

Genetics in the clinical setting

What nurses need to know to provide the best patient care.

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THE CENTRAL DOGMA of biology (deoxyribonucleic acid [DNA] to ribonucleic acid [RNA] to protein) was first described in 1957, before the current average-aged 50-year-old nurse was born. And it wasn't until 2008 that genetics was considered essential to nursing education, when most experienced nurses were already at least 45. In other words, many nurses have minimal genetics education and may not feel comfortable incorporating genetics assessment and implications into a patient care plan.

Since 2003, when human genome sequencing was completed, much genetic information and technology has been introduced into healthcare, requiring nurses to understand and translate these concepts to patients. However, without a strong foundation in genetic facts, how do nurses know what's important? How do we identify the red flags of inherited diseases, use a family assessment to recognize risk factors, develop a plan of care to educate patients, and ensure proper diagnosis?

This article explains basic genetic terminology and processes and

describes assessment steps to help clinical nurses care for and manage patients at risk for inherited adult-onset diseases.

Genetics, genomics, and epigenetics

Genes are composed of DNA sequences located in segments along an individual's chromosomes. A person's genes are passed from one generation to the next, making ge-

netics the study of heredity. The complete length of a person's DNA within a cell is called the genome, making genomics the study of the structure of the genome through mapping and sequencing of DNA. Epigenetics studies the environment's role in activating and deactivating genes. (See *Genetics primer*.)

Pharmacogenomics

Pharmacogenomics, the study of how a person metabolizes medications based on his or her personal genetic makeup, is one of the earliest applications of genetic and genomic research into clinical intervention. (See *Genetic markers for drug response and function*.) Pharmacogenomics has been most commonly used in psychiatry to determine drug choice and response, and in pain management to assess addiction potential. In addition, genetic testing can be used to tailor medication management to reduce and minimize side effects and promote treatment plan adherence.

While not routinely used in general practice, this type of personalized medicine may become more



LEARNING OBJECTIVES

1. Recall key genetic processes.
2. Describe the essentials of a genetic assessment.
3. Discuss how nurses can integrate genetics into their clinical practice.

The planners and all authors of this CNE activity except Everett have disclosed no relevant financial relationships with any commercial companies pertaining to this activity. Everett is a speaker for Myriad Genetics and a sales representative for Imperium Health Resources. Peer review found no evidence of bias. See the last page of the article to learn how to earn CNE credit.

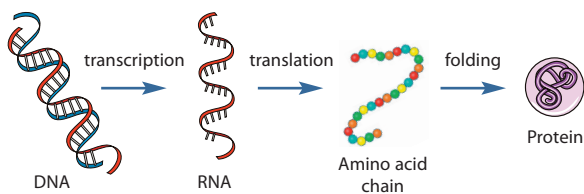
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Genetics primer

Understanding genetics requires a grasp of terminology and processes.

Transcription

Through the process of **transcription**, DNA inside the nucleus is transcribed into messenger RNA (mRNA). The mRNA then moves into the cytoplasm to the site of the ribosome, where it's translated into amino acids, which are the building blocks of proteins. Proteins maintain homeostasis in the body, and they're used as enzymes, which trigger cellular activity, and are responsible for cellular growth and repair. In other words, an individual's DNA sequence is responsible for gene regulation and all cellular activities.



During periods of rest from transcription, DNA rolls tightly around histones (proteins that bind to the DNA to condense it in the cell nucleus) and then loosens to enable transcription.

Epigenetic changes

Epigenetic changes tag the DNA, interfering with transcription and causing normal and natural alterations influenced by the environment, disease, and lifestyles. Epigenetic changes affect how cells read and interpret genes, resulting in visible characteristics (phenotypes). A collection of chemical tags, like methylation, can interfere with transcription to turn genes on or off and help fine-tune gene expression (protein production) in response to what's happening in the environment.

