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Genetic Testing Summary

Enclosed are the genetic testing results for

CB 569

No amount of genetic testing can guarantee that a child will not be affected with a genetic condition. Genetic testing can inform you of the likelihood of passing on the genetic conditions that are tested for, but it cannot eliminate the risk of passing on any genetic condition.

The genetic conditions Cryobio tests for are inherited in an autosomal recessive manner. This means that the child would have to inherit a genetic mutation from both the sperm source and the egg source to be affected with the condition. When both the sperm source and the egg source have undergone genetic carrier screening and the test results are negative, the risk of a child being affected with the conditions tested for is significantly reduced, but it cannot be completely eliminated.

All recipients should discuss both or their own risk for passing on genetic conditions and whether would benefit from genetic counseling and testing with their health care provider. Before using a donor that is a carrier for a specific recessive genetic condition or conditions, we strongly recommend that the recipient (or egg source, if different) consider genetic counseling and testing to determine if they are a carrier for the same genetic condition or conditions as the donor.

Screening and testing have changed dramatically over the years, and so the screening and testing done on each donor may very depending on the testing that was in place when he was actively in Cryobio's donor program. Earlier donors may not have had as extensive testing as later donors. Screening and testing may change again in the future, so please review the results each time before ordering as both the testing done and the results may change.

cryobio

A note about donor CB 569's genetic carrier screening results:

At the time donor CB 569 was entering the donor program, Cryobio was in the process of choosing a new laboratory to perform genetic carrier screening through. Because of this, donor CB 569 had expanded genetic carrier screening from two different laboratories to determine their carrier status for a combined total of 689 recessive genetic conditions. Genetic testing is complex, and every lab is set up differently to decide which genetic variants should be reported. This is one reason why even after negative carrier screening, there is a residual (or remaining) risk/possibility of being a carrier. Referring to the performing laboratories residual risk after negative testing is important to keep in mind, as negative testing does not eliminate the risk of being a carrier for any condition. Donor CB 569 was reported as a carrier by one lab (Invitae) for three conditions, while the other lab (LabCorp) reported him as negative as a carrier. This summary is provided to help summarize the reasons for these differences. Please contact Cryobio if you have any additional questions.

- Cystic fibrosis and *CFTR*-related conditions (*CFTR* gene):
    - Different combinations of specific mutations or variants in the *CFTR* gene can result in different levels of severity of cystic fibrosis or *CFTR*-related conditions. The specific variant identified in donor CB 569's *CFTR* gene is called the "5T 12 TG variant". It is unique in that it has the potential to be clinically significant, but only when in combination with other specific types of *CFTR* variants. Additionally, it can be seen in individuals with some of the "less severe *CFTR* related conditions", but also in individuals who are asymptomatic. Because of this, some practitioners' guidelines (for example the national society of genetic counselors) do not recommend the routine screening and evaluation of the 5T variant unless the presence of an additional variant (called R117H) that is known to be influenced heavily by the poly T tract status. Therefore, LabCorp chooses not to report the poly 5T 12 TG variant status in individuals if it is the only variant found, while Invitae chooses to report it anyway.
- Congenital adrenal hyperplasia due to 21-hydroxylase deficiency (CYP21A2 gene):
    - LabCorp only tests for 7 of the more "common" mutations in the CYP21A2 gene; ie-their testing platform does not screen for the specific variant reported and identified by Invitae for donor CB 569. Because Invitae does look beyond the 7 common mutations, donor CB 569 was identified as a carrier by Invitae.
- Glycogen storage disease type II (Pompe disease) (GAA gene):
    - The specific c.1194+3G>C variant that donor CB 569 is reported to be a carrier for is a VUS in LabCorp's system, and most labs do not report VUS on carrier screening panels.
    - A variant of uncertain significance (VUS) in genetics refers to a change or mutation that has been identified in a gene, but its clinical significance and association with disease risk is unclear. VUS results typically require further research, functional analysis, or additional clinical data to determine whether they are pathogenic (disease-causing) or benign. Different labs may classify VUS' differently due to variations in interpretation criteria, access to data, expertise, evolving knowledge, sample size, in-house databases, testing methods, reporting practices, and collaboration, making it essential to consider residual risk estimates when screening negative for a given condition through carrier screening.
    - Invitae has interpreted the available data them, and reports this variant to be disease-causing, therefore reporting donor CB 569 as a carrier for GSD type II.

INVITAE

INVITAE CARRIER SCREEN RESULTS

Patient name:	CB 569	**Sample type:**	Blood	**Report date:**	15-JUN-2023
DOB:		**Sample collection date:**	31-MAY-2023	**Invitae #:**	
Sex assigned at birth:	Male	**Sample accession date:**	01-JUN-2023	**Clinical team:**	Chase Fulton David Prescott
Gender:					
Patient ID (MRN):					

Reason for testing

Gamete donor

Test performed

Invitae Comprehensive Carrier Screen

- Primary Panel (CF, SMA)
- Add-on Comprehensive Carrier Screen genes

RESULT: POSITIVE

This carrier test evaluated 556 gene(s) for genetic changes (variants) that are associated with an increased risk of having a child with a genetic condition. Knowledge of carrier status for one of these conditions may provide information that can be used to assist with family planning and/or preparation. Carrier screening is not intended for diagnostic purposes. To identify a potential genetic basis for a condition in the individual being tested, diagnostic testing for the gene(s) of interest is recommended.

This test shows the presence of clinically significant genetic change(s) in this individual in the gene(s) indicated below. No other clinically significant changes were identified in the remaining genes evaluated with this test.

RESULTS	GENE	VARIANT(S)	INHERITANCE	PARTNER TESTING RECOMMENDED
Carrier: CFTR-related conditions	CFTR	c.1210-34TG[12]T[5] (Intronic)	Autosomal recessive	Yes
Carrier: Congenital adrenal hyperplasia due to 21-hydroxylase deficiency	CYP21A2	c.1360C>T (p.Pro454Ser)	Autosomal recessive	Yes
Carrier: Glycogen storage disease type II (Pompe disease)	GAA	c.1194+3G>C (Intronic)	Autosomal recessive	Yes

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Next steps

- See the table above for recommendations regarding testing of this individual's reproductive partner.
- Even for genes that have a negative test result, there is always a small risk that an individual could still be a carrier. This is called “residual risk.” See the Carrier detection rates and residual risks document.
- Discussion with a physician and/or genetic counselor is recommended to further review the implications of this test result and to understand these results in the context of any family history of a genetic condition.
- All patients, regardless of result, may wish to consider additional screening for hemoglobinopathies by complete blood count (CBC) and hemoglobin electrophoresis, if this has not already been completed.
- Individuals can register their tests at **https://www.invitae.com/patients/** to access online results, educational resources, and next steps.

Clinical summary

RESULT: CARRIER

CFTR-related conditions

A single Pathogenic variant, c.1210-34TG[12]T[5] (Intronic), was identified in CFTR. This variant has unique interpretation considerations. See "What are CFTR-related conditions?" and Variant details for additional information.

What are CFTR-related conditions?

The c.1210-34TG[12]T[5] cystic fibrosis (CF) variant was identified in this individual. There are multiple forms of the 5T variant, which are classified by the number of TG repeats. Each form of the 5T variant is associated with a different degree of risk for CFTR-related symptoms when inherited in combination with a pathogenic variant from the other parent, ranging from a healthy individual to congenital absence of the vas deferens (CAVD) in males to an individual with mild/atypical CF. The combination of the c.1210-34TG[12]T[5] variant with a severe pathogenic CFTR variant from the other parent is associated with symptoms in the majority of individuals; however, most individuals who are homozygous for the c.1210-34TG[12]T[5] variant are asymptomatic (see Variant details section).

R117H is another change which can occur within CFTR as part of a complex allele with a 5T variant. If present, the R117H variant would be reported as a Result to Note.

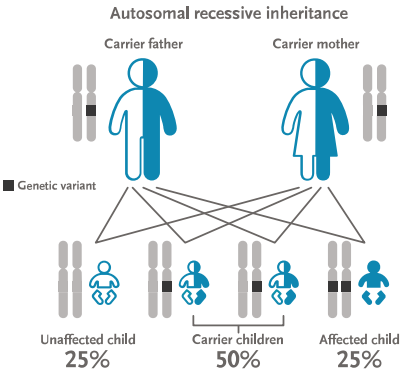
CFTR-related conditions encompass a spectrum of disorders that typically impact the respiratory and/or digestive systems, and cause male infertility. Cystic fibrosis (CF) is typically a childhood-onset disease in which abnormally thick mucus production can cause a variety of symptoms including recurrent respiratory infections and progressive lung disease, as well as nutritional deficiencies and poor growth due to deficiency of enzymes produced by the pancreas to digest food (pancreatic insufficiency). Symptoms range from mild to severe. Prognosis depends on the severity of symptoms as well as response to treatments; many affected individuals live well into adulthood. Milder forms of CFTR-related conditions include CAVD associated with male infertility, variable respiratory manifestations, and hereditary pancreatitis. Life span is not typically impacted with less severe CFTR-related conditions. Intellect is not affected with the various CFTR-related conditions. The combination of variants identified in an affected individual impacts the observed clinical features and severity of the symptoms. Additional genetic and environmental factors are believed to play a role in determining the risk of developing these complex CFTR-related conditions.

Additionally, individuals with a single disease-causing CFTR variant (heterozygous carriers) may have an approximately 4-10 fold increased risk for chronic pancreatitis, although the absolute risk of pancreatitis remains low (less than 1 in 100). Hereditary pancreatitis is characterized by recurrent episodes of acute inflammation of the pancreas (pancreatitis) beginning in childhood or adolescence, leading to chronic pancreatitis. Chronic pancreatitis is a risk factor for pancreatic cancer. Due to this potential increased risk for chronic pancreatitis, heterozygous carriers may consider follow-up with a medical provider.

Follow-up depends on each affected individual's specific situation, and discussion with a healthcare provider should be considered.

Next steps

Carrier testing for the reproductive partner is recommended.



If your partner tests positive:

In autosomal recessive inheritance, an individual must have disease-causing genetic changes in each copy of the CFTR gene to be affected. Carriers, who have a disease-causing genetic change in only one copy of the gene, typically do not have symptoms. When both reproductive partners are carriers of an autosomal recessive condition, there is a 25% chance for each child to have the condition.

If your partner tests negative:

A negative carrier test result reduces, but does not eliminate, the chance that a person may be a carrier. The risk that a person could still be a carrier, even after a negative test result, is called a residual risk. See the table below for your partner's hypothetical residual risk after testing negative for CFTR-related conditions. These values are provided only as a guide, are based on the detection rate for the condition as tested at Invitae, and assume a negative family history, the absence of symptoms, and vary based on the ethnic background of an individual. For genes associated with both dominant and recessive inheritance, the numbers provided apply to the recessive condition(s) associated with the gene.

DISORDER (INHERITANCE)	GENE	ETHNICITY	CARRIER FREQUENCY BEFORE SCREENING	CARRIER RESIDUAL RISK AFTER NEGATIVE RESULT
CFTR-related conditions (AR) NM_000492.3	CFTR *	Pan-ethnic - classic CF	1 in 45	1 in 4400
		Pan-ethnic - classic CF and CFTR-related disorders	1 in 9	1 in 800

RESULT: CARRIER

Congenital adrenal hyperplasia due to 21-hydroxylase deficiency

A single Pathogenic variant, c.1360C>T (p.Pro454Ser), was identified in CYP21A2. This variant is primarily associated with non-classic congenital adrenal hyperplasia due to 21-hydroxylase deficiency. See "What is congenital adrenal hyperplasia due to 21-hydroxylase deficiency?" and Variant details for additional information.

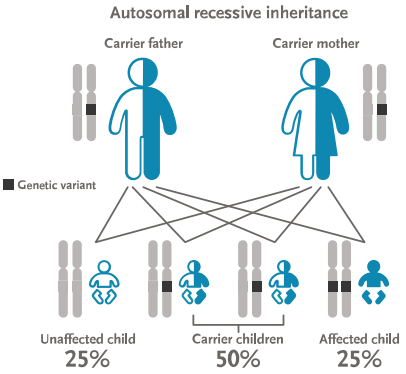
What is congenital adrenal hyperplasia due to 21-hydroxylase deficiency?

