4. Provide patients and families with access to accurate and balanced sources of information and support, including referrals to appropriate resources, and addressing family communication issues.
5. Communicate unfavorable results or outcomes to patients and families in an accurate and compassionate manner.
6. Work as part of a care team, communicating appropriately with patients, family members, and other health professionals.

Competency 5: Apply knowledge of a genetic condition to formulate, implement, and monitor a management plan.**Learning Objectives:**

1. Critically evaluate data on the clinical utility (*e.g.*, effectiveness, risks, and benefits) of available modes of treatment.
2. Follow clinical practice guidelines for management and treatment of patients with or at-risk for genetic disorders, where available.
3. Make an appropriate decision as to whether a treatment should be managed by a geneticist or by another specialist.
4. Insure that patients with genetic disorders have a medical home to provide coordination of care.
5. Educate patients and other care providers regarding indications for, as well as risks and benefits of, treatments.
6. Provide ongoing monitoring and appropriate reporting for adverse events, long-term complications, and effectiveness of therapeutic interventions.
7. Formulate plans and work with families and other health providers to facilitate smooth transitions from pediatric to adult care for individuals with genetic diagnoses.

Competency 6: Assess and participate in a clinical or translational research study or clinical trial involving patients with or at-risk for a genetic disorder.**Learning Objectives:**

1. Critically evaluate protocols and/or publications reporting results of clinical research studies and clinical trials relevant to genetic disorders.
2. Achieve IRB certification to participate in human subjects research.
3. Appreciate the ethical issues that are specific to genetic and genomic studies, such as return of research results, identification of a participant through genetic data, revelation of unexpected family relationships, or discovery of incidental findings that may be clinically significant.
4. Educate participants regarding risks and benefits of participation in research and obtain informed consent and/or assent.

Competency 7: Apply knowledge of the core public health functions (assessment, assurance, policy development) to patient care.**Learning objectives:**

1. Recognize the role of quality assurance and improvement efforts in the delivery of genetic services, including newborn screening, prenatal screening, carrier screening, genetic risk assessment for common diseases, and genetic consultation for rare disorders.
2. Recognize how policy development serves the public interest to promote the appropriate use of genetic services, including: (a) oversight/regulation of the development and marketing of genetic tests and products, (b) education of the health professional workforce in basic competencies in genetics/genomics, (c) ensuring adequate numbers of genetics professionals in the healthcare workforce, (d) development and dissemination of evidence-based care standards and guidelines, (e) informing the public on limitations and benefits of genetic information, and (f) enacting and enforcing genetic nondiscrimination laws.

Competency 8: Provide patient care with sensitivity to the ethical issues that relate to the delivery of genetic services.**Learning Objectives:**

1. Recognize the ethical considerations for *patients/consumers* related to delivery of genetic services, including: (a) potential benefits, harms and limitations, (b) right to know/right to not know (autonomy), (c) potential for coercion to test, treat, or participate in research, (d) privacy of medical/genetic information, (e)

- impact on reproductive decision making, and (f) testing of minor children for adult-onset conditions.
2. Recognize the ethical considerations for *clinicians* related to delivery of genetic services, including: (a) duty to inform patients about risks to family members, (b) duty to recontact patients about new information relating to a genetic diagnosis or test result, (c) maintaining confidentiality, and (d) testing of minors for adult-onset conditions.
 3. Recognize the ethical considerations for *communities* related to delivery of genetic services, including: (a) the fair distribution of benefits and burdens across a population, (b) balance of benefits over harms and other costs/utility, and (c) maintenance of trust within a community.

Competency 9: Provide counseling to individuals regarding the application of whole genome or whole exome sequencing.

Learning Objectives:

1. Explain to an individual contemplating whole exome or genome analysis the potential risks, benefits and limitations of the information that will be obtained and facilitate informed decision-making.
2. Prioritize the information obtained from whole exome or genome analysis, including carrier status for recessive disorders, single gene disorders, pharmacogenetic traits, and alleles that confer risk of common disease, in providing feedback and counseling.
3. Describe potential risks and benefits that may be associated with disclosing risks of adult-onset disorders in children.
4. Utilize genomic databases and bioinformatics tools to filter results on genetic variants and assess their clinical significance.
5. Explain the difference between variants of known clinical significance and variants of unknown clinical significance in providing counseling on whole exome or genome analysis.
6. Explain the concepts of odds ratio and relative and absolute risk, and the limitations in interpretation of genotypic data regarding risk of common disease.

Discipline-Specific Competencies

Biochemical/Metabolic Genetics

Competency 1: Recognize the acute presentations of inherited metabolic disorders in newborns, children, and adults – especially those disorders amenable to specific treatments – and guide the appropriate initial therapies and diagnostic evaluations.

Learning Objectives:

1. Recognize that the acute clinical presentations of metabolic disorders are medical emergencies that are often heralded by nonspecific symptoms, such as lethargy, vomiting, hypotonia, or seizures, and that one must consider metabolic disorders along with other causes of such symptoms and promptly send appropriate metabolic screening tests.
2. Recognize that when acute metabolic instability, such as hypoglycemia, metabolic acidosis, hyperammonemia, or other metabolic “intoxications” are found or strongly suspected, initial therapy – usually including intravenous administration of sufficient glucose to lessen catabolism – must not be delayed and should proceed in conjunction with ongoing diagnostic evaluations.
3. Be familiar with the differential diagnoses of hypoglycemia, metabolic acidosis, hyperammonemia, the “neonate in crisis,” and acute liver disease, and be prepared to guide diagnostic evaluations and therapies for the possible metabolic causes of these clinical problems.

Competency 2: Evaluate patients found to have abnormal newborn screening test results suggestive of inherited metabolic disorders, including appropriate triage of such patients for repeat screening and primary care medical evaluation or, when necessary, provision of timely biochemical genetic evaluation and treatment, while also advising primary care physicians and counseling parents with regard to these matters.

Learning Objectives:

1. Recognize that newborn screening programs are not uniform in their extent or operation in all jurisdictions, but generally try to screen – predominantly through testing of dried blood spots – neonates for a set of congenital disorders for which early detection and treatment are likely to be beneficial.
2. Describe the newborn screening test panels in your jurisdiction and neighboring geographical areas, as well as follow-up systems.