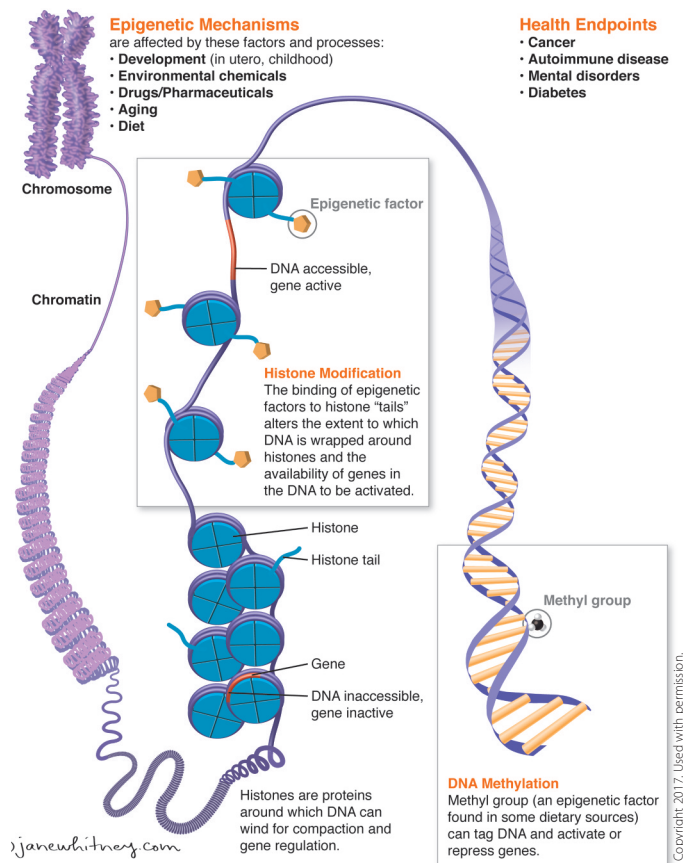
In some situations, epigenetic alterations can result in cell differentiation that leads to cancer or other disorders.

Chromosomes, diploid cells, and alleles

Chromosomes are the structures within a nucleus that carry genetic information and exist in pairs. The 46 chromosomes include 22 pairs of autosomes and one pair of sex chromosomes.

Diploid cells are formed when one chromosome copy is inherited from both the father and the mother, carrying thousands of chromosomes that contain genetic traits.

Alleles are a different version of the same gene and are distinguishable by phenotype or observable expression. Because of the vast amount of chromosome exchange during cell division,



genetically identical individuals are virtually impossible unless, of course, they're identical twins.

Incorrect translation, germline mutations, and somatic mutations

Disease results when a change in gene DNA nucleotides (base pairs) is caused by **incorrect translation** in the mRNA. This creates a modification in the amino acid, which leads to insufficient or dysfunctional protein production. Environmental chemicals, drugs, diet, stress, trauma, and even aging also can cause mutations in any cell after conception.

Hereditary **germline mutations** arise from inherited DNA in the gametes or sex chromosomes and are duplicated in every cell. Conversely, **somatic mutations** are acquired genetic alterations within cells that can be passed to future progenies of a cell, but not sperm or eggs.

commonplace as we begin to tie patient outcomes to reimbursement. Adverse drug reactions are the fourth leading cause of death and are responsible for over 1 million emergency department visits each year, with 25% of these patients requiring hospitalization for further treatment. Issues related to drug metabolism cost \$3.5 billion per

year in supplementary healthcare expenditures.

Nursing care and genetics

The initial *Scope and Standards for Clinical Genetics Nursing Practice* was first published in 1998 after the American Nurses Association (ANA) recognized genetics as a nursing specialty. Then, shortly after comple-

tion of human genome sequencing, ANA published the *Essentials of Genetic and Genomic Nursing: Competencies, Curricular Guidelines, and Outcome Indicators*, which was endorsed by 47 nursing organizations. These guidelines challenge nurses to:

- recognize how their personal attitudes about genetics might impact their practice

Genetic markers for drug response and function

An individual's genetic makeup plays a role in how his or her body metabolizes medication. The Food and Drug Administration includes biomarker information in its labeling, which nurses can use as a source for medication and metabolism pathways. Up to 80% of the most commonly ordered medications include pharmacogenomic information. The following list of genetic markers indicates the drug response and function of each.