21-hydroxylase deficiency (21-OHD) is one of a group of conditions called congenital adrenal hyperplasia (CAH), which impair hormone production by the adrenal glands. The adrenal glands produce hormones that regulate many essential functions in the body, including sexual development and maturation. There are several types of CAH, which are caused by changes in different genes.

Symptoms of 21-OHD CAH range in severity, and are caused by the adrenal glands producing excess male sex hormones (androgens). There are three types of 21-OHD which include two classic forms, known as the salt-wasting and simple virilizing types, and the third is called the non-classic type. The salt-wasting type is the most severe, the simple virilizing type is less severe, and the non-classic type is the mildest form. Individuals with the salt-wasting type of 21-OHD lose large amounts of sodium in the urine, which can be life-threatening in early infancy. Infants with the simple virilizing type of 21-OHD do not experience salt-wasting. Female infants with classic 21-OHD usually have external genitalia that do not look clearly male or female (ambiguous genitalia). Male infants with classic 21-OHD usually have normal genitalia, although the testes may be smaller than typical. Individuals with a classic form of 21-OHD may have decreased fertility. Females with non-classic 21-OHD are born with typical external genitalia. They may experience irregular menstruation, decreased fertility, excess hair growth on the face and body (hirsutism), and male-pattern baldness. Males with non-classic 21-OHD may experience early beard growth and have small testes. Some individuals with non-classic 21-OHD may not have signs or symptoms of the condition (asymptomatic). The form(s) of 21-OHD CAH for which an individual would be at risk depends on the specific CYP21A2 variants inherited from the reproductive parents. Follow-up depends on each affected individual's specific situation, and discussion with a healthcare provider should be considered.

Next steps

Carrier testing for the reproductive partner is recommended.



If your partner tests positive:

The various forms of congenital adrenal hyperplasia due to 21-hydroxylase deficiency are inherited in an autosomal recessive fashion. In autosomal recessive inheritance, an individual must have disease-causing genetic changes in each copy of the CYP21A2 gene to be affected. Carriers, who have a disease-causing genetic change in only one copy of the gene, typically do not have symptoms. When both reproductive partners are carriers of an autosomal recessive condition, there is a 25% chance for each child to have the condition. The form(s) of 21-OHD CAH for which an individual's offspring would be at risk depends on the specific CYP21A2 variants inherited from the reproductive parents. When an individual has a CYP21A2 variant on each chromosome (in trans), and at least one of the variants is most commonly associated with the non-classic form of the condition, then the individual is most likely to be at risk to have non-classic 21-OHD.

If your partner tests negative:

A negative carrier test result reduces, but does not eliminate, the chance that a person may be a carrier. The risk that a person could still be a carrier, even after a negative test result, is called a residual risk. See the table below for your partner's hypothetical residual risk after testing negative for congenital adrenal hyperplasia due to 21-hydroxylase deficiency. These values are provided only as a guide, are based on the detection rate for the condition as tested at Invitae, and assume a negative family history, the absence of symptoms, and vary based on the ethnic background of an individual. For genes associated with both dominant and recessive inheritance, the numbers provided apply to the recessive condition(s) associated with the gene.

DISORDER (INHERITANCE)	GENE	ETHNICITY	CARRIER FREQUENCY BEFORE SCREENING	CARRIER RESIDUAL RISK AFTER NEGATIVE RESULT
Congenital adrenal hyperplasia due to 21-hydroxylase deficiency (AR) NM_000500.7	CYP21A2 *	Pan-ethnic	1 in 61	1 in 751

RESULT: CARRIER

Glycogen storage disease type II (Pompe disease)

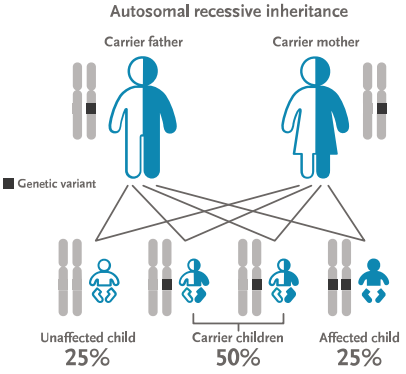
A single Pathogenic variant, c.1194+3G>C (Intronic), was identified in GAA.

What is glycogen storage disease type II (Pompe disease)?

Glycogen storage disease (GSD) is a group of conditions in which individuals have difficulty breaking down a complex sugar called glycogen. A buildup of glycogen impairs the function of certain organs and tissues. The symptoms of glycogen storage disease type II (GSD II), also called Pompe disease, vary in age of onset and severity. Classical Pompe disease typically presents in infancy and is characterized by low muscle tone (hypotonia), poor growth (failure to thrive), muscle weakness (myopathy), an enlarged heart (cardiomegaly) and thickened heart muscle (hypertrophic cardiomyopathy). The condition is often fatal in infancy or early childhood due to heart or breathing problems. Non-classical forms of Pompe disease can present in infancy, childhood, adolescence, or adulthood, often with milder symptoms and slower disease progression. Symptoms may include weakness in the arm and leg muscles that are closest to the body (proximal myopathy) and breathing difficulties, with little to no heart muscle involvement. Enzyme replacement therapy is available and early initiation may delay the onset of the symptoms and reduce their severity. Follow-up depends on each affected individual's specific situation, and discussion with a healthcare provider should be considered.

Next steps

Carrier testing for the reproductive partner is recommended.



If your partner tests positive:

In autosomal recessive inheritance, an individual must have disease-causing genetic changes in each copy of the GAA gene to be affected. Carriers, who have a disease-causing genetic change in only one copy of the gene, typically do not have symptoms. When both reproductive partners are carriers of an autosomal recessive condition, there is a 25% chance for each child to have the condition.

If your partner tests negative:

A negative carrier test result reduces, but does not eliminate, the chance that a person may be a carrier. The risk that a person could still be a carrier, even after a negative test result, is called a residual risk. See the table below for your partner's hypothetical residual risk after testing negative for glycogen storage disease type II (Pompe disease). These values are provided only as a guide, are based on the detection rate for the condition as tested at Invitae, and assume a negative family history, the absence of symptoms, and vary based on the ethnic background of an individual. For genes associated with both dominant and recessive inheritance, the numbers provided apply to the recessive condition(s) associated with the gene.

DISORDER (INHERITANCE)	GENE	ETHNICITY	CARRIER FREQUENCY BEFORE SCREENING	CARRIER RESIDUAL RISK AFTER NEGATIVE RESULT
Glycogen storage disease type II (Pompe disease) (AR) NM_000152.3	GAA	Pan-ethnic	1 in 100	1 in 9900

Results to note

FMR1

- Normal triplet repeats observed: 30. CGG repeat ranges: normal (<45 CGG repeats), intermediate (45-54 CGG repeats), premutation (55-200 CGG repeats), full mutation (>200 CGG repeats).

SMN1

- Negative result. SMN1: 2 copies; c.*3+80T>G not detected.

Pseudodeficiency allele(s)

- Benign change, c.1685T>C (p.Ile562Thr), known to be a pseudodeficiency allele, identified in the GALC gene. Pseudodeficiency alleles are not known to be associated with disease, including Krabbe disease.
- The presence of a pseudodeficiency allele does not impact this individual's risk to be a carrier. Individuals with pseudodeficiency alleles may exhibit false positive results on related biochemical tests, including newborn screening. However, pseudodeficiency alleles are not known to cause disease, even when there are two copies of the variant (homozygous) or when in combination with another disease-causing variant (compound heterozygous). Carrier testing for the reproductive partner is not indicated based on this result.

Variant details

CFTR, Intron 9, c.1210-34TG[12]T[5] (Intronic), heterozygous, PATHOGENIC

- This sequence change, also referred to as 5T;TG12 or TG12-5T in the literature, consists of 12 TG and 5 T sequence repeats on the same chromosome, and is located in intron 9 of the CFTR gene. It does not directly change the encoded amino acid sequence of the CFTR protein.
- The frequency data for this variant in the population databases is considered unreliable, as metrics indicate poor data quality at this position in the gnomAD database.
- The TG[12]T[5] allele has been observed in males with congenital bilateral absence of the vas deferens (CBAVD) and in both males and females with cystic fibrosis (CF) when present on the opposite chromosome (in trans) from a severe pathogenic CFTR variant (PMID: 14685937). When this allele is observed in trans with a severe pathogenic CFTR variant, the penetrance of CFTR-related conditions (CBAVD and/or non-classic CF) is expected to be high (>90%); however, the penetrance of classic CF is low (<20%) (PMID: 14685937, 27447098). Individuals who are homozygous for this variant, or who have this variant in combination with TG[11]T[5], are likely to be asymptomatic (PMID: 34196078).
- Algorithms developed to predict the effect of variants on protein structure and function are not available or were not evaluated for this variant.
- Experimental studies demonstrate that the 5T allele leads to exclusion of exon 10 (referred to as exon 9 in some publications) from the mRNA, which ultimately results in a non-functional CFTR protein (PMID: 7691356, 7684641, 10556281, 14685937, 21658649). Importantly, the number of TG repeats (11, 12 or 13) modifies the extent of exon 10 skipping when in cis with the 5T allele (PMID: 14685937, 10556281, 9435322). In a mini-gene assay, the percentage of CFTR mRNA without exon 10 was 54% for TG[11]T[5], 72% for TG[12]T[5] and 100% for TG[13]T[5] (PMID: 10556281).
- Algorithms developed to predict the effect of sequence changes on RNA splicing suggest that this variant is not likely to affect RNA splicing.
- For these reasons, this variant has been classified as Pathogenic.

CYP21A2, Exon 10, c.1360C>T (p.Pro454Ser), heterozygous, PATHOGENIC

- This sequence change replaces proline, which is neutral and non-polar, with serine, which is neutral and polar, at codon 454 of the CYP21A2 protein (p.Pro454Ser).
- The frequency data for this variant in the population databases (gnomAD) is considered unreliable due to the presence of homologous sequence, such as pseudogenes or paralogs, in the genome.

- This missense change has been observed in individual(s) with clinical features of non-classic congenital adrenal hyperplasia due to 21-hydroxylase deficiency (PMID: 1406699, 10720040, 12222711, 12887291, 21444649, 21843885, 22270556, 23073904, 31333583, 32966723). In at least one individual the data is consistent with being in trans (on the opposite chromosome) from a pathogenic variant.
- This variant is also known as P453S.
- ClinVar contains an entry for this variant (Variation ID: 12159).
- Advanced modeling of protein sequence and biophysical properties (such as structural, functional, and spatial information, amino acid conservation, physicochemical variation, residue mobility, and thermodynamic stability) performed at Invitae indicates that this missense variant is not expected to disrupt CYP21A2 protein function.
- Experimental studies have shown that this missense change affects CYP21A2 function (PMID: 18381579, 24953648, 30968594).
- For these reasons, this variant has been classified as Pathogenic.

GAA, Intron 7, c.1194+3G>C (Intronic), heterozygous, PATHOGENIC

- This sequence change falls in intron 7 of the GAA gene. It does not directly change the encoded amino acid sequence of the GAA protein. It affects a nucleotide within the consensus splice site.
- This variant is present in population databases (rs368539333, gnomAD 0.03%).
- This variant has been observed in individual(s) with biochemical features of Pompe disease (PMID: 33073003, 33202836; Invitae; External communication). In at least one individual the data is consistent with being in trans (on the opposite chromosome) from a pathogenic variant.
- ClinVar contains an entry for this variant (Variation ID: 198393).
- Variants that disrupt the consensus splice site are a relatively common cause of aberrant splicing (PMID: 17576681, 9536098). Algorithms developed to predict the effect of sequence changes on RNA splicing suggest that this variant may disrupt the consensus splice site.
- For these reasons, this variant has been classified as Pathogenic.

