Reproductive Technologies, Inc.
THE SPERM BANK OF CALIFORNIA
2115 MILVIA STREET, BERKELEY 94704 PHONE 510.841.1858 www.thespermbankofca.org A 501(C)(3) CORPORATION

Acknowledgement of Positive Carrier Screening Results: Donor 6183

I, the undersigned recipient, understand that this donor has tested **POSITIVE** as a carrier for the following condition(s). More information regarding these conditions can be found in his Expanded Carrier Screening results.

- **WNT10A-related conditions**
- **Hereditary hemochromatosis type 1**

I intend to use sperm samples from this donor for insemination or other assisted conception procedure(s).

I acknowledge that The Sperm Bank of California (TSBC) has made the donor's genetic testing results available to me and my medical providers, and that I have reviewed these results. I understand that TSBC **strongly recommends** that I review these genetic testing results with a Genetic Counselor and my medical providers. I understand that TSBC can refer me to genetic counseling services if desired.

It is strongly recommended recipients who use this donor's sperm undergo carrier screening for WNT10A-related conditions. WNT10A related conditions can be inherited in both an autosomal recessive and autosomal dominant pattern.

I understand that recipient testing is strongly recommended when a donor has positive carrier screening results and that such testing can reduce but not eliminate risks.

I acknowledge that I personally assume all risks associated with use of semen samples provided by a donor who has tested **POSITIVE as a carrier for WNT10A-related conditions and Hereditary hemochromatosis type 1.**

On behalf of myself and my spouse, heirs, representatives, I hereby release and forever hold harmless TSBC and its current and former officers, directors, employees, attorneys, insurers, consultants, agents, and representatives (collectively "Releases") from any liability or responsibility whatsoever for any and all outcomes, and hereby release and forever discharge Releases from any and all actions, causes of action, demands, damages, losses, liabilities, suits, expenses, including attorneys' fees and costs, of whatever character, in law or in equity, whether currently known, suspected, unknown or unsuspected, matured or unmatured, arising out of my use of sperm donated by a donor who has tested **POSITIVE as a carrier for WNT10A-related conditions and Hereditary hemochromatosis type 1. This release involves the waiver of all rights and benefits that I may have under California Civil Code section 1542, which states: "A general release does not extend to claims that the creditor or releasing party does not know or suspect to exist in his or her favor at the time of executing the release and that, if known by him or her, would have materially affected his or her settlement with the debtor or released party."**

Please select one of the following:

- ☐ I have been tested for the above named condition(s) and/or I plan to be tested prior to using the samples.
- ☐ I understand that TSBC **strongly recommends** that I discuss these results with a Genetic Counselor and my medical providers and consider testing for the above named condition(s). At this time I have **declined** testing and/or **do not anticipate being tested**.

I understand that if I transfer my vials (or embryos if applicable) to any other person, including my spouse, that TSBC requires that person (1) register with TSBC and (2) complete an **Acknowledgement of Positive Carrier Screening Results**. I understand that any and all questions as to the legal interpretation, validity or any other aspect of this agreement shall be determined by the laws of the State of California, regardless of the location or residence of any of the parties.

Recipient's signature	Recipient's printed name	Date

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GENETIC TESTING: POSITIVE CARRIER STATUS

This donor tested **POSITIVE** as a carrier for one or more autosomal recessive conditions as described on the prior page and in the attached genetic testing results.

What does it mean to be a carrier?

All people carry genetic mutations in their DNA. Genetic testing can help to identify some, but not all, of these mutations. While this donor carries a mutation for one or more recessively inherited condition(s), **offspring from this donor are not expected to be at risk of developing these condition(s) unless the recipient (or egg provider if different from the recipient) also carries a genetic mutation for the same condition(s).** For this reason, we strongly encourage you to discuss carrier screening for yourself (or your egg provider) with your physician and a genetic counselor. Genetic testing can reduce but not eliminate risks.

What are my next steps?