3. Describe the clinical findings, appropriate follow-up diagnostic evaluations, and initial treatments for the disorders often covered by newborn screening tests.
4. Recognize the multiple possible causes of “false positive” results on newborn screening tests and be sensitive to the emotional stresses any “positive” result (whether truly positive or falsely positive) may cause for parents/caregivers.
5. Recognize that even a single, initial (not yet confirmed) newborn screening test result may represent a medical emergency and may require immediate medical evaluation if the diagnosis suggested by that test result may present with catastrophic early infantile complications.
6. Be prepared to offer appropriate advice to primary care physicians when abnormal newborn screening test results are found, including appropriately triaging patients based on their initial newborn screening test results, recognizing that the appropriate care may sometimes only require repeating the newborn screening test and general primary care evaluation, but may at other times require urgent and/or more specialized medical evaluation and/or treatment.
7. Use evidence-based recommendations and/or clinical practice guidelines, when available, to provide appropriate medical evaluation, treatment, and counseling for disorders detected by newborn screening tests.

Competency 3: Recognize the sub-acute or chronic presentations of inherited metabolic disorders, such as failure-to-thrive, developmental delay, neurological deterioration, seizures, liver dysfunction, myopathy, organomegaly, or other associated neurological or somatic findings, and guide appropriate diagnostic evaluations.

Learning Objectives:

1. Describe the natural histories and clinical findings of metabolic disorders having sub-acute or chronic presentations, including mitochondrial, lysosomal, and peroxisomal disorders, as well as specific enzymatic defects (including but not limited to amino acid disorders, urea cycle disorders, neurotransmitter deficiencies, organic acidurias, fatty acid oxidation defects, and carbohydrate disorders).
2. Describe the major differential diagnoses of failure-to-thrive, developmental delay, neurological deterioration, leukodystrophy, microcephaly, liver dysfunction, cardiac and/or skeletal myopathy, organomegaly, “coarse facial features,” dysostosis multiplex, cataracts, corneal opacities, and retinal pigmentary abnormalities.
3. Use available evidence-based recommendations and/or clinical practice guidelines in the metabolic evaluation of patients.

4. Recognize clues (such as episodes of acute metabolic instability, food avoidance, odd body odor, developmental regression, or physical exam findings) that may make a diagnosis of a metabolic disorder more likely.
5. Based on an appropriate differential diagnosis and familiarity with available diagnostic testing options, recommend a reasonable (often prioritized and sequential) set of diagnostic tests to be considered in the metabolic genetic evaluation of patients with sub-acute or chronic symptoms suggestive of a possible metabolic disorder.
6. Place the highest priority on the detection of possibly treatable disorders.

Competency 4: Provide ongoing metabolic care for patients with known or suspected inherited metabolic disorders, especially those for which effective, specific medical and/or dietary therapy exists.

Learning Objectives:

1. Recognize the importance of cooperative multidisciplinary care for patients affected by metabolic disorders, including contributions from primary care physicians and other medical specialists, as well as metabolic dietitians and psychological and social support professionals and school/educational and community resources.
2. Guide the coordinated medical and/or dietary treatment of metabolic disorders for which such therapies are indicated, including galactosemia, phenylketonuria, tyrosinemia, maple syrup urine disease, other amino acid disorders, urea cycle disorders, organic acidurias, fatty acid oxidation disorders, hereditary fructose intolerance, glycogen storage disorders, pyruvate dehydrogenase deficiency, and mitochondrial disorders.
3. Prescribe and oversee enzyme replacement therapies for applicable disorders, including lysosomal storage disorders.

Cancer Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, inheritance and natural history of cancer to guide the appropriate use of genetic testing in diagnosis, risk assessment, and counseling of inherited cancer susceptibility syndromes and communicate results to patients and families.

Learning Objectives:

1. Differentiate between sporadic, familial, and Mendelian forms of cancer and incorporate these categories into counseling patients and family members about inheritance and risk for cancer.
2. Use family history, age at diagnosis, and tumor parameters (stage, grade, histopathology, and tumor markers) for a patient with breast cancer to formulate a differential diagnosis of familial breast cancer.
3. Develop a genetic testing strategy for breast cancer based on knowledge of the genetic and cellular pathways associated with familial breast cancer and cancer risk computer algorithms.
4. Use family history, age at diagnosis, and tumor parameters (stage, grade, histopathology, and tumor markers) for a patient with colorectal cancer or colorectal polyps to formulate a differential diagnosis of familial colorectal cancer.
5. Develop a genetic testing strategy for colorectal cancer based on knowledge of the genetic and cellular pathways in the adenoma to carcinoma sequence.
6. Use family history plus the type of cancer, stage, grade, histopathology, and tumor markers to formulate a differential diagnosis of rare familial cancer syndromes, such as multiple endocrine neoplasia, familial medullary thyroid carcinoma, Li-Fraumeni syndrome, retinoblastoma, *etc.*
7. Recognize the risks of cancer occurring as a complication of developmental disorders, such as Fanconi anemia, ataxia telangiectasia, Bloom syndrome, *etc.*

Competency 2: Provide counseling, testing, and longitudinal management for patients and family members with familial cancer syndromes.

Learning Objectives:

1. Develop a management strategy for women and men with hereditary breast and ovarian cancer syndrome, including interval surveillance, imaging, chemoprevention, and preventative strategies.
2. Develop a management strategy for men and women with hereditary nonpolyposis colon cancer and familial adenomatous polyposis, including interval surveillance, screening, and consideration of preventative surgery.

3. Provide counseling and genetic testing and/or referral of at-risk family members in kindreds with known cancer susceptibility mutations, incorporating the age, sex, and pedigree position of the family member.
4. Develop a management strategy for familial cancers without identifiable cancer susceptibility mutations (*e.g.*, strong family histories with or without uncertain variants).

Competency 3: Interpret the results of genomic tests for diagnosis or prognosis of patients with cancer and/or computer risk algorithms to determine risk for cancer in the general population.

Learning Objectives:

1. Counsel patients and other healthcare providers about the clinical significance of colon tumor tests for mismatch repair deficiency (*e.g.*, microsatellite instability and immunohistochemistry).
2. Based on knowledge of the clinical utility of direct DNA tests in the stool, provide guidance to patients and other healthcare providers about the associated risks and management options for colon cancer.
3. Explain to cancer patients who have specific tumor tests, such as breast cancer expression array testing or colon cancer K-ras testing, the clinical utility of these tests.
4. Counsel patients and healthcare providers about the mechanism of action of tumor-specific therapies (*e.g.*, imatinib for chronic myelogenous leukemia, Herceptin for Her2/neu positive breast cancer).
5. Develop a management plan and counsel patients about cancer risk markers found on genomic tests (*e.g.*, APC I1307K allele and colon cancer risk in an Ashkenazi Jewish individual; Vitamin D markers for colon cancer, SNP markers and breast cancer risk).
6. Based on knowledge of statistical risk algorithms, provide interpretation of risks to patients and other healthcare providers for a) risk for disease development (*e.g.*, Gail and Claus models); and b) risk for having specific cancer susceptibility mutation (*e.g.*, BRCA1, BRCA2, MMR1, MMR2).