Residual risk

No carrier test can detect 100% of carriers. There still remains a small risk of being a carrier after a negative test (residual risk). Residual risk values assume a negative family history and are inferred from published carrier frequencies and estimated detection rates based on testing technologies used at Invitae. You can view Invitae's complete Carrier detection rates and residual risks document (containing all carrier genes) online at https://www.invitae.com/carrier-residual-risks/. Additionally, the order-specific information for this report is available to download in the portal (under this order's documents) or can be requested by contacting Invitae Client Services. The complete Carrier detection rates and residual risks document will not be applicable for any genes with specimen-specific limitations in sequencing and/or deletion/duplication coverage. Please see the final bullet point in the Limitations section of this report to view if this specimen had any gene-specific coverage gaps.

Genes analyzed

This table represents a complete list of genes analyzed for this individual, including the relevant gene transcript(s). If more than one transcript is listed for a single gene, variants were reported using the first transcript listed unless otherwise indicated in the report. An asterisk (*) indicates that this gene has a limitation. Please see the Limitations section for details. Results are negative, unless otherwise indicated in the report.

GENE	TRANSCRIPT
AAAS	NM_015665.5
ABCA12	NM_173076.2
ABCA3	NM_001089.2
ABCA4	NM_000350.2
ABCB11	NM_003742.2
ABCB4	NM_000443.3
ABCC2*	NM_000392.4
ABCC8	NM_000352.4
ABCD1	NM_000033.3
ACAD9	NM_014049.4
ACADM	NM_000016.5
ACADVL	NM_000018.3
ACAT1	NM_000019.3
ACOX1	NM_004035.6
ACSF3	NM_174917.4
ADA	NM_000022.2
ADAMTS2	NM_014244.4
ADAMTSL4	NM_019032.5
ADGRG1	NM_005682.6
ADGRV1	NM_032119.3
AGA	NM_000027.3
AGL	NM_000642.2
AGPS	NM_003659.3
AGXT	NM_000030.2
AHI1	NM_017651.4
AIPL1*	NM_014336.4
AIRE	NM_000383.3
ALDH3A2	NM_000382.2
ALDH7A1	NM_001182.4
ALDOB	NM_000035.3
ALG1	NM_019109.4
ALG13	NM_001099922.2
ALG6	NM_013339.3
ALMS1	NM_015120.4
ALPL	NM_000478.5
AMN*	NM_030943.3
AMT	NM_000481.3
ANO10*	NM_018075.3
AP1S1	NM_001283.3
AQP2	NM_000486.5
AR*	NM_000044.3
ARG1	NM_000045.3
ARL6	NM_177976.2
ARSA	NM_000487.5
ARSB	NM_000046.3
ARSE	NM_000047.2
ARX*	NM_139058.2
ASL	NM_000048.3
ASNS	NM_133436.3
ASPA	NM_000049.2
ASS1	NM_000050.4
ATM*	NM_000051.3
ATP6V1B1	NM_001692.3
ATP7A	NM_000052.6
ATP7B	NM_000053.3
ATP8B1*	NM_005603.4
ATRX	NM_000489.4
AVPR2	NM_000054.4
BBS1	NM_024649.4
BBS10	NM_024685.3
BBS12	NM_152618.2
BBS2	NM_031885.3
BBS4	NM_033028.4
BBS5	NM_152384.2
BBS7	NM_176824.2
BBS9*	NM_198428.2
BCKDHA	NM_000709.3
BCKDHB	NM_183050.2
BCS1L	NM_004328.4
BLM	NM_000057.3
BLOC1S3	NM_212550.4
BLOC1S6	NM_012388.3
BMP1	NM_006129.4;NM_001199.3
BRIP1	NM_032043.2
BSND	NM_057176.2
BTK	NM_000061.2
CAD	NM_004341.4
CANT1	NM_138793.3
CAPN3	NM_000070.2
CASQ2	NM_001232.3
CBS	NM_000071.2
CC2D1A	NM_017721.5
CC2D2A	NM_001080522.2
CCDC103	NM_213607.2
CCDC39	NM_181426.1
CCDC88C	NM_001080414.3
CD3D	NM_000732.4
CD3E	NM_000733.3
CD40	NM_001250.5
CD40LG	NM_000074.2
CD59	NM_203330.2
CDH23	NM_022124.5
CEP152	NM_014985.3
CEP290	NM_025114.3
CERKL	NM_001030311.2
CFTR*	NM_000492.3
CHAT	NM_020549.4
CHM	NM_000390.2
CHRNE	NM_000080.3
CHRNG	NM_005199.4
CIITA	NM_000246.3
CLCN1	NM_000083.2
CLN3	NM_001042432.1
CLN5	NM_006493.2
CLN6	NM_017882.2
CLN8	NM_018941.3
CLRN1	NM_174878.2
CNGB3	NM_019098.4

GENE	TRANSCRIPT
COL11A2*	NM_080680.2
COL17A1	NM_000494.3
COL27A1	NM_032888.3
COL4A3	NM_000091.4
COL4A4	NM_000092.4
COL4A5	NM_000495.4
COL7A1	NM_000094.3
COX15	NM_004376.6
CPS1	NM_001875.4
CPT1A	NM_001876.3
CPT2	NM_000098.2
CRB1	NM_201253.2
CRTAP	NM_006371.4
CTNS	NM_004937.2
CTSA	NM_000308.3
CTSC	NM_001814.5
CTSD	NM_001909.4
CTSK	NM_000396.3
CYBA	NM_000101.3
CYBB	NM_000397.3
CYP11A1	NM_000781.2
CYP11B1	NM_000497.3
CYP11B2	NM_000498.3
CYP17A1	NM_000102.3
CYP19A1	NM_031226.2
CYP1B1	NM_000104.3
CYP21A2*	NM_000500.7
CYP27A1	NM_000784.3
CYP27B1	NM_000785.3
CYP7B1	NM_004820.3
DBT	NM_001918.3
DCAF17	NM_025000.3
DCLRE1C	NM_001033855.2
DDX11*	NM_030653.3
DFNB59	NM_001042702.3
DGAT1	NM_012079.5
DGUOK	NM_080916.2
DHCR7	NM_001360.2
DHDDS	NM_024887.3

GENE	TRANSCRIPT
DKC1	NM_001363.4
DLD	NM_000108.4
DLL3	NM_016941.3
DMD	NM_004006.2
DNAH11	NM_001277115.1
DNAH5	NM_001369.2
DNAI1	NM_012144.3
DNAI2	NM_023036.4
DNMT3B	NM_006892.3
DOK7	NM_173660.4
DUOX2*	NM_014080.4
DYNC2H1	NM_001080463.1
DYSF	NM_003494.3
EDA	NM_001399.4
EIF2AK3	NM_004836.6
EIF2B1	NM_001414.3
EIF2B2	NM_014239.3
EIF2B3	NM_020365.4
EIF2B4	NM_015636.3
EIF2B5	NM_003907.2
ELP1	NM_003640.3
EMD	NM_000117.2
EPG5	NM_020964.2
ERCC2	NM_000400.3
ERCC6	NM_000124.3
ERCC8	NM_000082.3
ESCO2	NM_001017420.2
ETFA	NM_000126.3
ETFB	NM_001985.2
ETFDH	NM_004453.3
ETHE1	NM_014297.3
EVC	NM_153717.2
EVC2	NM_147127.4
EXOSC3	NM_016042.3
EYS*	NM_001142800.1
F9	NM_000133.3
FAH*	NM_000137.2
FAM161A	NM_001201543.1
FANCA	NM_000135.2

GENE	TRANSCRIPT
FANCB	NM_001018113.1
FANCC	NM_000136.2
FANCD2*	NM_033084.3
FANCE	NM_021922.2
FANCG	NM_004629.1
FANCI	NM_001113378.1
FANCL*	NM_018062.3
FBP1	NM_000507.3
FBXO7	NM_012179.3
FH*	NM_000143.3
FHL1	NM_001449.4
FKBP10	NM_021939.3
FKRP	NM_024301.4
FKTN	NM_001079802.1
FMO3	NM_006894.6
FMR1*	NM_002024.5
FOXN1	NM_003593.2
FOXRED1	NM_017547.3
FRAS1	NM_025074.6
FREM2	NM_207361.5
FUCA1	NM_000147.4
G6PC	NM_000151.3
G6PC3	NM_138387.3
GAA	NM_000152.3
GALC*	NM_000153.3
GALE*	NM_000403.3
GALK1	NM_000154.1
GALNS	NM_000512.4
GALNT3	NM_004482.3
GALT	NM_000155.3
GAMT	NM_000156.5
GATM	NM_001482.2
GBA*	NM_001005741.2
GBE1	NM_000158.3
GCDH	NM_000159.3
GCH1	NM_000161.2
GDF5	NM_000557.4
GFM1	NM_024996.5
GHR*	NM_000163.4

GENE	TRANSCRIPT
GJB1	NM_000166.5
GJB2	NM_004004.5
GLA	NM_000169.2
GLB1	NM_000404.2
GLDC	NM_000170.2
GLE1	NM_001003722.1
GNE*	NM_001128227.2
GNPAT	NM_014236.3
GNPTAB	NM_024312.4
GNPTG	NM_032520.4
GNS	NM_002076.3
GORAB	NM_152281.2
GRHPR	NM_012203.1
GRIP1	NM_021150.3
GSS	NM_000178.2
GUCY2D	NM_000180.3
GUSB	NM_000181.3
HADH	NM_005327.4
HADHA	NM_000182.4
HADHB	NM_000183.2
HAMP	NM_021175.2
HAX1	NM_006118.3
HBA1*	NM_000558.4
HBA2	NM_000517.4
HBB	NM_000518.4
HCFC1	NM_005334.2
HEXA	NM_000520.4
HEXB	NM_000521.3
HGSNAT	NM_152419.2
HJV	NM_213653.3
HLCS	NM_000411.6
HMGCL	NM_000191.2
HMOX1	NM_002133.2
HOGA1	NM_138413.3
HPD	NM_002150.2
HPRT1	NM_000194.2
HPS1	NM_000195.4
HPS3	NM_032383.4
HPS4	NM_022081.5

GENE	TRANSCRIPT
HPS5	NM_181507.1
HPS6	NM_024747.5
HSD17B10	NM_004493.2
HSD17B3	NM_000197.1
HSD17B4	NM_000414.3
HSD3B2	NM_000198.3
HYAL1	NM_153281.1
HYLS1	NM_145014.2
IDS*	NM_000202.6
IDUA	NM_000203.4
IGHMBP2	NM_002180.2
IKBKB	NM_001556.2
IL2RG	NM_000206.2
IL7R	NM_002185.3
INVS	NM_014425.3
ITGA6	NM_000210.3
ITGB3	NM_000212.2
ITGB4	NM_001005731.2
IVD	NM_002225.3
JAK3	NM_000215.3
KCNJ1	NM_000220.4
KCNJ11	NM_000525.3
L1CAM	NM_000425.4
LAMA2	NM_000426.3
LAMA3	NM_000227.4
LAMB3	NM_000228.2
LAMC2	NM_005562.2
LARGE1	NM_004737.4
LCA5	NM_181714.3
LDLR	NM_000527.4
LDLRAP1	NM_015627.2
LHX3	NM_014564.4
LIFR*	NM_002310.5
LIG4	NM_002312.3
LIPA	NM_000235.3
LMBRD1	NM_018368.3
LOXHD1	NM_144612.6
LPL	NM_000237.2
LRAT	NM_004744.4

GENE	TRANSCRIPT
LRP2	NM_004525.2
LRPPRC	NM_133259.3
LYST	NM_000081.3
MAK	NM_001242957.2
MAN2B1	NM_000528.3
MANBA	NM_005908.3
MCEE	NM_032601.3
MCOLN1	NM_020533.2
MCPH1	NM_024596.4
MECP2	NM_004992.3;NM_001110792.1
MECR	NM_016011.3
MED17	NM_004268.4
MESP2	NM_001039958.1
MFSD8	NM_152778.2
MID1*	NM_000381.3
MKKS	NM_018848.3
MKS1	NM_017777.3
MLC1*	NM_015166.3
MLYCD	NM_012213.2
MMAA	NM_172250.2
MMAB	NM_052845.3
MMACHC	NM_015506.2
MMADHC	NM_015702.2
MOCS1	NM_001358530.2
MOCS2A	NM_176806.3
MOCS2B	NM_004531.4
MPI	NM_002435.2
MPL	NM_005373.2
MPV17	NM_002437.4
MRE11	NM_005591.3
MTHFR*	NM_005957.4
MTM1	NM_000252.2
MTR	NM_000254.2
MTRR	NM_002454.2
MTTP	NM_000253.3
MUSK	NM_005592.3
MUT	NM_000255.3
MVK	NM_000431.3
MYO15A	NM_016239.3