OPRM1—opioid analgesic effectiveness

SLC6A4—antidepressant response

SLCO1B1—statin safety and efficacy

VKORC1—warfarin sensitivity

MTHFR—dietary folate conversion to its active form

BDNF and DRD2—dopamine release enhancement

Hepatic isoenzymes (cytochrome P450, including CYP2D6, CYP2C9, CYP2C19, CYP3A4, CYP3A5, CYP2B6, and CYP1A2)—drug metabolism interference

omic influences and risks during physical assessments, when collecting personal and family health histories, and when analyzing this information. In addition, assess the patient's knowledge and perceptions of genetic and genomic information, as well as his or her responses, and address any issues or concerns. In developing the care plan in conjunction with the patient, integrate clinical judgment, patient preferences, evidence-based research, and family implications to plan genetic- and genomic-focused care.

Identification of hereditary risk

In the clinical setting, identification

- advocate for clients for genetic services and autonomous genetic decision-making
- incorporate genetic and genomic information into their practices and regularly evaluate their competency
- tailor genetic and genomic information to patients based on their culture, literacy, religion, and preferred language.

To incorporate these competencies into practice, nurses need basic genetic and genomic knowledge. ANA provides a list of current genetics publications and resources that are earmarked for nurses (nursingworld.org/genetics). The competencies divide the professional practice guidelines into four categories—nursing assessment; identification of hereditary risk; referrals; and education, care, and support.

Nursing assessment

To assess a patient's genetic risk, you must understand the relationship of genetics and genomics to health, prevention, screening, treatment, and monitoring. Essential nursing competencies include basic knowledge of genetic and genomic principles, genetic resources, current research, and professional guidelines and recommendations. Consider genetic, environmental, and ge-



Family history resources

Access these online resources to learn more about genetics, genomics, and family histories.

American Academy of Family Physicians Genomics CME

aafp.org/afp/topicModules/viewTopicModule.htm?topicModuleId=56#0

Collection of the best content from the *American Family Physician* journal on genetics, family history, and individual syndromes.

Centers for Disease Control and Prevention

cdc.gov/genomics/famhistory/famhist_professionals.htm

This site provides links to genetic, genomic, and family health history resources, including case studies, for health professionals.

Genetic Alliance

geneticalliance.org/familyhealthhistory

The Genetic Alliance promotes patient awareness of family health history with links to downloadable booklets in English and Spanish to help patients share their histories with clinicians.

U.S. Surgeon General

hhs.gov/familyhistory/

This patient-friendly website reviews the importance of family history and includes a web-based tool to organize and print family history information.

Understanding monogenic and multifactorial disorders

of hereditary risk begins with the primary care nurse. Obtain a three-generation family history to identify individual and family genetic risk factors. Start with the patient's history, then gather information on first- (children, siblings, and parents), second- (maternal and paternal grandparents, aunts, uncles, nieces, and nephews), and third-degree (first cousins) relatives. Note any missing information or unknown family history. (See *Family history resources*.)

For each family member, collect the following information:

- Name, date of birth
- Health status, including medical conditions and age at diagnosis
- If deceased, age and cause of death
- Racial and ethnic ancestry of maternal and paternal grandparents.

After all data are gathered, analyze the information to determine patterns of both monogenic and multifactorial disease risks. (See *Understanding monogenic and multifactorial disorders*.) A drawn pedigree is a succinct way to visualize this information.

Electronic health records (EHRs) typically include a family history section for documenting health information over three generations. Ideally, an alert would prompt you to clarify information related to genetic risk factors. The best EHR would generate a pedigree based on the family history entered. Current EHRs aren't able to produce pedigrees or prompt practitioners to potential genetic risks, but the need for this software development is recognized.

Several red flags in a patient's personal and family history may indicate a potential for inherited susceptibility to a disease or genetic condition. Both the Genetic Alliance and the National Coalition for Health Professional Education in Genetics are reliable resources to learn about red flags. Primary care, cardiology, oncology, and other specialties have published data that

Adult-onset **monogenic disorders** are single-gene disorders with disease signs and symptoms (phenotypes) that can begin during childhood. These rare heritable conditions may be seen in multiple generations of a family and include:

- hereditary hemochromatosis
- alpha-1 antitrypsin deficiency resulting in obstructive pulmonary disease
- Huntington's disease
- autosomal dominant polycystic kidney disease
- Gaucher disease
- Fanconi syndrome II
- inherited cancer syndromes, such as hereditary breast/ovarian cancer and Lynch syndrome.