Connective Tissue

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of connective tissue disorders to guide the appropriate use of genetic testing in diagnosis and counseling of connective tissue disorders and communicate results to patients and families.

Learning Objectives:

1. Conduct a physical examination appropriate for evaluation of an individual with a suspected connective tissue disorder, including appropriate body measurements (arm span, upper/lower segment ratios, Beighton score, arachnodactyly, hindfoot valgus, pes planus, pectoral abnormalities, *etc.*).
2. Formulate a differential diagnosis for a patient with joint laxity using family history, developmental history, medical history, and physical examination.
3. Formulate a differential diagnosis for a patient with Marfanoid habitus using family history, medical history and physical examination, and differentiate familial tall stature from tall stature consistent with a connective tissue disorder.
4. Formulate a differential diagnosis for a patient with aortic dilatation using family history, medical history, and physical examination.
5. Apply diagnostic criteria to establish a diagnosis of Marfan syndrome and be able to differentiate from conditions that may present similarly, such as Loeys-Dietz syndrome, Ehlers-Danlos syndrome (EDS), and homocystinuria.
6. Apply diagnostic criteria to establish a diagnosis of Loeys-Dietz syndrome, including use of imaging (such as evidence of vascular tortuosity).
7. Establish the specific type of EDS based on diagnostic criteria using the findings on physical examination and family and medical history, recognizing the importance of differentiating between the various types of EDS in order to provide the most appropriate counseling and surveillance.
8. Apply clinical and laboratory criteria to establish a diagnosis of Stickler syndrome.
9. Explain to patients the sensitivity and limitations of genetic testing for the different connective tissue disorders.

Competency 2: Apply knowledge of pathophysiology and natural history of the disorders to provide anticipatory guidance and longitudinal management to patients with connective tissue disorders.

Learning Objectives:

1. Provide anticipatory guidance, surveillance for complications (such as imaging of the aorta, ophthalmological surveillance for lens dislocation and retinal detachment), medical management, and specialty referral to patients with

- Marfan syndrome. Formulate a plan for acute management of events in individuals with Marfan syndrome.
2. Provide anticipatory guidance, appropriate ongoing surveillance for complications (such as imaging of vasculature, assessment of cervical spine instability), medical management and specialty referral to patients with Loeys-Dietz syndrome. Formulate a plan for acute management of events in individuals with Loeys-Dietz syndrome.
 3. Based upon the specific type of Ehlers-Danlos syndrome, provide appropriate anticipatory guidance, surveillance for complications, medical management, and specialty referral to patients with Ehlers-Danlos syndrome. Formulate a plan for chronic management of patients with EDS, such as ongoing orthopedic and pain management care. Formulate a plan for acute management of events in individuals with EDS.
 4. Provide the appropriate anticipatory guidance, surveillance for complications (hearing loss, retinal detachment and degenerative arthritis) for individuals with Stickler syndrome.

Competency 3: Apply knowledge of the underlying inheritance patterns and available genetic testing to provide appropriate genetic counseling to patients and families with connective tissue disorders.

Learning Objectives:

1. Provide counseling and recurrence risk estimates to the family, identify at-risk relatives, and recommend genetic and/or screening tests as appropriate.
2. Discuss appropriate family planning issues with affected family members (pregnancy complications, inheritance patterns, possible prenatal diagnostic options).

Cardiovascular Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of cardiovascular disease to guide the appropriate use of genetic testing in diagnosis and counseling of isolated cardiovascular disease (nonsyndromic congenital heart disease, cardiomyopathy, channelopathy, or dyslipidemia) and communicate results to patients and families.

Learning Objectives:

1. Formulate a differential diagnosis for a patient with isolated cardiovascular disease using family history and interpretation of lipid profile, echocardiogram, ECG, and/or MRI results.
2. Order appropriate genetic testing based upon the cardiovascular phenotype and interpret the results, identify and test or screen at-risk family members, and provide counseling and recurrence risk estimates to families.
3. Develop a differential diagnosis for sudden death based on available medical history and autopsy report. Identify at-risk family members. Determine the utility of genetic testing of the proband (if DNA is available) *versus* at-risk relatives and test as appropriate. Identify at-risk family members, counsel the family, provide recurrence risk estimates, and recommend screening or genetic testing as appropriate.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with syndromic congenital heart disease.

Learning Objectives:

1. Formulate a differential diagnosis using family history, developmental history, medical history, physical examination, and laboratory and imaging results.
2. Recognize the particular congenital heart lesions that are often associated with a specific diagnosis and apply to the formulation of a differential diagnosis.
3. Offer genetic testing as appropriate to the differential diagnoses, interpret the results, identify and evaluate and/or test at-risk relatives, and provide counseling and recurrence risk estimates to the family.
4. Provide anticipatory guidance, surveillance for complications, and long-term coordination of care, including transition from pediatric to adult care, based upon published guidelines when available.

Competency 3: Establish diagnosis and provide counseling and longitudinal management to patients with metabolic cardiomyopathy.**Learning Objectives:**

1. Formulate a differential diagnosis for a child with suspected metabolic cardiomyopathy using family history, developmental history, medical history, physical examination, and interpretation of biochemical screening, imaging, and pathology results.
2. Offer diagnostic genetic testing when available, identify and test at-risk relatives, and provide counseling and recurrence risk estimates to the family.
3. Provide anticipatory guidance, surveillance for complications, medical treatment(s), and specialty referral.

Competency 4: Interpret results of genome-wide testing and provide counseling and recurrence risk estimates to families with cardiovascular disease.**Learning Objectives:**

1. Interpret the implications of pathogenic CNVs and SNPs associated with cardiovascular disease, using available databases and publications. Counsel and use parental testing to provide recurrence risk estimates.
2. Describe the genetic factors that influence common cardiovascular disorders such as hypertension and coronary artery disease and apply them to risk assessment.

Deafness

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of the auditory system to guide the appropriate use of genetic testing in diagnosis and counseling of patients with congenital or acquired deafness or hearing loss.

Learning Objectives:

1. Formulate a differential diagnosis newborn identified with congenital deafness either through newborn screening or clinically.
2. Explain the distinction between syndromic and nonsyndromic forms of deafness.
3. Explain the role of congenital infection in the etiology of deafness and the use of tests to establish a diagnosis.
4. Interpret audiologic tests and distinguish different patterns of hearing impairment, including sensorineural and conductive.
5. Describe the application of imaging in the evaluation of hearing loss and the structural and tumor-related diagnoses that can be established.
6. Describe the indications for tests such as ECG, imaging, kidney function testing, thyroid function testing, and ophthalmological assessment in the evaluation of hearing loss.
7. Formulate a management plan for a child or an adult with congenital or progressive hearing impairment, including referral to appropriate specialists, discussion of prostheses such as hearing aids and cochlear or brainstem implants, and consideration of learning sign language.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with syndromic congenital heart disease.