GENE	TRANSCRIPT
MYO7A	NM_000260.3
NAGA	NM_000262.2
NAGLU	NM_000263.3
NAGS	NM_153006.2
NBN	NM_002485.4
NCF2	NM_000433.3
NDRG1	NM_006096.3
NDUFAF2	NM_174889.4
NDUFAF5	NM_024120.4
NDUFS4	NM_002495.3
NDUFS6	NM_004553.4
NDUFS7	NM_024407.4
NDUFV1	NM_007103.3
NEB*	NM_001271208.1
NEU1	NM_000434.3
NGLY1	NM_018297.3
NPC1	NM_000271.4
NPC2	NM_006432.3
NPHP1	NM_000272.3
NPHS1	NM_004646.3
NPHS2	NM_014625.3
NR0B1	NM_000475.4
NR2E3	NM_014249.3
NSMCE3	NM_138704.3
NTRK1	NM_001012331.1
OAT*	NM_000274.3
OCA2	NM_000275.2
OCRL	NM_000276.3
OPA3	NM_025136.3
OSTM1	NM_014028.3
OTC	NM_000531.5
OTOA*	NM_144672.3
OTOF	NM_194248.2;NM_194323.2
P3H1	NM_022356.3
PAH	NM_000277.1
PANK2	NM_153638.2
PC	NM_000920.3
PCBD1	NM_000281.3
PCCA	NM_000282.3
PCCB	NM_000532.4
PCDH15	NM_033056.3
PCNT	NM_006031.5
PDHA1	NM_000284.3
PDHB	NM_000925.3
PEPD	NM_000285.3
PET100	NM_001171155.1
PEX1*	NM_000466.2
PEX10	NM_153818.1
PEX12	NM_000286.2
PEX13	NM_002618.3
PEX16	NM_004813.2
PEX2	NM_000318.2
PEX26	NM_017929.5
PEX5	NM_001131025.1
PEX6	NM_000287.3
PEX7	NM_000288.3
PFKM	NM_000289.5
PGM3	NM_001199917.1
PHGDH	NM_006623.3
PHKB	NM_000293.2;NM_001031835.2
PHKG2	NM_000294.2
PHYH	NM_006214.3
PIGN	NM_176787.4
PKHD1*	NM_138694.3
PLA2G6	NM_003560.2
PLEKHG5	NM_020631.4
PLOD1	NM_000302.3
PLP1	NM_000533.4
PMM2	NM_000303.2
PNPO	NM_018129.3
POLG	NM_002693.2
POLH	NM_006502.2
POMGNT1	NM_017739.3
POMT1	NM_007171.3
POMT2	NM_013382.5
POR	NM_000941.2
POU1F1	NM_000306.3
PPT1	NM_000310.3
PRCD	NM_001077620.2
PRDM5	NM_018699.3
PRF1	NM_001083116.1
PROP1	NM_006261.4
PRPS1	NM_002764.3
PSAP	NM_002778.3
PTPRC*	NM_002838.4
PTS	NM_000317.2
PUS1	NM_025215.5
PYGM	NM_005609.3
QDPR	NM_000320.2
RAB23	NM_183227.2
RAG1	NM_000448.2
RAG2	NM_000536.3
RAPSN	NM_005055.4
RARS2	NM_020320.3
RDH12	NM_152443.2
RLBP1	NM_000326.4
RMRP	NR_003051.3
RNASEH2A	NM_006397.2
RNASEH2B	NM_024570.3
RNASEH2C	NM_032193.3
RP2	NM_006915.2
RPE65	NM_000329.2
RPGRIP1L	NM_015272.2
RS1	NM_000330.3
RTEL1	NM_001283009.1
RXYLT1	NM_014254.2
RYR1	NM_000540.2
SACS	NM_014363.5
SAMD9	NM_017654.3
SAMHD1	NM_015474.3
SCO2	NM_005138.2
SEC23B	NM_006363.4
SEPSECS	NM_016955.3
SGCA	NM_000023.2
SGCB	NM_000232.4
SGCD	NM_000337.5
SGCG	NM_000231.2

GENE	TRANSCRIPT
SGSH	NM_000199.3
SKIV2L	NM_006929.4
SLC12A1	NM_000338.2
SLC12A3	NM_000339.2
SLC12A6	NM_133647.1
SLC17A5	NM_012434.4
SLC19A2	NM_006996.2
SLC19A3	NM_025243.3
SLC1A4	NM_003038.4
SLC22A5	NM_003060.3
SLC25A13	NM_014251.2
SLC25A15	NM_014252.3
SLC25A20	NM_000387.5
SLC26A2	NM_000112.3
SLC26A3	NM_000111.2
SLC26A4	NM_000441.1
SLC27A4	NM_005094.3
SLC35A3	NM_012243.2
SLC37A4	NM_001164277.1
SLC38A8	NM_001080442.2
SLC39A4	NM_130849.3
SLC45A2	NM_016180.4
SLC4A11	NM_032034.3
SLC5A5	NM_000453.2
SLC6A8	NM_005629.3
SLC7A7	NM_001126106.2
SMARCAL1	NM_014140.3
SMN1*	NM_000344.3
SMPD1	NM_000543.4
SNAP29	NM_004782.3
SPG11	NM_025137.3
SPR	NM_003124.4
SRD5A2	NM_000348.3
ST3GAL5	NM_003896.3
STAR	NM_000349.2
STX11	NM_003764.3
STXBP2	NM_006949.3
SUMF1	NM_182760.3
SUOX	NM_000456.2

GENE	TRANSCRIPT
SURF1	NM_003172.3
SYNE4	NM_001039876.2
TANGO2	NM_152906.6
TAT	NM_000353.2
TAZ	NM_000116.4
TBCD	NM_005993.4
TBCE*	NM_003193.4
TCIRG1	NM_006019.3
TCN2	NM_000355.3
TECPR2	NM_014844.3
TERT	NM_198253.2
TF	NM_001063.3
TFR2	NM_003227.3
TG*	NM_003235.4
TGM1	NM_000359.2
TH	NM_199292.2
TK2	NM_004614.4
TMC1	NM_138691.2
TMEM216	NM_001173990.2
TMEM67	NM_153704.5
TMPRSS3	NM_024022.2
TPO	NM_000547.5
TPP1	NM_000391.3
TREX1	NM_033629.4
TRIM32	NM_012210.3
TRIM37	NM_015294.4
TRMU	NM_018006.4
TSEN54	NM_207346.2
TSFM*	NM_001172696.1
TSHB	NM_000549.4
TSHR	NM_000369.2
TTC37	NM_014639.3
TTPA	NM_000370.3
TULP1	NM_003322.4
TYMP	NM_001953.4
TYR*	NM_000372.4
TYRP1	NM_000550.2
UBR1	NM_174916.2
UNC13D	NM_199242.2

GENE	TRANSCRIPT
USH1C*	NM_005709.3
USH2A	NM_206933.2
VDR	NM_001017535.1
VLDLR	NM_003383.4
VPS11	NM_021729.5
VPS13A*	NM_033305.2
VPS13B	NM_017890.4
VPS45	NM_007259.4
VPS53*	NM_001128159.2
VRK1	NM_003384.2
VSX2	NM_182894.2
WAS	NM_000377.2
WISP3	NM_003880.3
WNT10A	NM_025216.2
WRN*	NM_000553.4
XPA	NM_000380.3
XPC	NM_004628.4
ZBTB24	NM_014797.2
ZFYVE26	NM_015346.3
ZNF469	NM_001127464.2

Methods

- Genomic DNA obtained from the submitted sample is enriched for targeted regions using a hybridization-based protocol, and sequenced using Illumina technology. Unless otherwise indicated, all targeted regions are sequenced with ≥50x depth or are supplemented with additional analysis. Reads are aligned to a reference sequence (GRCh37), and sequence changes are identified and interpreted in the context of a single clinically relevant transcript, indicated in the Genes Analyzed table. Enrichment and analysis focus on the coding sequence of the indicated transcripts, 20bp of flanking intronic sequence, and other specific genomic regions demonstrated to be causative of disease at the time of assay design. Promoters, untranslated regions, and other non-coding regions are not otherwise interrogated. Exonic deletions and duplications are called using an in-house algorithm that determines copy number at each target by comparing the read depth for each target in the proband sequence with both mean read-depth and read-depth distribution, obtained from a set of clinical samples. Markers across the X and Y chromosomes are analyzed for quality control purposes and may detect deviations from the expected sex chromosome complement. Such deviations may be included in the report in accordance with internal guidelines. Invitae utilizes a classification methodology to identify next-generation sequencing (NGS)-detected variants that require orthogonal confirmation (Lincoln, et al. J Mol Diagn. 2019 Mar;21(2):318-329). Confirmation of the presence and location of reportable variants is performed as needed based on stringent criteria using one of several validated orthogonal approaches (PubMed ID 30610921). Sequencing is performed by Invitae Corporation (1400 16th Street, San Francisco, CA 94103, #05D2040778). Confirmatory sequencing is performed by Invitae Corporation (1400 16th Street, San Francisco, CA 94103, #05D2040778).

  The following additional analyses are performed if relevant to the requisition. For GBA the reference genome has been modified to mask the sites of polymorphic paralog sequence variants (PSVs) in both the gene and pseudogene. For CYP21A2 and GBA, if one or more reportable variants, gene conversion, or fusion event is identified via our NGS pipeline (see Limitations), these variants are confirmed by PacBio sequencing of an amplicon generated by long-range PCR and subsequent short-range PCR. In some cases, it may not be possible to disambiguate between the gene and pseudogene. For GJB2, the reportable range includes large upstream deletions overlapping GJB6. For HBA1/2, the reference genome has been modified to force some sequencing reads derived from HBA1 to align to HBA2, and variant calling algorithms are modified to support an expectation of 4 alleles in these regions. HBA1/2 copy number calling is performed by a custom hypothesis testing algorithm which generates diplotype calls. If sequence data for a sample does not support a unique high confidence match from among hypotheses tested, that sample is flagged for manual review. Copy number variation is only reported for coding sequence of HBA1 and HBA2 and the HS-40 region. This assay does not distinguish among the -α3.7 subtypes, and all -α3.7 variants are called as HBA1 deletions. This assay may not detect overlapping copy gain and copy loss events when the breakpoints of those events are similar. For FMR1, cytosine-guanine-guanine (CGG) triplet repeats in the 5' untranslated region (5' UTR) of the FMR1 gene are detected by triplet repeat-primed PCR (RP-PCR) with fluorescently labeled primers followed by capillary electrophoresis. Reference ranges: Normal: <45 CGG repeats, intermediate: 45-54 CGG repeats, premutation: 55-200 CGG repeats, full mutation: >200 CGG repeats. For alleles with 55-90 triplet repeats, the region surrounding the FMR1 repeat is amplified by PCR. The PCR amplicons are then processed through PacBio SMRTBell library prep and sequenced using PacBio long read technology. The number of AGG interruptions within the 55-90 triplet repeat is read directly from the resulting DNA sequences.

- This report only includes variants that have a clinically significant association with the conditions tested as of the report date. Variants of uncertain significance, benign variants, and likely benign variants are not included in this report. However, if additional evidence becomes available to indicate that the clinical significance of a variant has changed, Invitae may update this report and provide notification.
- A PMID is a unique identifier referring to a published, scientific paper. Search by PMID at **http://www.ncbi.nlm.nih.gov/pubmed**.
- An rsID is a unique identifier referring to a single genomic position, and is used to associate population frequency information with sequence changes at that position. Reported population frequencies are derived from a number of public sites that aggregate data from large-scale population sequencing projects, including ExAC (**http://exac.broadinstitute.org**), gnomAD (**http://gnomad.broadinstitute.org**), and dbSNP (**http://ncbi.nlm.nih.gov/SNP**).