More common are **multifactorial disorders** that result from a combination of genetic and environmental factors. They occur any time during the lifespan, but tend to be more common in adulthood. Like monogenic disorders, many multifactorial disorders can be identified in multiple family generations. They include:

- hypertension
- hypercholesterolemia
- coronary artery disease
- stroke
- autoimmune disorders (for example, rheumatoid arthritis, systemic lupus erythematosus, psoriasis, Graves' disease, multiple sclerosis, scleroderma)
- Alzheimer's disease
- Parkinson's disease
- schizophrenia
- alcoholism
- cancer
- bipolar affective disorder.

specify red flags in their specialty. (See *Genetic red flags*.)

According to the Genetics in Primary Care Institute, red flags vary based on the assessment. For example, red flags for hereditary cancer will be different from those for a preconception evaluation. Also, an individual's ethnicity and race have a significant influence on the distribution, incidence, and prevalence of many genetic diseases.

Referral

When red flags are identified during the family history, you or the provider should make a referral to a genetic specialist. To help patients and families make informed decisions and to decrease their anxiety, provide information about the reasons for testing, types of tests, and benefits and risks.

Benefits of genetic testing include providing a definitive diagnosis, offering information related to

familial risk, and identifying prevention, management, and treatment options. Risks include the potential for discrimination based on genetic results, anxiety over the uncertainty of incidental findings of unknown significance, and the psychological impact of what the findings mean. (See *Uses of genetic testing*.)

Be aware of barriers to genetic technology and services, including culture, language, family values, traditions, religion, and health beliefs. In addition, stay up-to-date on current health policy regarding reimbursement for genetic and genomic health services as well as genetic discrimination related to insurance and employment.

Local and national resources can help facilitate referrals. The International Society of Nurses in Genetics and the National Society of Genetic Counselors can help locate genetic professionals. Genetic services are frequently offered by specialty (for

Genetic red flags

Genetic red flags identified during a family history may indicate high risk for an inherited disorder. The following examples of red flags should prompt referral to a genetic specialist.

Known genetic disorder in family Family history of disease

Multiple generations of affected maternal or paternal relatives

- Two affected first-degree relatives
- Three or more affected maternal or paternal relatives
- Moderate risk on both sides of the pedigree (for example, two maternal relatives with cancer and two paternal relatives with heart disease)

Early onset of disease in first- or second-degree relative, including:

- Breast, ovarian, endometrial cancers (< 50 years old)
- Colon cancer (< 50 years old)
- Prostate cancer (< 50 years old)
- Stroke (< 50 years old)
- Coronary artery disease (males < 55 years old, females < 65 years old)
- Type 2 diabetes (< 50 years old)
- Dementia (< 60 years old)

Sudden cardiac death of an individual considered healthy

Ethnic predisposition to certain genetic disorders including:

- Sickle cell disease in individuals of African American heritage
- Tay-Sachs disease in Ashkenazi Jewish families
- Alpha thalassemia in individuals from Southeast Asia

Adapted from Schaa K. Red flags suggestive of a genetic component. In: Kasper CE, Schneidereith TA, Lashley FR, eds. *Lashley's Essentials of Clinical Genetics in Nursing Practice*. 2nd ed. New York, NY: Springer Publishing Company; 2016.

example, cardiology or oncology), so keep a list of local resources. Genetests.org is another useful clinical tool to assist in identifying available genetic testing in clinical and research labs.

In addition to genetic and genomic referrals, the personal or family history may require risk-management referrals to appropriate specialists. You can be instrumental in initiating these referrals and providing follow-up.

Education, care, and support

The genetic testing process, from initial counseling through disclosure of test results, can take 4 weeks or more. During this time, you can offer emotional support and discuss potential strategies for action after the results are received. (See *Interpreting genetic test results*.)

After learning the test results, help clarify information provided by genetic professionals, explore implications for the patient and family, recommend health promotion and prevention practices based on genetic risk factors, and collaborate with healthcare providers for optimal care delivery. Individuals identified as high risk for genetic diseases should be referred for early detection and screenings based on recommended national guidelines. Encourage patients to discuss risks with family members so each person can make individual decisions for referral, intervention, and testing.

Offer support as patients navigate a new diagnosis associated with a genetic mutation. This can include exploring the effect of genetic information on extended family members, supporting lifestyle changes based on genetic predisposition, explaining pharmacogenomic therapies, and identifying strategies for reimbursement of genetic services.