Learning Objectives:

1. Describe the specific findings on physical examination that can indicate syndromes associated with deafness, such as dystopia canthorum, white forelock, and heterochromia iridis, pre-auricular pits, branchial cleft pits, and external ear anomalies.
2. Develop a plan for monitoring hearing in patients with genetic disorders that may be complicated by hearing loss, such as neurofibromatosis 2, osteogenesis imperfecta, Stickler syndrome, Waardenburg syndrome, branchio-oto-renal syndrome, *etc.*

Competency 3: Interpret results of genome-wide testing and provide counseling and recurrence risk estimates to families regarding risk of deafness.

Learning Objectives:

1. Interpret the results of multigene panels used in the evaluation of infants identified by newborn hearing screening, or in the evaluation of individuals presenting with hearing loss.
2. Interpret results of genome-wide tests, including whole genome sequencing, that may predict risk of hearing impairment and provide counseling to individuals and families.

Dermatologic Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of dermatological disease to guide the appropriate use of genetic testing in diagnosis and counseling of patients with suspected genodermatoses and communicate results to patients and families.

Learning Objectives:

1. Formulate a differential diagnosis for a patient with abnormal skin pigmentation based on the type of defect (hyperpigmentation, hypopigmentation, depigmentation), lesion morphology and distribution, and associated clinical features.
2. Formulate a differential diagnosis for a patient with an ichthyosiform disorder based on family history, physical examination, associated features, and skin biopsy.
3. Recognize the features of skin fragility and blistering associated with epidermolysis bullosa. Identify subtype using family history and clinical features, along with results from skin biopsy and genetic testing.
4. Formulate a differential diagnosis for a patient with abnormal ectodermal structures (hair, teeth, nails, sweat glands) based on family history and physical examination.
5. Formulate a differential diagnosis for a patient with premature aging, photosensitivity, vascular lesions or multiple cutaneous neoplasms or hamartomas using family and medical history, physical examination, skin biopsy and laboratory testing.
6. Order appropriate genetic testing for suspected genodermatoses based on the phenotype and interpret the result. Identify and test or screen at-risk family members, and provide counseling and recurrence risk estimates to families.
7. Recognize the cutaneous features that are associated with multisystem disorders, such as café-au-lait spots, hypopigmented macules, angiofibromas, pigmentary dysplasia, dermal hypoplasia, and cutaneous vascular anomalies, and guide the workup to establish a definitive diagnosis.
8. Recognize the cutaneous features that are found in disorders with malignant potential, such as basal cell nevi, pigmented labial macules, and other multiple skin hamartomas and guide the workup to establish a definitive diagnosis and surveillance protocol.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with complex syndromes that present with dermatological features, such as phakomatoses and premature aging syndromes.

Learning Objectives:

1. Formulate a differential diagnosis using family history, developmental history, medical history, physical examination, and laboratory and imaging results.
2. Recognize the particular skin lesions that are often associated with a specific diagnosis and apply to the formulation of a differential diagnosis.
3. Offer genetic testing as appropriate for the differential diagnoses, interpret the results, identify and evaluate and/or test at-risk relatives, and provide counseling and recurrence risk estimates to the family.
4. Provide anticipatory guidance, surveillance for complications, and long-term coordination of care, based upon published guidelines when available.

Competency 3: Interpret results of genome-wide testing and provide counseling to individuals at risk for dermatological disorders, such as psoriasis and skin cancer.

Learning Objectives:

1. Interpret the implications of copy number variations (CNVs) and single nucleotide polymorphisms (SNPs) using available databases and publications. Counsel patient and family members as appropriate, using parental testing to provide recurrence risk estimates.

Dysmorphology

Competency 1: Classify congenital anomalies according to etiological mechanism and use this information in the evaluation and management of the patient.

Learning objectives:

1. Determine if a congenital anomaly represents a malformation, deformation, disruption, or dysplasia.
2. Explain the difference between a syndrome, sequence, and association.
3. Explain congenital anomalies in terms of dysfunction of normal development, both at the level of the embryo and at the level of cellular mechanisms of morphogenesis.
4. Recognize the roles of teratogens, chromosome abnormalities, single gene defects, multifactorial traits, inborn errors of metabolism, and methylation abnormalities in the etiology of congenital anomalies.

Competency 2: Apply skills in obtaining history and performing physical examination in formulating a differential diagnosis of a patient with congenital anomalies.

Learning Objectives:

1. Explain how fetal exposures/environment can adversely affect fetal growth and/or development.
2. Explain how prenatal studies can facilitate diagnostic evaluation.
3. Obtain a complete pre- and perinatal history, including delivery, Apgar scores, growth parameters, newborn nursery course, feeding, metabolic instability, newborn screening results, hearing screening, presence of anomalies or other physical findings.
4. Define developmental milestones and growth parameters and recognize patterns of abnormal development.
5. Obtain a complete postnatal history, including review of systems, prior testing, imaging, previous evaluations, medications, and allergies.
6. Obtain a comprehensive family history appropriate to the patient, including structural anomalies, intellectual/learning disabilities, infant or sudden deaths.
7. Explain why inquiring about recurrent pregnancy loss or history of infertility is relevant in the evaluation of the newborn with multiple congenital anomalies or intrauterine growth retardation (IUGR).
8. Explain how seemingly unrelated medical conditions can result from the same genetic disorder.

Competency 3: Apply knowledge of anatomy, pathophysiology, and natural history of conditions associated with congenital anomalies to inform differential diagnosis and direct genetic testing strategies.

Learning objectives:

1. Formulate a differential diagnosis and testing strategy for a patient with one or more major anomalies.
2. Recognize the specific patterns of dysmorphic features that allow for clinical diagnosis of recognizable genetic conditions.
3. Formulate a differential diagnosis for a patient with hypotonia and dysmorphic features.
4. Formulate a differential diagnosis for a patient with disordered growth.
5. Formulate a differential diagnosis for a patient with autism and dysmorphic features.

Competency 4. Establish diagnosis and provide counseling, education, and longitudinal management to patients with congenital anomaly syndromes.