1. **Download the genetic test results and review with your medical providers**
   We **strongly recommend** that you discuss this donor's genetic test results with your physician **PRIOR TO SCHEDULING A SHIPMENT OR PICK-UP**, to confirm the donor is suitable for your use. Vials retrieved from the building cannot be exchanged or refunded. The donor's genetic test results are available for free download on the donor's page at https://www.thespermbankofca.org/donor-catalog.

2. **We recommend scheduling a genetic counseling session.**
   A genetic counselor can explain the results in detail including the inheritance pattern, potential risks to your children, and the available testing options that you may want to consider for yourself (or your egg provider). Phone or in person consultations are available for a fee with TSBC's Genetic Counselors at San Francisco Genetic Counseling (https://www.sfgenetics.org/) or you can locate a genetic counselor at www.findageneticcounselor.com.

3. **Complete and return the Acknowledgement of Positive Carrier Screening Results**
   TSBC requires that all recipients selecting this donor complete this acknowledgement form **PRIOR TO SCHEDULING A SHIPMENT OR PICK-UP**. Completing this form documents that you have been informed about this donor's genetic test results and that you are aware of TSBC's recommendation to discuss the genetic test results with your medical providers as noted above.

DATE: 10/12/2023

Reproductive Technologies, Inc.

THE SPERM BANK OF CALIFORNIA

EXPANDED CARRIER SCREENING RESULTS DONOR 6183

Expanded carrier screening for 525 autosomal recessive conditions was completed by Invitae and reported on 09/28/2023.

The results were **POSITIVE** for **WNT10A-related conditions and Hereditary hemochromatosis type 1**. Donor is a carrier for these conditions.

It is strongly recommended that recipients who use this donor's sperm undergo carrier screening for these specific conditions. It is strongly recommended recipients who use this donor's sperm undergo carrier screening for WNT10A-related conditions. WNT10A related conditions can be inherited in both an autosomal recessive and autosomal dominant pattern.

Testing was negative for the remainder of genes screened.

Disease	Result	Residual risk to be a carrier
WNT10A-related conditions*	POSITIVE	n/a
Hereditary hemochromatosis type 1 (HFE)**	p.His63Asp Reduced penetrance	n/a
Cystic Fibrosis	Negative	1 in 4,400
Spinal Muscular Atrophy	Negative: 2 copies exon 7 c.*3+80T>G variant not detected	1 in 784
HBB Hemoglobinopathies	Negative	1 in 4,800
Alpha Thalassemia	Negative	1 in 241

* The variant detected in WNT10A (c.682A>T; p.Phe228Ile) can cause a common condition called isolated tooth agenesis, which affects 2-8% of the general population. Tooth agenesis, also called hypodontia, is the absence of one or more teeth. It's estimated people who carry the variant are 2-3 times more likely to have one or more missing teeth. All offspring of donor 6183 have a 50% chance to inherit the c.682A>T WNT10A variant and be at increased risk for isolated tooth agenesis/ hypodontia.

** Hereditary hemochromatosis, type 1 is an autosomal recessive adult-onset condition with variable presentation and penetrance. The specific mutation the donor carries is associated with mild-moderate disease when clinical features are present, for which there is good treatment. Carrier screening for the HFE gene is available and recommended to recipients considering this donor. Recipients who are carriers for HFE-related conditions should have genetic counseling to best assess the risk for a child affected with hemochromatosis, type 1.

Genetic screening tests can significantly reduce, but never completely eliminate, the chance that a person is a carrier for a particular disorder.

Please refer to the donor's Invitae expanded carrier test report for more information on the testing completed and the donor's results.

Please also see the Health Problems List for a summary of the information that this donor has provided to us regarding personal and family medical history.

Sincerely,

Janine Mash
LCGC Certified Genetic Counselor
San Francisco Genetic Counseling

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Reclassification of a genetic variant in the *WNT10A* gene:

What it means for patients and their families

Why am I receiving this amended report?