Nursing and precision medicine

Precision medicine (tailoring medical treatment to each patient's individual characteristics) has become



You can help patients and families understand the purpose behind genetic testing options.

Diagnostic testing confirms or rules out a diagnosis. This testing is indicated when symptoms already exist.

Carrier testing determines whether an individual is a carrier of a recessive or X-linked Mendelian disorder.

Predictive or presymptomatic testing indicates whether a person is very likely to develop a condition such as Huntington's disease.

Prenatal or antenatal testing looks for genetic and chromosomal disorders such as Down syndrome.

Susceptibility testing determines an individual's genetic risk for an etiologically complex disorder that involves multiple risk factors, such as diabetes or heart disease.

Pharmacogenetic testing analyzes genetic variants to predict an individual's response to a specific medication or class of medications.

Interpreting genetic test results

Understanding what test results mean can help you explain them to patients and their families, connect them to resources, and provide support.

Positive test results:

- show a change in a particular gene, chromosome, or protein of interest.
- may confirm a diagnosis, but generally can't be used to predict the course or severity of a condition.
- may provide options for prevention and management of the disorder.

Negative test results:

- indicate no change in the gene, chromosome, or protein of interest.
- virtually rule out a particular disorder, assuming the test is highly accurate and the individual's symptoms can be attributed to other causes.
- don't rule out the presence of a mutation in another gene that could cause the same disorder.

Variant of unknown significance results:

- indicate a finding of a variation in the DNA that's not normal, but hasn't yet been associated with a disorder in other people.
- may be difficult to evaluate because everyone has common natural variations in their DNA (polymorphisms) that don't affect health.

an important component of nursing practice. Research supports precision medicine as an evolving strategy for disease treatment and prevention that includes attention to an individual's variability in genes, environment, and lifestyle.

The National Institute of Nursing Research (NINR) supports research across diverse populations and settings to develop more personalized strategies to prevent and manage the adverse symptoms of illness. NINR-supported scientists are actively engaged in implementing clinical applications of genomics to accelerate discoveries that allow healthcare providers and researchers to accurately predict what disease treatment and prevention strategies will work in which groups of people. In contrast to a one-size-fits-all approach, precision medicine challenges nurses to think genetically across specialties and practice settings.

Nursing at the forefront

For 15 years, the Gallup Honesty and Ethics poll has ranked nursing as the most trusted profession in the United States. This public trust places nurses in the unique position to educate individuals and their families on

the presence, absence, or future possibility of disease to improve health outcomes and promote delivery of patient-centered care.

Essential competencies related to genetics have been developed for nurses with undergraduate and graduate degrees. You can access these and other online resources for continuing education, professional organizations dedicated to nursing genetics and genomics, and additional information. (Visit: americannursetoday.com/genetics-clinical-setting for a list of resources.)

As nurses become more aware of genetics and the need to incorporate genetic assessment into everyday practice, we're initiating and facilitating referrals to improve patient care and outcomes. However, each state has a nursing scope of practice regarding genetics and genomics, so make sure you know the restrictions within your state.

As treatment becomes more individualized based on genetic profiles, nurses must acquire genetic and genomic knowledge to provide the best patient care. Primary care nurses knowledgeable in genetics and genomics will be at the forefront of this new era in medicine. ★

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Please mark the correct answer online.

1. Which statement about genetic processes is correct?

- a. DNA inside the cytoplasm is transcribed into messenger RNA (mRNA).
- b. DNA on the ribosome is translated into amino acids.
- c. mRNA inside the nucleus is transcribed into DNA.
- d. mRNA on the ribosome is translated into amino acids.

2. Proteins that bind to DNA to condense it in the cell nucleus are called

- a. genomes.
- b. chromosomes.
- c. histones.
- d. chromatins.

3. Epigenetic changes

- a. tag DNA, interfering with transcription.
- b. tag mRNA, interfering with transcription.
- c. do not affect how cells interpret genes.
- d. use enzymes to fine-tune gene expression.

4. The correct term for a different version of the same gene that is distinguishable by phenotype or observable expression is

- a. allele.
- b. chromatin.
- c. diploid cell.
- d. mutation.

5. Which of the following are structures within a nucleus that carry genetic information?

- a. Alleles
- b. Methyl groups
- c. Diploid cells
- d. Chromosomes

6. Which is the type of mutation that arises from inherited DNA in the gametes or sex chromosomes and is duplicated in every cell?