Disclaimer

DNA studies do not constitute a definitive test for the selected condition(s) in all individuals. It should be realized that there are possible sources of error. Errors can result from trace contamination, rare technical errors, rare genetic variants that interfere with analysis, recent scientific developments, and alternative classification systems. This test should be one of many aspects used by the healthcare provider to help with a diagnosis and treatment plan, but it is not a diagnosis itself. This test was developed and its performance characteristics determined by Invitae. It has not been cleared or approved by

the FDA. The laboratory is regulated under the Clinical Laboratory Improvement Act (CLIA) as qualified to perform high-complexity clinical tests (CLIA ID: 05D2040778). This test is used for clinical purposes. It should not be regarded as investigational or for research.

Limitations

- Based on validation study results, this assay achieves >99% analytical sensitivity and specificity for single nucleotide variants, insertions and deletions <15bp in length, and exon-level deletions and duplications. Invitae's methods also detect insertions and deletions larger than 15bp but smaller than a full exon but sensitivity for these may be marginally reduced. Invitae's deletion/duplication analysis determines copy number at a single exon resolution at virtually all targeted exons. However, in rare situations, single-exon copy number events may not be analyzed due to inherent sequence properties or isolated reduction in data quality. Certain types of variants, such as structural rearrangements (e.g. inversions, gene conversion events, translocations, etc.) or variants embedded in sequence with complex architecture (e.g. short tandem repeats or segmental duplications), may not be detected. Additionally, it may not be possible to fully resolve certain details about variants, such as mosaicism, phasing, or mapping ambiguity. Unless explicitly guaranteed, sequence changes in the promoter, non-coding exons, and other non-coding regions are not covered by this assay. Please consult the test definition on our website for details regarding regions or types of variants that are covered or excluded for this test. This report reflects the analysis of an extracted genomic DNA sample. While this test is intended to reflect the analysis of extracted genomic DNA from a referred patient, in very rare cases the analyzed DNA may not represent that individual's constitutional genome, such as in the case of a circulating hematolymphoid neoplasm, bone marrow transplant, blood transfusion, chimerism, culture artifact or maternal cell contamination.
- FMR1 testing is limited to repeat expansion analysis only, and does not include coding region sequence, CNV analysis or FMR1 methylation. Sizing accuracy is expected to be +/-1 for CGG repeat alleles less than or equal to 90 repeat units and +/-3 for CGG repeat alleles greater than 90 repeat units. If the two CGG repeat counts listed are the same, it most likely indicates homozygosity; however, in very rare scenarios it could be the result of biological or technical reasons including, but not limited to, sex chromosome anomalies, allelic dropout, or sample submission errors. This test is not intended to diagnose sex chromosome aneuploidy, although evidence of such incidental findings may be present in the analysis and reported. The number of AGG interruptions is only determined for females ≥12 years of age with triplet repeat sizes of 55-90. Due to somatic mosaicism and/or repeat instability of expanded alleles, repeat size identified in DNA isolated from peripheral blood, buccal cells, or saliva may not reflect the repeat size in untested tissues (e.g. brain, gonads). In addition, a negative result does not definitively rule out the presence of an expansion in the mosaic state, as the current test is not validated to detect low-level mosaic variants. This report reflects the analysis of an extracted genomic DNA sample. While this test is intended to reflect the analysis of extracted genomic DNA from a referred patient, in very rare cases the analyzed DNA may not represent that individual's constitutional genome, such as in the case of a circulating hematolymphoid neoplasm, bone marrow transplant, blood transfusion, chimerism, culture artifact or maternal cell contamination. DUOX2: Deletion/duplication and sequencing analysis is not offered for exons 6-7. PTPRC: Sequencing analysis is not offered for exons 3, 15. ABCC2: Deletion/duplication analysis is not offered for exons 24-25. OTOA: Deletion/duplication and sequencing analysis is not offered for exons 20-28. TBCE: Sequencing analysis for exons 2 includes only cds +/- 10 bp. GALE: Sequencing analysis for exons 10 includes only cds +/- 5 bp. DDX11: NM_030653.3:c.1763-1G>C variant only. PKHD1: Deletion/duplication analysis is not offered for exon 13. SMN1: Systematic exon numbering is used for all genes, including SMN1, and for this reason the exon typically referred to as exon 7 in the literature (PMID: 8838816) is referred to as exon 8 in this report. This assay unambiguously detects SMN1 exon 8 copy number. The presence of the g.27134T>G variant (also known as c.*3+80T>G) is reported if SMN1 copy number = 2. SMN1 or SMN2: NM_000344.3:c.*3+80T>G variant only. VPS13A: Deletion/duplication analysis is not offered for exons 2-3, 27-28. GNE: Sequencing analysis for exons 8 includes only cds +/- 10 bp. NEB: Deletion/duplication analysis is not offered for exons 82-105. NEB variants in this region with no evidence towards pathogenicity are not included in this report, but are available upon request. BBS9: Deletion/duplication analysis is not offered for exon 4. WRN: Deletion/duplication analysis is not offered for exons 10-11. Sequencing analysis for exons 8, 10-11 includes only cds +/- 10 bp. OAT: Deletion/duplication analysis is not offered for exon 2. GHR: Deletion/duplication and sequencing analysis is not offered for exon 3. CFTR: Sequencing analysis for exons 7 includes only cds +/- 10 bp. EYS: Sequencing analysis for exons 30 includes only cds +/- 0 bp. FH: Sequencing analysis for exons 9 includes only cds +/- 10 bp. ANO10: Sequencing analysis for exons 8 includes only cds +/- 0 bp. ATP8B1: Sequencing analysis for exons 19 includes only cds +/- 10 bp. FANCD2: Deletion/duplication analysis is not offered for exons 14-17, 22 and sequencing analysis is not offered for exons 15-17. Sequencing analysis for exons 6, 14, 18, 20, 23, 25, 34 includes only cds +/- 10 bp. ARX: Analysis is validated to detect polyalanine expansions but sensitivity may be reduced. COL11A2: Deletion/duplication analysis is not offered for exon 36. TSFM: Sequencing analysis is not offered for exon 5. VPS53: Sequencing analysis for exons 14 includes only cds +/- 5 bp. HBA1/2: This assay is designed to detect deletions and duplications of HBA1 and/or HBA2, resulting from the -alpha20.5, --MED, --SEA, --FIL/--THAI, -alpha3.7, -alpha4.2, anti3.7 and anti4.2. Sensitivity to detect other copy number variants may be reduced. Detection of overlapping deletion and duplication events will be limited to combinations of events with significantly differing boundaries. In addition, deletion of the enhancer element HS-40 and the sequence variant, Constant Spring (NM_000517.4:c.427T>C), can be

identified by this assay. MTHFR: The NM_005957.4:c.665C>T (p.Ala222Val) (aka 677C>T) and c.1286A>C (p.Glu429Ala) (aka 1298A>C) variants are not reported in our primary report. GBA: c.84dupG (p.Leu29Alafs*18), c.115+1G>A (Splice donor), c.222_224delTAC (p.Thr75del), c.475C>T (p.Arg159Trp), c.595_596delCT (p.Leu199Aspfs*62), c.680A>G (p.Asn227Ser), c.721G>A (p.Gly241Arg), c.754T>A (p.Phe252Ile), c.1226A>G (p.Asn409Ser), c.1246G>A (p.Gly416Ser), c.1263_1317del (p.Leu422Profs*4), c.1297G>T (p.Val433Leu), c.1342G>C (p.Asp448His), c.1343A>T (p.Asp448Val), c.1448T>C (p.Leu483Pro), c.1504C>T (p.Arg502Cys), c.1505G>A (p.Arg502His), c.1603C>T (p.Arg535Cys), c.1604G>A (p.Arg535His) variants only. Rarely, sensitivity to detect these variants may be reduced. When sensitivity is reduced, zygosity may be reported as "unknown". MID1: Sequencing analysis for exons 3 includes only cds +/- 0 bp. CYP21A2: Analysis includes the most common variants (c.92C>T(p.Pro31Leu), c.293-13C>G (intronic), c.332_339delGAGACTAC (p.Gly111Valfs*21), c.518T>A (p.Ile173Asn), c.710T>A (p.Ile237Asn), c.713T>A (p.Val238Glu), c.719T>A (p.Met240Lys), c.844G>T (p.Val282Leu), c.923dupT (p.Leu308Phefs*6), c.955C>T (p.Gln319*), c.1069C>T(p.Arg357Trp), c.1360C>T (p.Pro454Ser) and the 30Kb deletion) as well as select rare HGMD variants only (list available upon request). Full gene duplications are reported only in the presence of a pathogenic variant(s). When a duplication and a pathogenic variant(s) is identified, phase (cis/trans) cannot be determined. Full gene deletion analysis is not offered. Sensitivity to detect these variants, if they result from complex gene conversion/fusion events, may be reduced. AIPL1: Sequencing analysis for exons 2 includes only cds +/- 10 bp. LIFR: Sequencing analysis for exons 3 includes only cds +/- 5 bp. AMN: Deletion/duplication analysis is not offered for exon 1. PEX1: Sequencing analysis for exons 16 includes only cds +/- 0 bp. USH1C: Deletion/duplication analysis is not offered for exons 5-6. TYR: Deletion/duplication and sequencing analysis is not offered for exon 5. AR: CAG repeat numbers are not determined. TG: Deletion/duplication analysis is not offered for exon 18. Sequencing analysis for exons 44 includes only cds +/- 0 bp. FANCL: Sequencing analysis for exons 4, 10 includes only cds +/- 10 bp. IDS: Detection of complex rearrangements not offered (PMID: 7633410, 20301451). MLC1: Sequencing analysis for exons 11 includes only cds +/- 10 bp. ATM: Sequencing analysis for exons 6, 24, 43 includes only cds +/- 10 bp. FAH: Deletion/duplication analysis is not offered for exon 14. GALC: Deletion/duplication analysis is not offered for exon 6.

This report has been reviewed and approved by:

Fatimah Nahhas-Alwan, PhD, FACMG
Clinical Molecular Geneticist

Ordered Items: **Inheritest(R)500 PLUS Panel; Chromosome, Blood, Routine; Count 15-20 cells, 2 Karyotype; Chromosome Blood Routine 88230**

Date Collected: **02/28/2023**

Inheritest(R)500 PLUS Panel

Test	Current Result and Flag	Previous Result and Date	Units	Reference Interval
Result [A, 01]	PDF report to be sent separately **Effective March 20, 2023 630049 Inheritest(R)500 PLUS Panel** will be made non-orderable. Labcorp will offer order code 481893 Inheritest 500 PLUS Panel. For further information, please contact your local Labcorp Representative.			
PDF [01]	.			
Patient Gender [01]	Male			

Chromosome, Blood, Routine

Test	Current Result and Flag	Previous Result and Date	Units	Reference Interval
Specimen Type [02]	Comment: BLOOD			
Cells Counted [02]	20			
Cells Analyzed [02]	20			
Cells Karyotyped [02]	2			
GTG Band Resolution Achieved [02]	500			
Cytogenetic Result [02]	Comment: 46,XY			
Interpretation [02]	Comment: NORMAL MALE KARYOTYPE Cytogenetic analysis of PHA stimulated cultures has revealed a MALE karyotype with an apparently normal GTG banding pattern in all cells observed. This result does not exclude the possibility of subtle rearrangements below the resolution of cytogenetics or congenital anomalies due to other etiologies. Technical Component-Processing performed by LabCorp CLIA 34D1008914, 1904 TW Alexander Dr, Research Triangle Park, NC 27709. Medical Director, Anjen Chenn, M.D., Ph.D. Technical Component-Chromosome analysis performed at Virtual Scientific, Inc., CLIA# 34D2180949. 20 Grouse Wing Court, Biltmore NC 28715 . Laboratory Director Lisa R Smith, Ph.D.			
Director Review: [02]	Comment: Kaitlin C. Lenhart, PhD, FACMG			
PDF	.			