Millions of tiny differences exist between the DNA sequences of any two individuals. Although some of these changes, known as variants, can cause disease, most of them do not. Genetic test results, including your carrier screening results, do not mention these "benign" variants because they are not expected to cause health issues.

Yet the scientific community's understanding of which variants do and do not cause disease can change with time.

You are receiving this amended report because the understanding of a variant that we identified in your DNA—the c.682T>A (p.Phe228Ile) variant in the *WNT10A* gene—has changed and is now classified as "pathogenic (low penetrance)."

Why did the understanding of this variant change?

As you may know, as more people undergo genetic testing, we learn more about how genes vary from person to person. Sometimes this new information will change our understanding of a particular DNA variant. In rare cases, variants thought likely to cause disease may eventually be shown not to cause disease and, conversely, variants thought unlikely to cause disease may be shown to cause disease. When our understanding of a variant changes, we call this a variant reclassification. When this happens at Invitae, all reports that include that variant are automatically updated, and the updated reports are released to the healthcare provider who ordered the test.

Why are you sharing this information with me?

At Invitae, we feel that providing variant reclassifications to healthcare providers and patients is important for a variety of reasons. For carrier screening, the new information may change the reproductive risks for current or future pregnancies or may impact your or your family members' personal risk for disease. Providing amended reports also reduces the need for you to repeat the testing at a later time. Invitae's philosophy is that if we become aware of new medically important information that is relevant to you, that information should not be withheld.

What condition is the c.682T>A (p.Phe228Ile) variant in the *WNT10A* gene associated with?

The *WNT10A* gene, where your variant is located, is known to be associated with two conditions.

The first condition is autosomal recessive, which means that a child has to inherit two disease-causing variants—one from each biological parent—to be affected. In this scenario, the child would have a type of **ectodermal dysplasia**, which means abnormal growth of tissues arising from a tissue layer called the ectoderm. Forms of ectodermal dysplasia include odonto-onycho-dermal dysplasia and Schöpf-Schulz-Passarge syndrome, both of which can involve dental anomalies (extra, missing, or malformed teeth), weak hair and nails, and excessive sweating due to abnormal development of sweat glands.[1,2] Treatment is focused on managing symptoms. With early diagnosis and adequate management, many children with these conditions can have a normal life.

The second condition is autosomal dominant, meaning that a child needs to inherit only one disease-causing genetic change to be affected. Some patients with a single variant in *WNT10A* may have a few missing teeth, though others show no observable signs or symptoms of disease.[3–5]

What does pathogenic (low penetrance) mean?

Pathogenic means that a variant is capable of causing disease. Low penetrance means that only some people with the pathogenic variant will show signs and symptoms of the disease. The c.682T>A (p.Phe228Ile) variant is a pathogenic (low penetrance) variant in the *WNT10A* gene. This means that not all individuals with this specific genetic change will show the signs or symptoms of a *WNT10A*-related condition.

Individuals who carry one copy of the c.682T>A (p.Phe228Ile) variant and have no other disease-causing genetic changes typically do not have symptoms, although they may have been missing one or more teeth since birth.[6]

Individuals who carry the c.682T>A (p.Phe228Ile) variant along with another disease-causing variant in the *WNT10A* gene show signs and symptoms of ectodermal dysplasia somewhere between 15% and 60% of the time.

What does this reclassification mean for me?

If you have a single copy of this variant and no other changes in this gene, it is possible that you may have some mild dental differences, such as missing or underdeveloped teeth. However, not all people with a single variant have noticeable signs or symptoms. If you have a single copy of the variant, we encourage you to inform your doctor. Although it is unlikely to affect your medical care, it's important for your doctor to be aware.

What does the reclassification mean if I am pregnant?

The risk that your child will be affected with a *WNT10A*-related condition depends on multiple factors, including the number of variants you and your partner carry and the number of variants the child inherits. If you are pregnant, carrier testing for your reproductive partner is recommended, if it has not yet been completed.

If your partner does not have a change in the *WNT10A* gene, there is a 50% chance that your child will inherit the change. As described above, this typically results in mild dental differences or no signs or symptoms at all.