- a. Diploid
- b. Germline
- c. Somatic
- d. Transcription

7. Which statement about pharmacogenomics is not correct?

- a. Pharmacogenomics is used in pain management to assess addiction potential.
- b. It’s helpful for determining drug choice and response in psychiatry.
- c. It’s the study of how a person metabolizes medications based on personal genetic makeup.
- d. Pharmacogenomics information is typically not available on drug labels.

8. The genetic marker associated with opioid analgesic effectiveness is

- a. SLC6A4.
- b. OPRM1.
- c. MTHFR.
- d. VKORC1.

9. An example of an adult-onset monogenic disorder is

- a. Gaucher disease.
- b. alcoholism.
- c. Parkinson’s disease.
- d. stroke.

10. When conducting a genetic assessment, the nurse should

- a. not include first-degree cousins.
- b. not include siblings.
- c. obtain a two-generation family history.
- d. obtain a three-generation family history.

11. Which piece of information you learn during a genetic assessment is a red flag?

- a. An aunt with cardiovascular disease died after a sudden cardiac arrest.
- b. A 60-year-old cousin had an ischemic stroke 2 years ago.
- c. Three maternal relatives have been affected by the same disorder.
- d. A patient from Vietnam has sickle cell disease.

12. The type of genetic testing that determines an individual’s genetic risk for an etiologically complex disorder that involves multiple risk factors is

- a. susceptibility.
- b. predictive.
- c. carrier.
- d. diagnostic.

13. Which statement about variant of unknown significance results of genetic testing is correct?

- a. They may be difficult to evaluate because everyone has common natural variations in their cytoplasm that don’t affect health.
- b. They may be difficult to evaluate because everyone has common natural variations in their DNA that don’t affect health.
- c. They rule out a particular disorder, assuming the test is highly accurate and the individual’s symptoms can be attributed to other causes.
- d. They may confirm a diagnosis but generally can’t be used to predict the course or severity of a condition.

14. To support patients who are considering or have undergone genetic testing, do all of the following except

- a. provide information about the benefits of genetic testing, including the potential ability to determine a definitive diagnosis.
- b. provide information about the risks of genetic testing, including the potential for discrimination based on genetic results.
- c. discourage patients from discussing risks identified through genetic testing with family members to avoid creating unnecessary anxiety.
- d. recommend health promotion and prevention practices based on genetic risk factors and collaborate with others for optimal care delivery.

Online sidebar

Genetic and genomic resources

These websites offer helpful resources for nurses interested in learning more about genetics and genomics.


American Nurses Association—*Essentials of Genetic and Genomic Nursing: Competencies, Curricular Guidelines, and Outcome Indicators*

 [genome.gov/pages/careers/healthprofessionaleducation/geneticscompetency.pdf](https://www.genome.gov/pages/careers/healthprofessionaleducation/geneticscompetency.pdf)

American Nurses Association and International Society of Nurses in Genetics—*Essential Genetic and Genomic Competencies for Nurses with Graduate Degrees*

 [genome.gov/pages/health/healthcareprovidersinfo/grad_gen_comp.pdf](https://www.genome.gov/pages/health/healthcareprovidersinfo/grad_gen_comp.pdf)

Centers for Disease Control and Prevention—Training programs and courses

 [cdc.gov/genomics/training/](https://www.cdc.gov/genomics/training/)

Genetics/Genomics Competency Center—Online repository of peer-reviewed genomics educational materials, with links to courses, websites, and articles

 [genomicseducation.net/](https://www.genomicseducation.net/)

International Society of Nurses in Genetics—Dedicated to fostering scientific and professional growth of nurses in human genetics and genomics worldwide

 [isong.org](https://www.isong.org)

National Institutes of Health: Genetics Home Reference—Consumer-friendly information about the effects of genetics on health

 ghr.nlm.nih.gov/

The Surgeon General's Family Health History Initiative—Information and template to collect a family history

 [hhs.gov/familyhistory](https://www.hhs.gov/familyhistory)

University of Cincinnati/Cincinnati Children's Hospital Medical Center—Genetic counseling: graduate program

 geneticcounseling4u.org/online_courses/online_courses.html