Disclaimer
The Previous Result is listed for the most recent test performed by Labcorp in the past 5 years where there is sufficient patient demographic data to match the result to the patient. Results from certain tests are excluded from the Previous Result display.

Icon Legend
▲ Out of Reference Range ■ Critical or Alert

Comments
A: This test was developed and its performance characteristics determined by Labcorp. It has not been cleared or approved by the Food and Drug Administration.

Performing Labs
01: MNEGA - Medical Neurogenetic LLC 5424 Glenridge Dr NE, Atlanta, GA, 30342-1342 Dir: Geraldine McDowell, PhD
02: YU - Labcorp RTP 1904 TW Alexander Drive Ste C, RTP, NC, 27709-0153 Dir: Anjen Chenn, MDPhD
For Inquiries, the physician may contact Branch: 800-321-3862 Lab: 800-282-7300

Patient Details
Cb, 569

Phone:
Date of Birth:
Age:
Sex: **Male**
Patient ID:
Alternate Patient ID:

Physician Details
D PRESCOTT
Cryo Biology
4845 Knightsbridge Blvd., Ste 200,
Columbus, OH, 43214

Phone: **614-451-4375**
Account Number: **34334785**
Physician ID: **PRESCOTT,D**
NPI: **1285675868**

Specimen Details

Date Collected: **02/28/2023 0900 Local**
Date Received: **03/01/2023 0000 ET**
Date Entered: **03/01/2023 2131 ET**
Date Reported: **03/29/2023 0809 ET**

Specimen ID: **Container ID:**
Control ID: **Acct #:** 34334785 **Phone:**

CB, 569

Patient Details		Specimen Details		Physician Details	
DOB:		**Date Collected:**	02/28/2023 12:00 (Local)	**Ordering:**	PRESCOTT, D
Age (yyy/mm/dd):		**Date Received:**	03/02/2023	**Referring:**	
Gender:	Male	**Date Entered:**	03/02/2023	**ID:**	PRESCOTT,D
Patient ID:		**Date Reported:**	03/27/2023 21:39 (Local)	**NPI:**	

Ethnicity: Not provided
Indication: Carrier screening
Specimen Type: Blood
Lab ID: MNEGA
Genetic Counselor:

SUMMARY: NEGATIVE

NEGATIVE RESULTS

DISORDER *(GENE)*	RESULTS	INTERPRETATION
Cystic fibrosis (*CFTR*) NMID: NM_000492	NEGATIVE	This result reduces, but does not eliminate the risk to be a carrier. **Risk**: NOT at an increased risk for an affected pregnancy.
Spinal muscular atrophy (*SMN1*) NMID: NM_000344	NEGATIVE 2 or 3 copies of *SMN1*; negative for c.*3+80T>G SNP	This result reduces, but does not eliminate the risk to be a carrier. For ethnic-specific risk reduction see Methods/Limitations. **Risk**: NOT at an increased risk for an affected pregnancy.
ALL OTHER DISORDERS	NEGATIVE	This result reduces, but does not eliminate the risk to be a carrier. **Risk:** This individual is NOT at an increased risk for having a pregnancy that is affected with one of the other disorders covered by this test. For partner's gene-specific risks, visit www.integratedgenetics.com.

Genetic counseling is recommended to discuss the potential clinical and/or reproductive implications of positive results, as well as recommendations for testing family members and, when applicable, this individual's partner. Genetic counseling services are available. To access Integrated Genetics Genetic Counselors please visit www.integratedgenetics.com/genetic-counseling or call (855) GC-CALLS (855-422-2557).

ADDITIONAL CLINICAL INFORMATION

The individual is NOT at an increased risk for having a pregnancy that is affected with one of the disorders covered by this test. For partner's gene-specific risk reductions, visit www.integratedgenetics.com.

Reported by: Lei Wang, PhD

COMMENTS

This interpretation is based on the clinical information provided and the current understanding of the molecular genetics of the disorder(s) tested. References and additional information about the disorders tested are available at www.integratedgenetics.com.

The standard of care for Tay-Sachs disease carrier detection in all ethnic groups is enzyme (hexosaminidase A) analysis. For maximum sensitivity and specificity, enzyme analysis should be performed in addition to DNA variant analysis (Schneider, PMID:19876898). If Tay-Sachs enzyme analysis was ordered, results are reported separately.

The standard of care for determining carrier status for sickle cell disease and other hemoglobinopathies is to combine information from clinical assessment, complete blood count, hemoglobin electrophoresis, and DNA testing (Traeger-Synodinos, PMID:25052315). If hemoglobin electrophoresis was ordered, results are reported separately.

METHODS/LIMITATIONS

Single Nucleotide Polymorphism and Small Indel Sequencing Assessment: Genomic regions of interest are selected using a custom capture reagent for target enrichment (Twist Bioscience) and sequenced via the Illumina® next generation sequencing platform. Sequencing reads are aligned with the human genome reference GRCh37/hg19 build. Regions of interest include all exons and intron/exon junctions (+/- 20 nucleotides) for each gene analyzed. A minimum of 99% of bases are covered at >15X. Analytical sensitivity is estimated to be >99% for single nucleotide variants, >97% for insertions/deletions less than six base pairs, and >95% for insertions/deletions between six and fifteen base pairs.

Copy Number Variant Assessment: Next Generation Sequencing is performed and the data are assessed with Illumina's DRAGEN (Dynamic Read Analysis for GENomics) Bio-IT Platform. Genes listed in ClinVar with pathogenic deletions less than 10 exons in size are padded with additional intronic probes to allow single exon resolution CNV detection (List based on ClinVar Deletion Database: January 2019 release; see list below). For other genes, large deletions (>10 exons) can be detected. The resolution of this analysis can vary depending on region-specific features. Analytical sensitivity is estimated to be >95%. Padded genes: *ABCA12, ABCD1, ACADM, ACOX1, ADAMTS2, ADGRV1, AGL, AGPAT2, AGXT, AHI1, AIRE, ALDOB, ALMS1, AP3B1, ARL6, ARSA, ARSB, ATM, ATP7A, ATRX, BBS1, BBS2, BBS4, BBS5, BBS7, BBS9, BCKDHB, BLM, BRIP1, CAPN3, CBS, CDH23, CFTR, CLCN5, CLN3, CLN5, CLN8, CNTNAP2, COL4A5, CP, CPT1A, CTNS, CYBB, DBT, DCLRE1C, DHCR7, DMD, DOCK8, DOK7, DYSF, EIF2B5, ELP1, EMD, ERCC4, ETHE1, EYS, FA2H, FAM126A, FANCA, FANCC, FANCD2, FANCI, FKRP, FKTN, GAA, GALC, GALNS, GALT, GBE1, GLDC, GNE, GNPTAB, GUSB, HBB, HEXA, HEXB, HINT1, HJV, HPD, HSD17B4, IDS, IFT140, IL7R, ITPA, KCTD7, L1CAM, LAMA2, LAMP2, MCOLN1, MEGF8, MKKS, MKS1, MLC1, MMAB, MTM1, NBN, NCF2, NDUFAF2, NDUFS6, NEB, NPHP1, NR0B1, NTRK1, OAT, OCRL, OTC, PAH, PANK2, PCCA, PCDH15, PDHX, PEX1, PEX6, PHKA1, PHKA2, PHKB, PKHD1, PLA2G6, PMM2, POLH, POMGNT1, RAPSN, RDH12, RPGRIP1, RPS6KA3, SGCD, SGCG, SLC25A20, SLC26A4, SLC2A10, SLC35A3, SLC7A7, SPG11, STX11, SYNE4, TAZ, TMEM231, TMEM237, TMEM38B, TMEM70, TRIM32, USH2A, VLDLR, VPS13B, VRK1, WRN.*

Alpha thalassemia: Variants included in the analysis of the alpha-globin (*HBA*) gene cluster are the Constant Spring non-deletion variant and the following deletions: -alpha3.7, -alpha4.2, --alpha20.5, --SEA, --FIL, --THAI, --MED, and the HS-40 regulatory region. This analysis does not detect other variants in the alpha-globin genes and may not detect the co-occurrence of a deletion and a duplication. This assay is unable to distinguish between the --FIL and the --THAI deletions. Analytical sensitivity is estimated to be >99% for the targeted variants.

Congenital Adrenal Hyperplasia: This analysis will detect most large rearrangements/deletions/duplications within the *CYP21A2* gene, as well as the presence of seven of the most common pathogenic variants in the gene: 1) c.518T>A (p.Ile173Asn), Chr6:32007203 (GRCh37); 2) c.713T>A (p.Val238Glu); Chr6:32007587 (GRCh37); 3) c.719T>A (p.Met240Lys); Chr6:32007593 (GRCh37); 4) c.923dup (p.Leu308Phefs); Chr6:32007966 (GRCh37); 5) c.293-13C/A>G; Chr6:32006858 (GRCh37); 6) c.332_339delGAGACTAC (p.Gly111Valfs); Chr6:32006910-32006917 (GRCh37) 7) c.-113G>A; Chr6:32006087 (GRCh37). Other point mutations and small indels and reciprocal changes between *CYP21A2* and *CYP21A1P* are not detected by this analysis. The analytical sensitivity of this assay is estimated to be >99%.

Spinal Muscular Atrophy: This analysis will detect the copy number of exon 7 of the *SMN1* gene. When no copies of *SMN1* exon 7 are detected, *SMN2* exon 7 copy number is assessed and reported. This test is unable to differentiate between two copies of the *SMN1* gene on one allele (in cis) versus two copies of the gene on different alleles (in trans). When two copies of *SMN1* exon 7 are detected, the NGS data are assessed for the presence of the c.*3+80T>G "silent carrier" variant. This analysis does not test for any other variants that may be present in other regions of the *SMN1* gene. Therefore, normal results reduce, but do not eliminate the risk of this patient being a carrier of SMA. Post-test carrier risk reductions for individuals with no family history are shown in the table below.

Reported by: Lei Wang, PhD

SMA risk reductions for individuals with no family history						
				Post-test risk of being a carrier with 2 copies**		
Disorder (Gene) Reference sequence	**Population**	**Detection rate (Copy number + SNP)**	**Pre-test carrier risk**	**POSITIVE for the c.*3+80T>G SNP[a]**	**NEGATIVE for the c.*3+80T>G SNP**	**Post-test risk of being a carrier with 3 copies**
Spinal muscular atrophy (*SMN1*) NM_000344	African American	90.3%	1 in 72	1 in 34	1 in 375	1 in 4200
	Ashkenazi Jewish	92.8%	1 in 67	High risk	1 in 918	1 in 5400
	Asian	93.6%	1 in 59	High risk	1 in 907	1 in 5600
	Caucasian	95.0%	1 in 47	1 in 29	1 in 921	1 in 5600
	Hispanic	92.6%	1 in 68	1 in 140	1 in 906	1 in 5400
	Mixed or other ethnic backgrounds	For counseling purposes, consider using the ethnic background with the most conservative risk estimates.				

** includes carriers who are silent carriers (2+0) and carriers with a pathogenic variant not detected in this assay

[a]Feng, PMID 28125085; Luo, PMID 23788250; Sugarman, PMID 21811307

Reported Variants: Pathogenic and likely pathogenic variants are reported. Variants in *GJB2, GJB6, COL4A3,* and *OPA3* that act in a dominant fashion are not reported. *NEB* variants occurring in exons 82-105 and *SEPN1* variants occurring in exon 1 may not be reliably detected by this analysis and are not reported. Nondeletion variants are specified using the numbering and nomenclature recommended by the Human Genome Variation Society (HGVS, http://www.hgvs.org/). Variants of uncertain significance, likely benign, and benign variants are not reported. Variant classification is consistent with ACMG standards and guidelines (Richards, PMID:25741868). Detailed variant classification information is available upon request.

Limitations: Technologies used do not detect germline mosaicism and do not rule out the presence of large chromosomal aberrations, including rearrangements, variants in regions or genes not included in this test, or possible inter/intragenic interactions between variants. Variant classification and/or interpretation may change over time if more information becomes available. False positive or negative results may occur for reasons that include: rare genetic variants, sex chromosome abnormalities, pseudogene interference, blood transfusions, bone marrow transplantation, somatic or tissue-specific mosaicism, mislabeled samples, or erroneous representation of family relationships.