Learning objectives:

1. Apply diagnostic criteria to establish diagnosis of congenital anomaly syndromes, using and interpreting genetic testing as necessary.
2. Provide anticipatory guidance, surveillance for complications, and coordination of care for patients with congenital anomaly syndromes, using clinical practice guidelines when available
3. In the absence of clinical practice guidelines, develop individual management plans for coordination of patient care, to include communication with primary care and other health care providers.
4. Provide genetic counseling and education to patients and families based on known inheritance pattern or empiric risk.
5. Identify resources for patient and family support.

Endocrine Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of endocrine disorders to guide the appropriate use of genetic testing in diagnosis and counseling of inherited endocrine diseases and communicate results to patients and families.

Learning objectives:

1. Formulate a differential for a child with short stature, including syndromic causes and skeletal dysplasias, using family and medical history, physical examination findings (including anthropomorphic measures), and interpretation of laboratory results.
2. Evaluate a child born with ambiguous genitalia, performing a comprehensive physical examination to rule out a genetic syndrome, form a differential diagnosis, and order the appropriate genetic testing and interpret the results.
3. Recognize Albright's hereditary osteodystrophy and perform diagnostic testing to establish the diagnosis. Describe the role of genomic imprinting associated with pseudohypoparathyroidism.
4. Counsel families with a child with 21-hydroxylase deficiency on recurrence risk, risk of having an affected female, implications for genital development, and options for prenatal treatment of a potentially affected female with dexamethasone given to the mother during pregnancy.
5. Counsel adults with infertility on the genetic causes, including Klinefelter syndrome, mosaic Turner syndrome, and androgen insensitivity syndrome.
6. Formulate a differential diagnosis for sex reversal, perform the appropriate genetic testing, and counsel the patient and family.
7. Counsel families with multiple endocrine neoplasia (MEN) I or II on the recurrence risk, screening tests, and potential for prophylactic surgery.
8. Evaluate the child with thyroid abnormalities and hearing loss for Pendred syndrome.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with sex chromosome abnormalities and mixed gonadal dysgenesis.

Learning Objectives:

1. Diagnosis and counsel boys with Klinefelter syndrome and its variants, and provide a management plan, including hormonal treatments.
2. Evaluate the karyotype in a female with Turner syndrome, know when to order further genetic testing for Y markers, counsel the family when gonadectomy is indicated and explain the issues of mosaicism.

3. Provide anticipatory counseling and follow patients with Turner syndrome for cardiac, growth, developmental, and pubertal/reproductive issues.
4. Help with the transition to adult care and provide anticipatory counseling on adult-onset issues

Competency 3: Interpret the results of genomic tests for risk assessment of common endocrine disorders and provide counseling to patients and families

1. Interpret the implications of CNVs and SNPs for common endocrinological disorders such as diabetes mellitus, using available databases and publications.

Gastrointestinal Genetics

Competency 1: Apply knowledge of pathology, natural history and inheritance to guide the appropriate use of genetic testing in the diagnosis and counseling of patients with primary genetic disorders affecting the gastrointestinal system.

Learning Objectives:

1. Formulate a differential diagnosis for a patient with a personal or family history of polyposis. Order appropriate genetic testing based upon the phenotype and interpret the results, identify and test or screen at-risk family members, and provide counseling and recurrence risk estimates to families.
2. Provide a differential diagnosis for congenital anomalies such as intestinal aganglionosis, pyloric stenosis, intestinal malrotation, *etc.*, order and interpret genetic tests, and provide genetic counseling to patients and family members.
3. Formulate a differential diagnosis for patients with biliary atresia or arteriohepatic dysplasia, order and interpret genetic tests, and provide genetic counseling to patients and family members.
4. Formulate a differential diagnosis for patients with hereditary pancreatitis, order and interpret genetic tests, and provide genetic counseling to patients and family members.
5. Recognize the need for a cancer control plan for extra-intestinal cancers in polyposis syndromes (*e.g.*, breast cancer in Peutz-Jeghers syndrome).

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with gastrointestinal features.

Learning Objectives:

1. Recognize that meconium ileus and malabsorption are features of cystic fibrosis.
2. Order and interpret genetic tests for hemochromatosis and provide counseling to family members.
3. Order and interpret genetic tests for alpha-1-antitrypsin deficiency and provide counseling to family members.

Competency 3: Interpret the results of genomic tests for risk assessment of common gastrointestinal disorders and provide counseling to patients and families.

Learning Objectives:

1. Counsel patients on the significance of relative risk assessments for multifactorial gastrointestinal disorders such as inflammatory bowel disease based on results of genomic testing.

Hematological Genetics

Competency 1: Apply knowledge of pathophysiology, and natural history of disorders of the blood and bone marrow to guide the appropriate use of genetic testing in diagnosis and counseling of inherited hematologic diseases and communicate results to patients and families.

Learning objectives:

1. Guide evaluation in families with inherited blood diseases, taking into account the mode of inheritance of common blood disorders.
2. Differentiate the congenital bone marrow failure syndromes, both syndromic and nonsyndromic types, and formulate appropriate imaging and laboratory assessments when non-hematologic findings bring a patient to attention of a geneticist (*e.g.*, thumb or renal anomalies, radial ray defects, cutaneous stigmata, dystrophic nails).
3. Recognize stigmata of Fanconi anemia; appreciate the risks for future marrow failure and cancer predisposition.
4. Recognize the transient myeloproliferative disorder of infants with trisomy 21, and appreciate the role of *GATA1* mutations in pathogenesis.
5. Evaluate genetic causes of familial neutropenia syndromes (*e.g.*, cyclic or severe congenital neutropenia, and Shwachman-Diamond syndrome), and disorders of neutrophil function (*e.g.*, chronic granulomatous disease), focusing on recurrence risk, prognosis, and potential non-hematologic consequences of each.
6. Develop a differential diagnosis for genetic red cell membrane disorders such as hereditary spherocytosis, appreciating that most cases are autosomal dominant but that sporadic new mutations and recessive disease both occur.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with carrier status for hemoglobinopathies.

Learning Objectives:

1. Diagnose and counsel patients with sickle cell trait, beta thalassemia trait, and the various forms of alpha thalassemia trait, distinguishing deletional two-gene alpha thalassemia trait in “cis” (Asian) or “trans” (African origin).
2. Evaluate CBC and hemoglobin electrophoresis results for evidence of thalassemia trait and potential implications for family members.
3. Plan laboratory assessments for pregnant women with microcytic anemia and their partners, taking into account ethnicity and race, for assessment of risk and prognosis in hemoglobinopathies and thalassemia.
4. Counsel families with hemoglobinopathy regarding genetic risks and options for prenatal diagnosis, pre-implantation diagnosis, and potential post-natal therapy.