If your partner does have a change in the *WNT10A* gene, there is a 25% chance that the child will inherit two disease-causing variants. In this case, they may have a form of ectodermal dysplasia but, as described above, they may or may not show signs or symptoms of the disease, given the low penetrance of your *WNT10A* variant. However, there are other scenarios to consider. If your partner carries a *WNT10A* variant, you should consult a genetic counselor or another qualified healthcare provider to discuss these implications.

What does it mean if I am not pregnant?

If you or any of your children have signs or symptoms of a *WNT10A*-related condition, you may benefit from a clinical evaluation by a healthcare provider. If you are considering a pregnancy in the future, carrier testing for your reproductive partner is recommended.

Should my family members be tested?

Your biological relatives may wish to consider genetic testing, especially if they have any signs or symptoms of ectodermal dysplasia or are planning a pregnancy themselves. If they are planning a pregnancy and genetic testing shows that they carry the *WNT10A* variant, carrier testing for their reproductive partners should be considered.

What if I have more questions?

Please send us an email at clientservices@invitae.com or contact Client Services at (800) 436-3037.
We are available to discuss any further questions you may have.

References

1. Castori M, *et al.* Two families confirm Schöpf-Schulz-Passarge syndrome as a discrete entity within the *WNT10A* phenotypic spectrum. *Clin Genet.* 2011;79(1):92–5.
2. Plaisancié J, *et al.* Mutations in *WNT10A* are frequently involved in oligodontia associated with minor signs of ectodermal dysplasia. *Am J Med Genet A.* 2013;161A(4):671–8.
3. Song S, *et al. WNT10A* variants are associated with non-syndromic tooth agenesis in the general population. *Hum Genet.* 2014;133(1):117–24.
4. Van den Boogaard M-J, *et al.* Mutations in *WNT10A* are present in more than half of isolated hypodontia cases. *J Med Genet.* 2012;49(5):327–31.
5. Ruiz-Heiland G, *et al.* Prevalence of *WNT10A* gene mutations in non-syndromic oligodontia. *Clin Oral Investig.* 2019;23(7):3103–13.
6. Jonsson L, *et al.* Rare and common variants conferring risk of tooth agenesis. *J Dent Res.* 2018;97(5):515–22.

INVITAE

INVITAE CARRIER SCREEN RESULTS

Patient name:	6183 DONOR	**Sample type:**	Saliva	**Report date:**	09-OCT-2023
DOB:		**Sample collection date:**	27-SEP-2023	**Invitae #:**	RQ5602985
Sex assigned at birth:	Male	**Sample accession date:**	28-SEP-2023	**Clinical team:**	Janine Gessner Mash Lorraine Bonner, MD
Gender:					
Patient ID (MRN):	DONOR6183				

Reason for testing

Gamete donor

Test performed

Invitae Comprehensive Carrier Screen without X-linked Disorders

- Primary Panel (CF, SMA)
- Add-on Comprehensive Carrier Screen without X-linked Disorders genes
- Add-on genes with variable presentation

RESULT: POSITIVE

This carrier test evaluated 525 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: Hereditary hemochromatosis type 1	HFE	c.187C>G (p.His63Asp) §	Autosomal recessive	Yes
Carrier: WNT10A-related conditions	WNT10A	c.682T>A (p.Phe228Ile) § PERSONAL RISK ⚠	Autosomal recessive	Yes

§ This variant is known to have low penetrance. See Clinical summary and/or Variant details on following pages for more information.

⚠ This result may impact this person's health. See Clinical summary on following pages for more information.

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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

Hereditary hemochromatosis type 1

A single Pathogenic (low penetrance) variant, c.187C>G (p.His63Asp), was identified in HFE.