Reported by: Lei Wang, PhD

DISORDERS TESTED

3-Methylcrotonyl-CoA carboxylase deficiency (2 genes). Autosomal recessive: *MCCC1, MCCC2*.

3M syndrome (3 genes). Autosomal recessive: *CCDC8, CUL7, OBSL1*.

Abetalipoproteinemia (1 gene). Autosomal recessive: *MTTP*.

Acute infantile liver failure (3 genes). Autosomal recessive: *LARS, NBAS, TRMU*.

Adenosine deaminase deficiency (1 gene). Autosomal recessive: *ADA*.

Aicardi-Goutières syndrome (4 genes). Autosomal recessive: *RNASEH2A, RNASEH2B, RNASEH2C, SAMHD1*.

Alpha-mannosidosis (1 gene). Autosomal recessive: *MAN2B1*.

Alpha-thalassemia (2 genes). Autosomal recessive: *HBA1, HBA2*.

Alport syndrome (1 gene). Autosomal recessive: *COL4A3*. Only recessively inherited variants will be reported for *COL4A3*;

Alström syndrome (1 gene). Autosomal recessive: *ALMS1*.

Andermann syndrome (1 gene). Autosomal recessive: *SLC12A6*.

Arginase deficiency (1 gene). Autosomal recessive: *ARG1*.

Argininosuccinic aciduria (1 gene). Autosomal recessive: *ASL*.

Aromatic l-amino acid decarboxylase deficiency (1 gene). Autosomal recessive: *DDC*.

Arterial tortuosity syndrome (1 gene). Autosomal recessive: *SLC2A10*.

Arthrogryposis, mental retardation, and seizures (AMRS) (1 gene). Autosomal recessive: *SLC35A3*.

Asparagine synthetase deficiency (1 gene). Autosomal recessive: *ASNS*.

Aspartylglucosaminuria (1 gene). Autosomal recessive: *AGA*.

Ataxia with vitamin E deficiency (1 gene). Autosomal recessive: *TTPA*.

Ataxia-telangiectasia (1 gene). Autosomal recessive: *ATM*.

Autoimmune polyglandular syndrome type 1 (1 gene). Autosomal recessive: *AIRE*.

Autosomal recessive congenital ichthyosis (ARCI) (12 genes). Autosomal recessive: *ABCA12, ALOX12B, ALOXE3, CASP14, CERS3, CYP4F22, LIPN, NIPAL4, PNPLA1, SDR9C7, SLC27A4, TGM1*.

Autosomal recessive spastic ataxia of Charlevoix-Saguenay (ARSACS) (1 gene). Autosomal recessive: *SACS*.

Axonal neuropathy with neuromyotonia, autosomal recessive (1 gene). Autosomal recessive: *HINT1*.

Bardet-Biedl syndrome (12 genes). Autosomal recessive: *ARL6, BBS1, BBS10, BBS12, BBS2, BBS4, BBS5, BBS7, BBS9, MKKS, SDCCAG8, TTC8*.

Bare lymphocyte syndrome type II (4 genes). Autosomal recessive: *CIITA, RFX5, RFXANK, RFXAP*.

Bartter syndrome (3 genes). Autosomal recessive: *BSND, KCNJ1, SLC12A1*.

Beta-hemoglobinopathies, includes sickle cell disease and beta-thalassemias (1 gene). Autosomal recessive: *HBB*.

Beta-ketothiolase deficiency (1 gene). Autosomal recessive: *ACAT1*.

Beta-mannosidosis (1 gene). Autosomal recessive: *MANBA*.

Biotinidase deficiency (1 gene). Autosomal recessive: *BTD*.

Bloom syndrome (1 gene). Autosomal recessive: *BLM*.

Brittle cornea syndrome (2 genes). Autosomal recessive: *PRDM5, ZNF469*.

Canavan disease (1 gene). Autosomal recessive: *ASPA*.

Carbamoyl phosphate synthetase I deficiency (1 gene). Autosomal recessive: *CPS1*.

Carnitine palmitoyltransferase I deficiency (1 gene). Autosomal recessive: *CPT1A*.

Carnitine palmitoyltransferase II deficiency (1 gene). Autosomal recessive: *CPT2*.

Carnitine-acylcarnitine translocase deficiency (1 gene). Autosomal recessive: *SLC25A20*.

Carpenter syndrome (2 genes). Autosomal recessive: *MEGF8, RAB23*.

Cartilage-hair hypoplasia (1 gene). Autosomal recessive: *RMRP*.

Cerebellar hypoplasia, VLDLR-associated (1 gene). Autosomal recessive: *VLDLR*.

Cerebral creatine deficiency syndromes (2 genes). Autosomal recessive: *GAMT, GATM*.

Cerebrotendinous xanthomatosis (1 gene). Autosomal recessive: *CYP27A1*.

Chronic granulomatous disease (3 genes). Autosomal recessive: *CYBA, NCF2, NCF4*.

Ciliopathies (2 genes). Autosomal recessive: *CEP290, MKS1*.

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Citrullinemia (2 genes). Autosomal recessive: *ASS1, SLC25A13*.

Coats plus syndrome and dyskeratosis congenita, CTC1-related (1 gene). Autosomal recessive: *CTC1*.

Cockayne syndrome (2 genes). Autosomal recessive: *ERCC6, ERCC8*.

Cohen syndrome (1 gene). Autosomal recessive: *VPS13B*.

Cold-induced sweating syndrome, includes Crisponi syndrome (2 genes). Autosomal recessive: *CLCF1, CRLF1*.

Combined malonic and methylmalonic aciduria (1 gene). Autosomal recessive: *ACSF3*.

Congenital adrenal hyperplasia (6 genes). Autosomal recessive: *CYP11B1, CYP17A1, CYP21A2, HSD3B2, POR, STAR*. Fusion *CYP11B1* genes will not be reported;

Congenital amegakaryocytic thrombocytopenia (1 gene). Autosomal recessive: *MPL*.

Congenital disorder of deglycosylation (1 gene). Autosomal recessive: *NGLY1*.

Congenital disorders of glycosylation type 1 (4 genes). Autosomal recessive: *ALG1, ALG6, MPI, PMM2*.

Congenital generalized lipodystrophy (2 genes). Autosomal recessive: *AGPAT2, CAVIN1*.

Congenital insensitivity to pain with anhidrosis (1 gene). Autosomal recessive: *NTRK1*.

Congenital myasthenic syndrome (5 genes). Autosomal recessive: *CHAT, COLQ, DOK7, GFPT1, RAPSN*.

Corneal dystrophy and perceptive deafness (1 gene). Autosomal recessive: *SLC4A11*.

Costeff optic atrophy syndrome, autosomal recessive (1 gene). Autosomal recessive: *OPA3*.

Cutis laxa (5 genes). Autosomal recessive: *ATP6V0A2, ATP6V1E1, EFEMP2, LTBP4, PYCR1*.

Cystic fibrosis (1 gene). Autosomal recessive: *CFTR*.

Cystinosis (1 gene). Autosomal recessive: *CTNS*.

D-bifunctional protein deficiency (1 gene). Autosomal recessive: *HSD17B4*.

Deafness and hearing loss, nonsyndromic (5 genes). Autosomal recessive: *GJB2, GJB6, LOXHD1, OTOF, SYNE4*. Only recessively inherited variants will be reported for *GJB2* and *GJB6*;

Dihydrolipoamide dehydrogenase deficiency (1 gene). Autosomal recessive: *DLD*.

Dihydropyrimidine dehydrogenase deficiency (1 gene). Autosomal recessive: *DPYD*.

Distal spinal muscular atrophy, autosomal recessive (1 gene). Autosomal recessive: *PLEKHG5*.

Donnai-Barrow syndrome (1 gene). Autosomal recessive: *LRP2*.

Early infantile epileptic encephalopathy (2 genes). Autosomal recessive: *CAD, ITPA*.

Ehlers-Danlos syndrome type VIIC (1 gene). Autosomal recessive: *ADAMTS2*.

Ethylmalonic encephalopathy (1 gene). Autosomal recessive: *ETHE1*.

Familial dysautonomia (1 gene). Autosomal recessive: *ELP1*.

Familial hemophagocytic lymphohistiocytosis (4 genes). Autosomal recessive: *PRF1, STX11, STXBP2, UNC13D*.

Familial hyperinsulinism (1 gene). Autosomal recessive: *ABCC8*.

Familial Mediterranean fever (1 gene). Autosomal recessive: *MEFV*.

Fanconi anemia (9 genes). Autosomal recessive: *BRIP1, FANCA, FANCC, FANCD2, FANCE, FANCF, FANCG, FANCI, FANCL*.

Fraser syndrome (3 genes). Autosomal recessive: *FRAS1, FREM2, GRIP1*.

Fucosidosis (1 gene). Autosomal recessive: *FUCA1*.

Galactosemia (3 genes). Autosomal recessive: *GALE, GALK1, GALT*.

Galactosialidosis (1 gene). Autosomal recessive: *CTSA*.

Gaucher disease (1 gene). Autosomal recessive: *GBA*.

Glutaric acidemia type I (1 gene). Autosomal recessive: *GCDH*.

Glutaric acidemia type II (3 genes). Autosomal recessive: *ETFA, ETFB, ETFDH*.

Glutathione synthetase deficiency (1 gene). Autosomal recessive: *GSS*.

Glycine encephalopathy (2 genes). Autosomal recessive: *AMT, GLDC*.

Glycogen storage disease type I (2 genes). Autosomal recessive: *G6PC, SLC37A4*.

Glycogen storage disease type III (1 gene). Autosomal recessive: *AGL*.

Glycogen storage disease type IV (1 gene). Autosomal recessive: *GBE1*.

Glycogen storage disease type IX (2 genes). Autosomal recessive: *PHKB, PHKG2*.

Glycogen storage disease type V (1 gene). Autosomal recessive: *PYGM*.

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Glycogen storage disease type VII (1 gene). Autosomal recessive: *PFKM*.

GM1 gangliosidosis and mucopolysaccharidosis type IVB (1 gene). Autosomal recessive: *GLB1*.

GRACILE syndrome (1 gene). Autosomal recessive: *BCS1L*.

Gyrate atrophy of choroid and retina (1 gene). Autosomal recessive: *OAT*.

Hepatic venoocclusive disease with immunodeficiency (1 gene). Autosomal recessive: *SP110*.

Hereditary folate malabsorption (1 gene). Autosomal recessive: *SLC46A1*.

Hereditary fructose Intolerance (1 gene). Autosomal recessive: *ALDOB*.

Hereditary spastic paraplegia (4 genes). Autosomal recessive: *CYP7B1, SPG11, SPG21, TECPR2*.

Hermansky-Pudlak syndrome (10 genes). Autosomal recessive: *AP3B1, AP3D1, BLOC1S3, BLOC1S6, DTNBP1, HPS1, HPS3, HPS4, HPS5, HPS6*.

HMG-CoA lyase deficiency (1 gene). Autosomal recessive: *HMGCL*.

Holocarboxylase synthetase deficiency (1 gene). Autosomal recessive: *HLCS*.

Homocystinuria (1 gene). Autosomal recessive: *CBS*.

Hyaline fibromatosis syndrome (1 gene). Autosomal recessive: *ANTXR2*.

Hydrolethalus syndrome (1 gene). Autosomal recessive: *HYLS1*.

Hypomyelination and congenital cataract (1 gene). Autosomal recessive: *FAM126A*.

Hypophosphatasia (1 gene). Autosomal recessive: *ALPL*.

Immunodeficiency-centromeric instability-facial anomalies (ICF) syndrome (4 genes). Autosomal recessive: *CDCA7, DNMT3B, HELLS, ZBTB24*.

Inclusion body myopathy 2 (1 gene). Autosomal recessive: *GNE*.

Isovaleric acidemia (1 gene). Autosomal recessive: *IVD*.