5. Interpret results of hemoglobinopathy newborn screening. Appreciate the implications of sickle cell-related and non-sickle-cell related findings as they apply to medical risk and potential future genetic risk.
6. Interpret hemoglobinopathy molecular testing in the contexts of
 - a. The complex genetics of globin genes, including deletional and non-deletional mutations,
 - b. Globin as a paradigm for gene switching from fetal to adult beta globin (γ to β) during the first 18 months of life, and the implications for time of onset in alpha thalassemia (prenatal) to beta thalassemia (postnatal)
 - c. The potential for alpha gene deletions or duplications to ameliorate or exacerbate beta thalassemia

Competency 3: Interpret the results of genomic tests for risk assessment of common coagulation disorders and provide counseling to patients and families

Learning Objectives:

1. Counsel families with inherited coagulation disorders on recurrence risk, differentiating X-linked disorders (*e.g.*, Hemophilia A and B), autosomal dominant disorders (*e.g.*, von Willebrand disease), and the rare autosomal recessive syndromes (*e.g.*, factor VII deficiency).
2. Interpret the finding of factor VIII (*f8* gene) inversion mutations in the pathogenesis of severe hemophilia A
3. Evaluate genotype/phenotypic correlations in hemophilias with regard to disease severity and likelihood of development of inhibitors (neutralizing antibodies to antihemophilia factor).
4. Evaluate family histories of thrombotic disorders with regard to the likelihood and appropriate diagnostic evaluations for thrombophilia risk factors, taking into account non-genetic risks for thrombosis, the relative attributable risk and prevalence of various prothrombotic mutations, and factors unique to the consultand, including age, pregnancy status, and past medical history.

Immunological Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of immunologic disorders to guide the appropriate use of genetic testing in diagnosis and counseling of immune deficiency disorders and communicate results to patients and families.

Learning Objectives:

1. Formulate a differential diagnosis for a child with severe combined immune deficiency, including ordering appropriate immunological and genetic tests.
2. Interpret the results of newborn screening data for T cell deficiency, provide counseling, and refer to appropriate specialists for management.
3. Formulate a differential diagnosis for a patient with hypogammaglobulinemia, including ordering appropriate immunological and genetic tests.
4. Formulate a differential diagnosis for a patient with chronic granulomatous disease, including ordering appropriate immunological and genetic tests.
5. Recognize the signs of hereditary angioedema, order appropriate tests, and provide a management plan and counseling.

Competency 2: Monitor individuals with genetic syndromes at risk for immunodeficiency as part of a longitudinal management plan.

Learning Objectives:

1. Test patients with 22q11 deletion syndrome for thymic aplasia and monitor for immune deficiency.
2. Monitor patients with ataxia telangiectasia for immune deficiency and risk of lymphoma.
3. Monitor patients with Wiskott-Aldrich syndrome for autoimmune disease, risk of lymphoreticular malignancy, and thrombocytopenia.

Competency 3: Interpret the results of genomic tests for risk assessment of common immunological disorders and provide counseling to patients and families.

Learning Objectives:

1. Provide counseling on risk of autoimmune disorders based on family history and the results of genomic testing.

Nephrologic Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of renal disease to guide the appropriate use of genetic testing in diagnosis and counseling of inherited kidney disorders and communicate results to patients and families.

Learning Objectives:

1. Formulate a differential diagnosis for a child with a congenital anomaly of the urogenital tract using family and medical history, physical examination, and interpretation of imaging data.
2. Provide genetic counseling and order and interpret appropriate genetic tests for an individual who has or is at risk for infantile or adult polycystic kidney disease.
3. Recognize the genetic etiologies that contribute to nephrotic and renal tubular disorders and order appropriate genetic tests based on differential diagnosis and family history.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with genetic disorders with prominent renal manifestations.

Learning Objectives:

1. Apply diagnostic criteria to establish diagnosis of disorders including Bardet-Biedl syndrome, tuberous sclerosis complex, von Hippel-Lindau syndrome, Meckel syndrome, Zellweger syndrome, *etc.*, and order and interpret appropriate genetic tests.
2. Work with experts in nephrology to provide a program of surveillance for renal complications associated with these conditions.

Competency 3: Interpret the results of genomic tests for risk assessment of common renal disorders and provide counseling to patients and families.

Learning Objectives:

1. Counsel patients on the significance of relative risk assessments for adult-onset renal disorders based on results of genomic testing.

Neurogenetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of neurological disease to guide the appropriate use of genetic testing in diagnosis and counseling of inherited neurological disorders and communicate results to patients and families.

Learning Objectives:

1. Formulate a differential diagnosis for a child with microcephaly or a congenital anomaly of the central nervous system using family and medical history, physical examination, and interpretation of imaging data.
2. Order appropriate genetic tests as part of the evaluation of a patient with developmental delay or autism spectrum disorder.
3. Guide the genetic evaluation of a patient with a seizure disorder, integrating family history, physical examination, and results of electrophysiological and imaging studies and provide recurrence risk counseling to family members.
4. Recognize the genetic etiologies that contribute to cerebrovascular disorders such as stroke and vascular anomalies and order appropriate genetic tests based on differential diagnosis and family history.
5. Provide guidance on the use of targeted genetic tests to diagnose degenerative disorders of the central nervous system and provide counseling to families.
6. Recognize the signs of anterior horn cell disease in infants, children, and adults with spinal muscular atrophy or amyotrophic lateral sclerosis, order appropriate genetic tests, and provide counseling based on the results of testing.
7. Interpret the findings of physical examination, family history, and electrophysiological tests to formulate a differential diagnosis of patients with peripheral neuropathy and order and interpret appropriate genetic tests.
8. Use information from family history, electrophysiological testing, physical examination, and pathology to formulate a differential diagnosis of myopathic and dystrophic neuromuscular disorders and provide counseling to patients and families.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with phakomatoses.

Learning Objectives:

1. Apply diagnostic criteria to establish diagnosis of various forms of neurofibromatosis, tuberous sclerosis, and von Hippel Lindau syndrome, using and interpreting genetic testing as necessary.

2. Provide anticipatory guidance, surveillance for complications, and coordination of care to patients with phakomatoses.

Competency 3: Interpret the results of genomic tests for risk assessment of common neurological disorders and provide counseling to patients and families.

Learning Objectives:

1. Provide guidance on the appropriate use of apolipoprotein E (ApoE) testing to assess the risk of Alzheimer disease and provide counseling to families based on risk assessment.
2. Counsel patients on the significance of relative risk assessments for adult-onset neurological disorders based on results of genomic testing.

Ophthalmologic Genetics

Competency 1: Apply knowledge of anatomy, embryology, pathophysiology, and natural history of ophthalmologic disease and resources to guide the appropriate use of genetic testing in diagnosis and counseling of inherited nonsyndromic and syndromic ophthalmologic disorders.