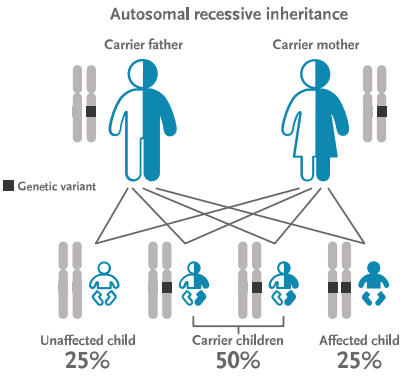
What is hereditary hemochromatosis type 1?

Hereditary hemochromatosis (HH) is a condition that causes the body to absorb too much iron from the diet, leading to tissue and organ damage from excess iron (iron overload). HH can be caused by changes in different genes. HH type 1, also called HFE hemochromatosis, begins in adulthood, and males are more likely to have symptoms than females. Early symptoms are nonspecific and can include joint pain, abdominal pain, and fatigue. Later signs and symptoms can include arthritis, skin discoloration, liver disease, diabetes, and heart disease. Symptoms may vary in response to the amount of iron in the diet, alcohol use, and infections. The prognosis depends on the extent of organ damage. Some symptoms can be reversed with treatment. With early detection and regular phlebotomy (blood removal) treatment to remove excess iron, patient outcomes are greatly improved.

Please note, the two most common genetic changes in HFE, c.845G>A (p.Cys282Tyr) and c.187C>G (p.His63Asp), are known to have low penetrance. This means that not all individuals with these genetic changes will show signs or symptoms of the condition. Individuals with two copies of c.187C>G (p.His63Asp) or one copy of c.845G>A (p.Cys282Tyr) AND one copy of c.187C>G (p.His63Asp) are less likely to develop clinical symptoms of hemochromatosis.

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 HFE 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 hereditary hemochromatosis type 1. 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
Hereditary hemochromatosis type 1 (AR) NM_000410.3	HFE	Pan-ethnic	1 in 4	1 in 300

RESULT: CARRIER

WNT10A-related conditions

A single Pathogenic (low penetrance) variant, c.682T>A (p.Phe228Ile), was identified in WNT10A. See "What are WNT10A-related conditions?" and Variant details for additional information.

What are WNT10A-related conditions?

WNT10A-related conditions include autosomal recessive odonto-onycho-dermal dysplasia (OODD) and Schöpf-Schulz-Passarge syndrome (SSPS) and autosomal dominant isolated tooth agenesis. Individuals with a clinically significant variant in this gene are carriers for the autosomal recessive conditions and may be at risk to develop the autosomal dominant condition associated with this gene.

Autosomal recessive WNT10A-related conditions, OODD and SSPS, refer to a spectrum of features associated with ectodermal dysplasia (ED), which causes abnormal development of the skin, hair, nails, teeth, and sweat glands. OODD is characterized by dental abnormalities including either fewer teeth than normal (hypodontia) or in more severe cases, the absence of six or more teeth (oligodontia), as well as a smooth tongue, malformed nails (onychodysplasia), clusters of enlarged blood vessels on the face (facial telangiectasias), and thickened skin (hyperkeratosis) with excessive sweating (hyperhidrosis) of the palms of the hands and soles of the feet. SSPS shares the same features as OODD, and is also associated with an increased risk of skin tumors which may be benign (non-cancerous) or malignant, and multiple eyelid cysts. Symptoms and severity of autosomal recessive WNT10A-related conditions are variable. Intellect and life span are not impacted.

Isolated tooth agenesis is a condition that affects the development of the teeth. It can be caused by changes in different genes. Isolated tooth agenesis is the congenital absence of one or more teeth, most commonly the permanent (secondary) teeth. Additional dental abnormalities may include small and/or irregular shaped teeth. Some individuals with WNT10A-related tooth agenesis have also been reported to have mild symptoms of ectodermal dysplasia (ED), which is a condition associated with abnormal development of the skin, hair, nails, teeth, and sweat glands. The severity of WNT10A-related tooth agenesis is variable, and some affected individuals may not have obvious symptoms (incomplete penetrance). Intellect and life span are not impacted.