Joubert syndrome and related disorders, including Meckel-Gruber syndrome (19 genes). Autosomal recessive: *AHI1, ARL13B, B9D1, B9D2, CEP104, CPLANE1, INPP5E, KIF14, NPHP1, NPHP3, RPGRIP1L, TCTN1, TCTN2, TCTN3, TMEM138, TMEM216, TMEM231, TMEM237, TMEM67*.

Junctional epidermolysis bullosa (3 genes). Autosomal recessive: *LAMA3, LAMB3, LAMC2*.

Juvenile hereditary hemochromatosis (2 genes). Autosomal recessive: *HAMP, HJV*.

Krabbe disease (1 gene). Autosomal recessive: *GALC*.

Leber congenital amaurosis (9 genes). Autosomal recessive: *AIPL1, LCA5, LRAT, RD3, RDH12, RPE65, RPGRIP1, SPATA7, TULP1*.

Leigh syndrome, autosomal recessive (11 genes). Autosomal recessive: *COX15, FBXL4, FOXRED1, LRPPRC, NDUFAF2, NDUFAF5, NDUFS4, NDUFS6, NDUFS7, NDUFV1, SURF1*.

Leukoencephalopathy with vanishing white matter (5 genes). Autosomal recessive: *EIF2B1, EIF2B2, EIF2B3, EIF2B4, EIF2B5*.

Limb-girdle muscular dystrophy, autosomal recessive (12 genes). Autosomal recessive: *CAPN3, DYSF, FKRP, POMGNT1, POMT1, POMT2, SGCA, SGCB, SGCD, SGCG, TRAPPC11, TRIM32*.

Lipoprotein lipase deficiency, familial (1 gene). Autosomal recessive: *LPL*.

Long-chain 3-hydroxyacyl-CoA dehydrogenase (LCHAD) deficiency (1 gene). Autosomal recessive: *HADHA*.

Lysinuric protein intolerance (1 gene). Autosomal recessive: *SLC7A7*.

Lysosomal acid lipase deficiency (1 gene). Autosomal recessive: *LIPA*.

Maple syrup urine disease (3 genes). Autosomal recessive: *BCKDHA, BCKDHB, DBT*.

Medium-chain acyl-CoA dehydrogenase (MCAD) deficiency (1 gene). Autosomal recessive: *ACADM*.

Megalencephalic leukoencephalopathy with subcortical cysts type 1 (1 gene). Autosomal recessive: *MLC1*.

Metachromatic leukodystrophy (2 genes). Autosomal recessive: *ARSA, PSAP*.

Methylmalonic acidemia (4 genes). Autosomal recessive: *MCEE, MMAA, MMAB, MMUT*.

Methylmalonic acidemia with homocystinuria (4 genes). Autosomal recessive: *ABCD4, LMBRD1, MMACHC, MMADHC*.

Mitochondrial complex I deficiency (1 gene). Autosomal recessive: *ACAD9*.

Mitochondrial complex V deficiency (1 gene). Autosomal recessive: *TMEM70*.

Mitochondrial DNA depletion syndrome, MVP17-related (1 gene). Autosomal recessive: *MPV17*.

Mitochondrial DNA depletion syndrome, TK2-related (1 gene). Autosomal recessive: *TK2*.

Mitochondrial myopathy, lactic acidosis, and sideroblastic anemia (1 gene). Autosomal recessive: *PUS1*.

Mucolipidosis type II and III (1 gene). Autosomal recessive: *GNPTAB*.

Mucolipidosis type IV (1 gene). Autosomal recessive: *MCOLN1*.

Mucopolysaccharidosis type I (1 gene). Autosomal recessive: *IDUA*.

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Mucopolysaccharidosis type III (4 genes). Autosomal recessive: *GNS, HGSNAT, NAGLU, SGSH*.

Mucopolysaccharidosis type IVA (1 gene). Autosomal recessive: *GALNS*.

Mucopolysaccharidosis type IX (1 gene). Autosomal recessive: *HYAL1*.

Mucopolysaccharidosis type VI (1 gene). Autosomal recessive: *ARSB*.

Mucopolysaccharidosis type VII (1 gene). Autosomal recessive: *GUSB*.

Multiple pterygium syndrome (1 gene). Autosomal recessive: *CHRNG*.

Multiple sulphatase deficiency (1 gene). Autosomal recessive: *SUMF1*.

Muscular dystrophy, LAMA2-related (1 gene). Autosomal recessive: *LAMA2*.

Nemaline myopathy (1 gene). Autosomal recessive: *NEB*.

Nephrotic syndrome (2 genes). Autosomal recessive: *NPHS1, NPHS2*.

Neurodegeneration with brain iron accumulation disorder (7 genes). Autosomal recessive: *ATP13A2, C19orf12, COASY, CP, DCAF17, FA2H, PLA2G6*.

Neuronal ceroid-lipofuscinosis (10 genes). Autosomal recessive: *CLN3, CLN5, CLN6, CLN8, CTSD, CTSF, KCTD7, MFSD8, PPT1, TPP1*.

Niemann-Pick disease type C (2 genes). Autosomal recessive: *NPC1, NPC2*.

Niemann-Pick disease types A and B (1 gene). Autosomal recessive: *SMPD1*.

Nijmegen breakage syndrome (1 gene). Autosomal recessive: *NBN*.

Omenn syndrome (3 genes). Autosomal recessive: *DCLRE1C, RAG1, RAG2*.

Ornithine translocase deficiency (1 gene). Autosomal recessive: *SLC25A15*.

Osteogenesis imperfecta, autosomal recessive (9 genes). Autosomal recessive: *BMP1, CRTAP, FKBP10, P3H1, PLOD2, PPIB, SERPINF1, TMEM38B, WNT1*.

Osteopetrosis, autosomal recessive (3 genes). Autosomal recessive: *OSTM1, TCIRG1, TNFSF11*.

Pantothenate kinase-associated neurodegeneration (1 gene). Autosomal recessive: *PANK2*.

Pendred syndrome (1 gene). Autosomal recessive: *SLC26A4*.

Peroxisomal acyl-CoA oxidase deficiency (1 gene). Autosomal recessive: *ACOX1*.

Phenylalanine hydroxylase deficiency, includes phenylketonuria (PKU) (1 gene). Autosomal recessive: *PAH*.

Phosphoglycerate dehydrogenase deficiency (1 gene). Autosomal recessive: *PHGDH*.

Pitt-Hopkins-like syndrome 1 (1 gene). Autosomal recessive: *CNTNAP2*.

Polycystic kidney disease, autosomal recessive (1 gene). Autosomal recessive: *PKHD1*.

Pompe disease (1 gene). Autosomal recessive: *GAA*.

Pontocerebellar hypoplasia (11 genes). Autosomal recessive: *AMPD2, CHMP1A, CLP1, EXOSC3, RARS2, SEPSECS, TSEN2, TSEN34, TSEN54, VPS53, VRK1*.

Primary carnitine deficiency (1 gene). Autosomal recessive: *SLC22A5*.

Primary congenital glaucoma (1 gene). Autosomal recessive: *CYP1B1*.

Primary hyperoxaluria (3 genes). Autosomal recessive: *AGXT, GRHPR, HOGA1*.

Progressive familial intrahepatic cholestasis (3 genes). Autosomal recessive: *ABCB11, ABCB4, ATP8B1*.

Progressive pseudorheumatoid dysplasia (1 gene). Autosomal recessive: *CCN6*.

Propionic acidemia (2 genes). Autosomal recessive: *PCCA, PCCB*.

Pseudocholinesterase deficiency (1 gene). Autosomal recessive: *BCHE*.

Pycnodysostosis (1 gene). Autosomal recessive: *CTSK*.

Pyridoxal 5'-phosphate-dependent epilepsy (1 gene). Autosomal recessive: *PNPO*.

Pyridoxine-dependent epilepsy (1 gene). Autosomal recessive: *ALDH7A1*.

Pyruvate dehydrogenase deficiency (4 genes). Autosomal recessive: *DLAT, PDHB, PDHX, PDP1*.

Renal tubular acidosis and deafness (2 genes). Autosomal recessive: *ATP6V0A4, ATP6V1B1*.

Retinitis pigmentosa (9 genes). Autosomal recessive: *CERKL, CWC27, DHDDS, EYS, FAM161A, IFT140, MAK, PRCD, RLBP1*.

Rhizomelic chondrodysplasia punctata (3 genes). Autosomal recessive: *AGPS, GNPAT, PEX7*.

Sandhoff disease (1 gene). Autosomal recessive: *HEXB*.

SELENON-related disorders (1 gene). Autosomal recessive: *SELENON*.

Severe combined immunodeficiency (SCID) (25 genes). Autosomal recessive: *AK2, CD247, CD3D, CD3E, CD3G, CD8A, CORO1A, DOCK8, FOXN1, IKBKB, IL2RA, IL7R, JAK3, LCK, LIG4, MALT1, MTHFD1, NHEJ1, PGM3, PNP, PRKDC, PTPRC, STK4, TTC7A, ZAP70*.

Severe congenital neutropenia (1 gene). Autosomal recessive: *HAX1*.

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Sialic acid storage disorders (1 gene). Autosomal recessive: *SLC17A5*.

Sialidosis (1 gene). Autosomal recessive: *NEU1*.

Sjogren-Larsson syndrome (1 gene). Autosomal recessive: *ALDH3A2*.

Smith-Lemli-Opitz syndrome (1 gene). Autosomal recessive: *DHCR7*.

Spinal muscular atrophy (1 gene). Autosomal recessive: *SMN1*.

Spondylothoracic dysostosis (1 gene). Autosomal recessive: *MESP2*.

Sulfate transporter-related osteochondrodysplasias, includes achondrogenesis type 1B, atelosteogenesis type 2, diastrophic dysplasia, and recessive multiple epiphyseal dysplasia (1 gene). Autosomal recessive: *SLC26A2*.

Sulfite oxidase deficiency (1 gene). Autosomal recessive: *SUOX*.

Tay-Sachs disease (1 gene). Autosomal recessive: *HEXA*.

Tetrahydrobiopterin deficiency (3 genes). Autosomal recessive: *PCBD1, PTS, QDPR*.

Trichohepatoenteric syndrome (2 genes). Autosomal recessive: *SKIV2L, TTC37*.

Trifunctional protein deficiency (1 gene). Autosomal recessive: *HADHB*.

Triple A syndrome (1 gene). Autosomal recessive: *AAAS*.

Tyrosine hydroxylase deficiency (1 gene). Autosomal recessive: *TH*.

Tyrosinemia type I (1 gene). Autosomal recessive: *FAH*.

Tyrosinemia type II (1 gene). Autosomal recessive: *TAT*.

Tyrosinemia type III (1 gene). Autosomal recessive: *HPD*.

Usher syndrome (hearing loss and retinitis pigmentosa) (9 genes). Autosomal recessive: *ADGRV1, CDH23, CIB2, CLRN1, PCDH15, USH1C, USH1G, USH2A, WHRN*.

Very long-chain acyl-CoA dehydrogenase (VLCAD) deficiency (1 gene). Autosomal recessive: *ACADVL*.

Walker-Warburg syndrome and other FKTN related dystrophies (1 gene). Autosomal recessive: *FKTN*.

Werner syndrome (1 gene). Autosomal recessive: *WRN*.

Wilson disease (1 gene). Autosomal recessive: *ATP7B*.

Xeroderma pigmentosum (8 genes). Autosomal recessive: *DDB2, ERCC2, ERCC3, ERCC4, ERCC5, POLH, XPA, XPC*.

Zellweger spectrum disorder/ peroxisome biogenesis disorder (13 genes). Autosomal recessive: *PEX1, PEX10, PEX11B, PEX12, PEX13, PEX14, PEX16, PEX19, PEX2, PEX26, PEX3, PEX5, PEX6*.

Performing Labs

Component Type	Performed at	Laboratory Director
Technical Component	Medical Neurogenetics, LLC, 5424 Glenridge Drive, Atlanta, GA 30342	Geraldine A. McDowell, PhD FACMG
Professional Component	Medical Neurogenetics, LLC, 5424 Glenridge Drive, Atlanta, GA 30342	Geraldine A. McDowell, PhD FACMG

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