Learning Objectives:

1. Recognize that 40% of all genetic disorders have associated eye and vision issues that necessitate appropriate ophthalmologic consultation.
2. Utilize resources for gene mutation screening, bio-repository, and phenotype collection with possible clinical trial participation, such as the National Eye Institute Eye Gene Network.
3. Using pedigree information and ophthalmologic assessments, order appropriate genetic testing and counsel patients and their family members with retinal dystrophies.
4. Provide resources of clinical trials in gene-replacement treatment strategies for childhood heritable retinal dystrophies
5. Formulate a differential diagnosis for a child with microphthalmia/anophthalmia/coloboma with or without a congenital anomaly of the central nervous system using family and medical history, perform a directed physical examination, interpret imaging data, order appropriate genetic tests, and establish co-managed specialist care for the patient.
6. Use information from family history, physical examination, laboratory and genetic testing, and ophthalmologic evaluation to delineate ocular from oculocutaneous albinism, and determine possible syndromic associations with platelet defects or immune system dysfunction.
7. Using family history, physical examination with anthropomorphic assessments, develop a genetic testing strategy for patients with craniofacial syndromes.
8. Recognize life-long ophthalmologic issues of shallow orbits with possible globe subluxation and/or corneal exposure, large angle strabismus, optic nerve atrophy.
9. Recognize that neonatal and early childhood visual pathway obstruction and media opacities such as cataract or corneal clouding are treatable and should be urgently assessed due to the threat of developing irreversible amblyopia.
10. Recognize the insidious and progressive nature of mitochondrial disorders and their affects on the eye, as well as associated cardiac conduction defects with mitochondrial disorders. Develop a genetic testing strategy and establish co-management surveillance.
11. Recognize the importance of ocular findings in multiple congenital anomaly syndromes. Establish a co-management strategy.

Competency 2: Establish diagnosis and provide counseling and longitudinal management of patients with the phakomatoses, ocular tumors, and genetic syndromes with ophthalmologic features.

Learning Objectives:

1. Use family history, age at diagnosis, and tumor parameters (laterality, uni- versus multifocal, tissue infiltration) for a patient with retinoblastoma to formulate a genetic testing strategy, provide counseling regarding cancer risk in family members, and develop a coordinated care management strategy including interval surveillance, imaging, chemoreduction, and oncologic/ophthalmologic intervention.
2. Apply diagnostic criteria to establish the diagnosis of various genetic syndromes with supporting ophthalmologic features, such as the Usher and Bardet-Biedel syndromes with associated retinitis pigmentosa, Alagille syndrome with associated posterior embryotoxon and optic nerve drusen, Stickler syndrome with myopia and retinal detachment risk, Marfan syndrome with lens ectopia, Ehlers-Danlos syndrome with corneal thinning, and the mucopolysaccharidoses with possible progressive corneal clouding.

Competency 3: Interpret the results of genomic tests for risk assessment of common ophthalmological disorders, and provide counseling to patients and their family members.

Learning Objectives:

1. Provide guidance on the appropriate use of complement factor H (CFH) testing to assess the risk of age-related macular degeneration and provide counseling to individuals and their families based on risk assessment.
2. Counsel patients on the significance of relative risk assessments for adult-onset eye disorders such as primary open angle glaucoma, diabetic retinopathy, and age-related macular degeneration.

Prenatal and Reproductive Genetics

Competency 1: Apply knowledge of embryology, pathophysiology, cytogenetics, molecular genetics and inherited diseases to guide appropriate testing for the screening, diagnosis and counseling of prenatal genetic diseases.

Learning Objectives:

1. Use information from the family history and population-specific genetic carrier tests to inform couples regarding their risk of an affected offspring and order the appropriate genetic testing for the couple and/or their fetus.
2. Counsel and initiate testing for specific genetic studies based on relevant personal and family histories of mental retardation, habitual miscarriage or stillbirth.
3. Recognize the stages of embryonic development and their relationship to teratogenic windows in the context of maternal teratogens such as alcohol, medications, or viral exposures and provide counseling.
4. Interpret the results of maternal serum screening in the first and second trimesters and nuchal translucency measurements in the context of Down syndrome screening and provide counseling for normal and abnormal results.
5. Recognize the range of normal variation in fetal ultrasound images, the associations of normal variants with and the limitations of ultrasound as a screening modality.
6. Counsel and initiate the appropriate prenatal genetic tests when a structural malformation and/or growth abnormality is identified by fetal ultrasound.
7. Guide the differential diagnosis, order the appropriate genetic testing, and provide counseling for a karyotypically normal fetus with a structural malformation or growth delay.
8. Counsel couples pursuing preimplantation genetic diagnosis regarding the nature of the testing, the sensitivity, limitations, and applicability to their specific genetic or chromosomal abnormality.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with prenatally diagnosed genetic abnormalities.

Learning Objectives:

1. Provide counseling regarding the benefits and risks of chorionic villus sampling and amniocentesis, including discussion of miscarriage rate, fetal morbidity, technical complexities and turn around time.
2. Provide guidance upon establishment of a diagnosis with referral to specialists, support for decision-making, and options for pregnancy management.

3. Maintain continuity for recurrence risk counseling at an appropriate interval.
4. Establish transition of care from prenatal to postnatal life with the appropriate care team.
5. Recognize the importance of the fetal autopsy and evaluation of products of conception in providing recurrence risk counseling to a couple.

Psychiatric Genetics

Competency 1: Apply knowledge of pathophysiology for general psychiatric disorders, as defined in the DSM diagnostic criteria, as well as teratogenic, epigenetic, and physiological factors to elucidate the causation of psychopathology and relate this to the natural history of the psychopathology and related comorbidities in a developmental context.

Learning objectives:

1. Formulate a genetic differential diagnosis based on DSM criteria.
2. When appropriate, order diagnostic tests, including but not limited to, blood, urine and imaging studies.
3. Recommend appropriate consultative evaluations, such as psychology, neuropsychology, psychiatry, developmental pediatrics, and neurology.
4. Recognize that some disorders, including Huntington disease, metachromatic leukodystrophy, some forms of porphyria, and Wilson disease may present with psychiatric symptomatology before other symptoms. Be able to diagnose, manage and counsel individuals with these disorders.
5. Be aware that inborn errors of metabolism, particularly syndromes elevating ammonia levels, may be associated with altered behaviors that are symptomatic of acute decompensation.
6. Apply knowledge of the features, consequences, and guidelines for management of fetal alcohol syndrome and fetal alcohol spectrum disorder (FASD).
7. Order and interpret genetic tests for evaluation of individuals with autism spectrum disorders.