Please note, the c.682T>A (p.Phe228Ile) variant identified in this individual is known to have low penetrance for both the associated autosomal recessive and autosomal dominant conditions. This means that not all individuals with this genetic change will show signs or symptoms of the condition.

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.

Due to the potential for personal health risk for this individual associated with this result, follow-up with a medical provider may be warranted.

If your partner tests positive:

The WNT10A gene is associated with conditions that are inherited in both an autosomal recessive and autosomal dominant fashion. In autosomal recessive inheritance, an individual must have disease-causing genetic changes in each copy of the WNT10A gene to be affected. Carriers, who have a disease-causing genetic change in only one copy of the gene, typically do not have symptoms of the autosomal recessive condition. When both reproductive partners are carriers of an autosomal recessive condition, there is a 25% chance for each child to have the condition. In autosomal dominant inheritance, an individual with a disease-causing change in one copy of the WNT10A gene is at risk to be affected with autosomal dominant isolated tooth agenesis. When one parent has a change in the WNT10A gene, there is a 50% chance for each child to inherit the change and be at risk to be affected with the autosomal dominant 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 WNT10A-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
WNT10A-related conditions (AR) NM_025216.2	WNT10A	Pan-ethnic	1 in 305	1 in 30400

Results to note

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

HFE, Exon 2, c.187C>G (p.His63Asp), heterozygous, Pathogenic (low penetrance)

- This sequence change replaces histidine, which is basic and polar, with aspartic acid, which is acidic and polar, at codon 63 of the HFE protein (p.His63Asp).
- This variant is present in population databases (rs1799945, gnomAD 14%), and has an allele count higher than expected for a pathogenic variant.
- This is a very common, low penetrance variant that is known to contribute to hemochromatosis when present with a second pathogenic allele in HFE. An estimated 1.5% of individuals of European descent who are affected with hemochromatosis are homozygous for this variant (PMID: 11479183), however, penetrance of the homozygous genotype is very low and is associated with variable phenotypes (PMID: 24729993, 11399207, 16132052, 11358905).
- ClinVar contains an entry for this variant (Variation ID: 10).
- 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) has been performed at Invitae for this missense variant, however the output from this modeling did not meet the statistical confidence thresholds required to predict the impact of this variant on HFE protein function.
- Experimental studies have shown that this missense change affects HFE function (PMID: 9162021, 9356458, 12429850, 14673107).
- In summary, this variant is reported to cause disease. However, as this variant is associated with a lower penetrance than other pathogenic alleles in the HFE gene, it has been classified as Pathogenic (low penetrance).

WNT10A, Exon 3, c.682T>A (p.Phe228Ile), heterozygous, Pathogenic (low penetrance)

- This sequence change replaces phenylalanine, which is neutral and non-polar, with isoleucine, which is neutral and non-polar, at codon 228 of the WNT10A protein (p.Phe228Ile).
- This variant is present in population databases (rs121908120, gnomAD 3%), including at least one homozygous and/or hemizygous individual.
- This variant has been observed in many individuals with autosomal recessive forms of ectodermal dysplasia (PMID: 19559398, 28976000, 30974434, Invitae). It has been found in trans (on the opposite chromosome) from many different pathogenic variants. Based on an internal analysis, this variant is associated with reduced penetrance for autosomal recessive disease (15% when in homozygosity and 30-60% when present with another pathogenic variant) compared to other pathogenic or likely pathogenic variants, which have a penetrance of 70-80% (Invitae). In addition, in a large meta-analysis, this variant conferred a 2.25-3.42-fold increased risk (95% CI: 1.39-4.10) for isolated tooth agenesis, the autosomal dominant condition associated with WNT10A (PMID: 29364747).
- ClinVar contains an entry for this variant (Variation ID: 4462).

- 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 expected to disrupt WNT10A protein function.
- In summary, this variant is reported to cause disease. However, because this variant is associated with a lower penetrance form of disease than other pathogenic alleles in the WNT10A gene, and because it is found in homozygosity in healthy individuals, it has been classified as Pathogenic (low penetrance).

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
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
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
ARG1	NM_000045.3
ARL6	NM_177976.2
ARSA	NM_000487.5
ARSB	NM_000046.3
ASL	NM_000048.3
ASNS	NM_133436.3
ASPA	NM_000049.2
ASS1	NM_000050.4
ATM*	NM_000051.3
ATP6V1B1	NM_001692.3
ATP7B	NM_000053.3
ATP8B1*	NM_005603.4
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
BTD	NM_000060.3
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
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
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
COL11A2*	NM_080680.2
COL17A1	NM_000494.3
COL27A1	NM_032888.3
COL4A3	NM_000091.4
COL4A4	NM_000092.4
COL7A1	NM_000094.3
COX15	NM_004376.6
CPS1	NM_001875.4
CPT1A	NM_001876.3
CPT2	NM_000098.2

GENE	TRANSCRIPT
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
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
DLD	NM_000108.4
DLL3	NM_016941.3
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
EIF2AK3	NM_004836.6

GENE	TRANSCRIPT
EIF2B1	NM_001414.3
EIF2B2	NM_014239.3
EIF2B3	NM_020365.4
EIF2B4	NM_015636.3
EIF2B5	NM_003907.2
ELP1	NM_003640.3
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
F11	NM_000128.3
F2	NM_000506.3
F5	NM_000130.4
FAH*	NM_000137.2
FAM161A	NM_001201543.1
FANCA	NM_000135.2
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
FKBP10	NM_021939.3
FKRP	NM_024301.4
FKTN	NM_001079802.1
FMO3	NM_006894.6
FOXN1	NM_003593.2

GENE	TRANSCRIPT
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
GJB2	NM_004004.5
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
GP1BA*	NM_000173.6
GP9	NM_000174.4
GRHPR	NM_012203.1
GRIP1	NM_021150.3
GSS	NM_000178.2
GUCY2D	NM_000180.3
GUSB	NM_000181.3

GENE	TRANSCRIPT
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
HEXA	NM_000520.4
HEXB	NM_000521.3
HFE	NM_000410.3
HGD	NM_000187.3
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
HPS1	NM_000195.4
HPS3	NM_032383.4
HPS4	NM_022081.5
HPS5	NM_181507.1
HPS6	NM_024747.5
HSD17B3	NM_000197.1
HSD17B4	NM_000414.3
HSD3B2	NM_000198.3
HYAL1	NM_153281.1
HYLS1	NM_145014.2
IDUA	NM_000203.4
IGHMBP2	NM_002180.2
IKBKB	NM_001556.2
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

GENE	TRANSCRIPT
KCNJ1	NM_000220.4
KCNJ11	NM_000525.3
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
LRP2	NM_004525.2
LRPPRC	NM_133259.3
LYST	NM_000081.3
MAK	NM_001242957.2
MAN2B1	NM_000528.3
MANBA	NM_005908.3
MCCC1	NM_020166.4
MCCC2	NM_022132.4
MCEE	NM_032601.3
MCOLN1	NM_020533.2
MCPH1	NM_024596.4
MECR	NM_016011.3
MED17	NM_004268.4
MEFV	NM_000243.2
MESP2	NM_001039958.1
MFSD8	NM_152778.2
MKKS	NM_018848.3
MKS1	NM_017777.3
MLC1*	NM_015166.3
MLYCD	NM_012213.2
MMAA	NM_172250.2

GENE	TRANSCRIPT
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
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
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

GENE	TRANSCRIPT
NR2E3	NM_014249.3
NSMCE3	NM_138704.3
NTRK1	NM_001012331.1
OAT*	NM_000274.3
OCA2	NM_000275.2
OPA3	NM_025136.3
OSTM1	NM_014028.3
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
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

GENE	TRANSCRIPT
PLA2G6	NM_003560.2
PLEKHG5	NM_020631.4
PLOD1	NM_000302.3
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
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
RPE65	NM_000329.2
RPGRIP1L	NM_015272.2
RTEL1	NM_001283009.1
RXYLT1	NM_014254.2
RYR1	NM_000540.2