Competency 2: Diagnose, provide management recommendations, and counseling for genetic disorders with psychopathology as a defining element.

1. Evaluate syndromic etiologies based on presentation, including sex and age of onset of symptomatology.
2. Recognize the cardinal features and implement management recommendations for microdeletion syndromes associated with behavioral psychopathology as a primary or major component, including Smith-Magenis syndrome, deletion 22q11.2, Williams syndrome, and Prader-Willi syndrome.
3. Recognize that poorly controlled metabolic disorders often have prominent psychiatric consequences, particularly symptoms of anxiety, depression, attention deficit/hyperactivity disorder (ADHD) and occasionally psychosis.
4. Use knowledge of the etiology, prognosis and management of triplet repeat disorders with prominent psychopathology, including fragile X syndrome and Huntington disease.

Competency 3: Interpret relevance of genomic data/candidate/risk genes to provide counseling and management guidance for individuals with, or at risk for, psychopathology.

Learning Objectives:

1. Recognize that, apart from rare instances (as above), most psychiatric disorders are multifactorial.
2. Use knowledge of the heritability levels and empiric risk of recurrence of common psychiatric disorders, specifically schizophrenia, mood disorders, anxiety, ADHD, obsessive compulsive disorders, and autism to provide recurrence risk counseling.
3. Recognize that the environmental component to risk of psychiatric disorders includes the psychosocial environment as well as biological and chemical agents, and that this is a dynamic factor amenable to intervention. Know whom to refer to (*e.g.*, psychiatrist, psychologist, social worker, primary care physician) in order to provide this intervention.
4. Interpret significance of candidate risk genes identified by personalized medicine or similar evaluations.

Pulmonary Genetics

Competency 1: Apply knowledge of pathology, natural history and inheritance to guide the appropriate use of genetic testing in the diagnosis and counseling of patients with primary genetic disorders affecting the pulmonary system.

Learning Objectives:

1. Formulate a differential diagnosis, order and interpret genetic testing, and provide counseling to patients and families with hereditary pulmonary emphysema.
2. Formulate a differential diagnosis, order and interpret genetic testing, and provide counseling to patients and families with idiopathic pulmonary hypertension.

Competency 2: Establish diagnosis and provide counseling and longitudinal management to patients with disorders having prominent pulmonary features.

Learning Objectives:

1. Order and interpret genetic tests for patients and families with or at-risk for cystic fibrosis.
2. Order and interpret genetic tests for alpha-1-antitrypsin deficiency and provide counseling to family members.
3. Interpret the results of newborn screening testing for cystic fibrosis and formulate a plan for further confirmatory testing and management.

Competency 3: Interpret the results of genomic tests for risk assessment of common pulmonary disorders and provide counseling to patients and families.

Learning Objectives:

1. Counsel patients on the significance of relative risk assessments for multifactorial pulmonary disorders based on results of genomic testing.

Skeletal Genetics

Competency 1: Apply knowledge of anatomy, pathophysiology, and natural history of skeletal diseases to guide the appropriate use of genetic testing in diagnosis and counseling of inherited skeletal disorders and communicate results to patients and families.

Learning objectives:

1. Utilize family and medical history, medical imaging studies, and laboratory tests to formulate a differential diagnosis of a fetus suspected of having a skeletal dysplasia or dysostosis and assess whether the condition is compatible with postnatal survival.
2. Formulate a differential diagnosis for a child with a congenital limb, axial, and/or craniofacial malformation, including teratogenic causes, syndromic causes, and skeletal dysostoses/dysplasias, using family and medical history, physical examination findings (including anthropomorphic measures), imaging studies, and interpretation of laboratory results.
3. Synthesize medical and family history, growth and developmental history, physical examination including anthropometric measures, and imaging studies to differentiate proportionate from disproportionate short stature, congenital versus childhood-onset growth failure, and environmental versus genetic causes. Suggest appropriate diagnostic studies and determine which other medical specialists should participate in the child's care.
4. Formulate a differential diagnosis for an individual who has a solitary or multifocal lesion that involves the skeletal system. Recognize that these types of lesions can result from somatic mosaicism, involve other organ systems, and undergo malignant transformation.
5. Synthesize medical and family history, growth and developmental history, physical examination, imaging studies, and laboratory studies to evaluate a patient with joint pain, differentiating inflammatory *versus* non-inflammatory conditions, environmental *versus* genetic causes, static *versus* progressive conditions. Suggest appropriate diagnostic studies. Determine which other medical specialists should participate in the individual's care.

Competency 2: Establish diagnosis, provide counseling, and coordinate longitudinal management of patients with skeletal dysplasia or skeletal fragility.

Learning Objectives:

1. Evaluate radiographs and other imaging studies and know when to order further biochemical or molecular genetic tests, as well as which tests are appropriate for a given situation.
2. Provide anticipatory guidance to the family that is specific to the skeletal dysplasia diagnosis.
3. Work with other professionals to formulate, implement, and monitor a treatment plan that could include pharmacologic intervention, physical therapy and rehabilitation, and psychosocial counseling.
7. Assist with the transition to adult care and provide anticipatory counseling on adult-onset issues.

Competency 3: Interpret the results of genomic tests that may be used in risk assessment for common skeletal problems, such as osteoporosis or osteoarthritis, or when seeking the underlying cause of a sporadically occurring skeletal malformation.

Learning Objectives:

1. Describe the benefits and limitations of using high-throughput candidate-gene sequencing, high density arrays for copy number variation, whole exome/genome sequencing, or other emerging technologies to evaluate an individual who has a skeletal disorder of unknown cause or a common skeletal problem that is assumed to be multifactorial in origin.

Conclusion

Medical genetics is one of the most rapidly evolving areas of medical practice. The diagnosis of rare disorders has become dramatically more sensitive since the introduction of genomic microarrays. Whole exome and whole genome sequencing are emerging as even more powerful diagnostic tools that may eventually replace gene-by-gene testing and may revolutionize genetic diagnosis. Insights into pathogenesis are offering opportunities to treat genetic disorders that formerly were viewed as beyond the reach of therapy. Genetic and genomic approaches are now being applied to common disorders, including in risk assessment, differential diagnosis, and choice of treatment. Although common disorders are less likely to be managed by medical geneticists, the geneticist can play an important role in interpretation of complex test results and communication of risks to patients and family members. It is hoped that these competencies will provide guidance in training the next generation of medical geneticists, and will also help to define the scope of practice of medical geneticists. It is expected that this document will need to evolve with the discipline, and therefore will likely require frequent updating and revision in the coming years.

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Appendix A : Participants in Stone Mountain Conference

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