GENE	TRANSCRIPT
SACS	NM_014363.5
SAMD9	NM_017654.3
SAMHD1	NM_015474.3
SCO2	NM_005138.2
SEC23B	NM_006363.4
SEPSECS	NM_016955.3
SERPINA1	NM_000295.4
SGCA	NM_000023.2
SGCB	NM_000232.4
SGCD	NM_000337.5
SGCG	NM_000231.2
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
SLC7A7	NM_001126106.2
SMARCAL1	NM_014140.3
SMN1*	NM_000344.3
SMPD1	NM_000543.4

GENE	TRANSCRIPT
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
SURF1	NM_003172.3
SYNE4	NM_001039876.2
TANGO2	NM_152906.6
TAT	NM_000353.2
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

GENE	TRANSCRIPT
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
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
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.
- ANO10: Sequencing analysis for exons 8 includes only cds +/- 0 bp. ATP8B1: Sequencing analysis for exons 19 includes only cds +/- 10 bp. AIPL1: Sequencing analysis for exons 2 includes only cds +/- 10 bp. GHR: Deletion/duplication and sequencing analysis is not offered for exon 3. TBCE: Sequencing analysis for exons 2 includes only cds +/- 10 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. TYR: Deletion/duplication and sequencing analysis is not offered for exon 5. 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. DUOX2: Deletion/duplication and sequencing analysis is not offered for exons 6-7. TG: Deletion/duplication analysis is not offered for exon 18. Sequencing analysis for exons 44 includes only cds +/- 0 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. FANCL: Sequencing analysis for exons 4, 10 includes only cds +/- 10 bp. ATM: Sequencing analysis for exons 6, 24, 43 includes only cds +/- 10 bp. CFTR: Sequencing analysis for exons 7 includes only cds +/- 10 bp. EYS: Sequencing analysis for exons 30 includes only cds +/- 0 bp. FAH: Deletion/duplication analysis is not offered for exon 14. FH: Sequencing analysis for exons 9 includes only cds +/- 10 bp. GALC: Deletion/duplication analysis is not offered for exon 6. 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". GNE: Sequencing analysis for exons 8 includes only cds +/- 10 bp. GP1BA: c.104delA (p.Lys35Argfs*4), c.165_168delTGAG (p.Ser55Argfs*12), c.376A>G (p.Asn126Asp), c.434T>C (p.Leu145Pro), c.515C>T (p.Ala172Val), c.584_586delTCC (p.Leu195del), c.673T>A (p.Cys225Ser), c.1454dupT (p.Ser486Ilefs*12), c.1480delA (p.Thr494Profs*59), c.1601_1602delAT (p.Tyr534Cysfs*82), c.1620G>A (p.Trp540*) variants only. 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. LIFR: Sequencing analysis for exons 3 includes only cds +/- 5 bp. MLC1: Sequencing analysis for exons 11 includes only cds +/- 10 bp. 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. 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. OAT: Deletion/duplication analysis is not offered for exon 2. PEX1: Sequencing analysis for exons 16 includes only cds +/- 0 bp. 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. TSFM: Sequencing analysis is not offered for exon 5. USH1C: Deletion/duplication analysis is not offered for exons 5-6. VPS13A: Deletion/duplication analysis is not offered for exons 2-3, 27-28. VPS53: Sequencing analysis for exons 14 includes only cds +/- 5 bp. AMN: Deletion/duplication analysis is not offered for exon 1. GALE: Sequencing analysis for exons 10 includes only cds +/- 5 bp. DDX11: NM_030653.3:c.1763-1G>C variant only. BBS9: Deletion/duplication analysis is not offered for exon 4. COL11A2: Deletion/duplication analysis is not offered for exon 36. WRN: Deletion/duplication analysis is not offered for exons 10-11. Sequencing analysis for exons 8, 10-11 includes only cds +/- 10 bp.

This report has been reviewed and approved by:

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