

# The genetic architecture of autism in an East African cohort

**Maria Chahrour, PhD**

University of Texas Southwestern Medical Center  
Eugene McDermott Center for Human Growth and Development  
Center for the Genetics of Host Defense  
Department of Neuroscience  
Department of Psychiatry  
Peter O'Donnell Jr. Brain Institute

October 12, 2023

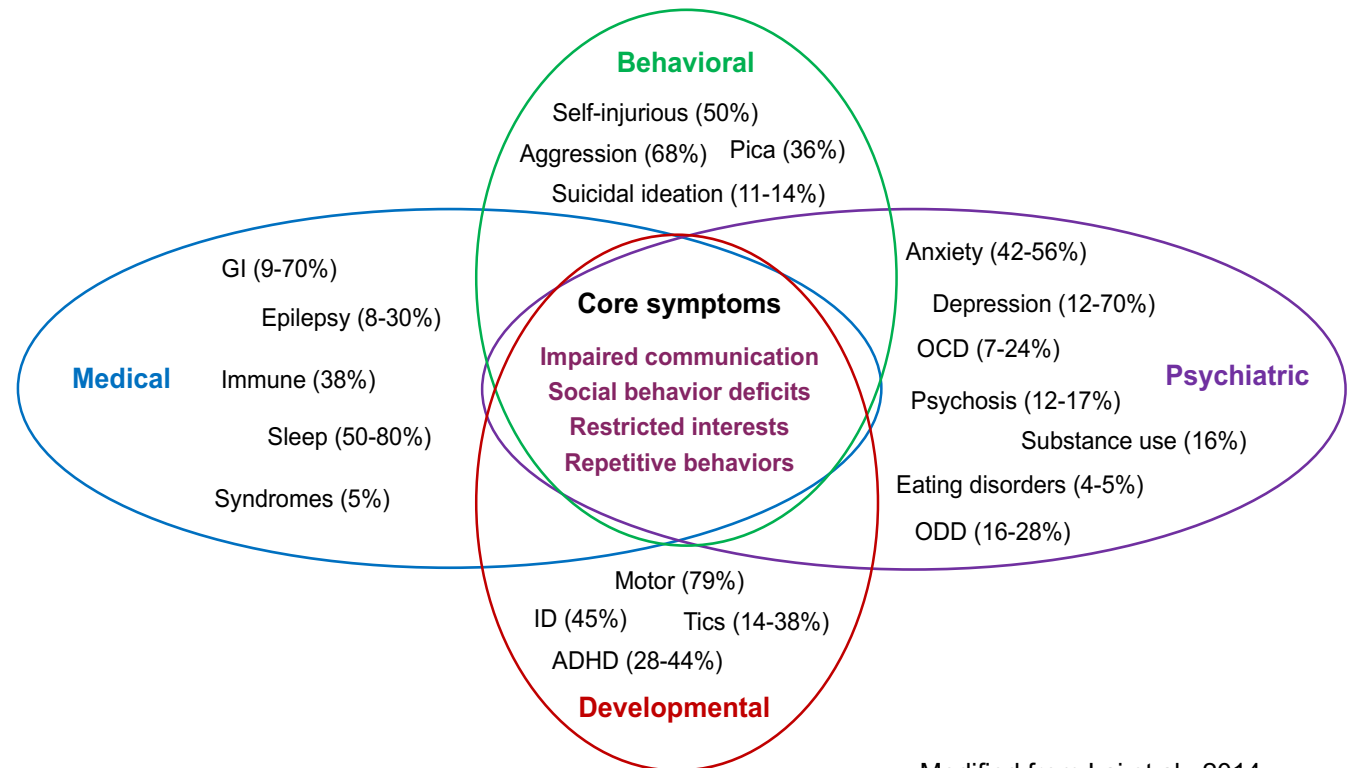


@MariaChahrour  
Chahrourlab.org

# Autism spectrum disorder

- A **spectrum** of neurodevelopmental disorders
- Affects ~ **2.8% of children** in the USA (~ 1:36)
- More **males** affected than females (~ 3 X more)
- Prevalence rate **increasing ~7% annually** for the past 20 years
- Huge societal and economic burdens

## ASD comorbidities



# Causes of ASD



Heritability ~83-90%

## *Genetics*



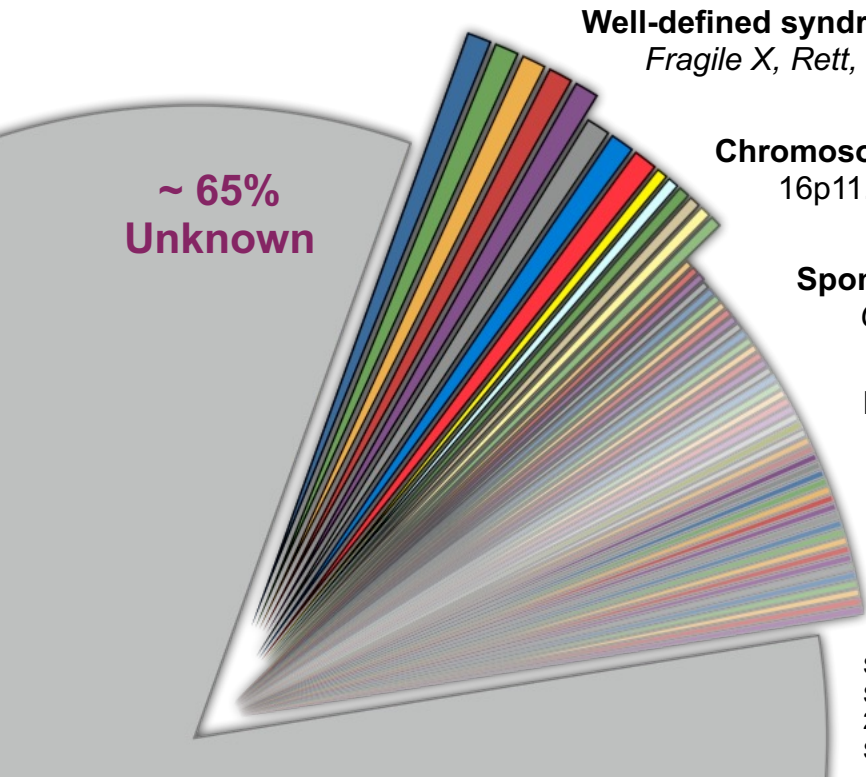
## *Environment*



Autism is very **complex**

# ASD genetics is heterogeneous and complex

- High heritability ~83-90%
- Hundreds of genes contribute to ASD
- Each gene contributes to a small proportion of patients



## Well-defined syndromes

*Fragile X, Rett, Tuberous Sclerosis, Angelman...*

## Chromosomal abnormalities or copy number variants

16p11.2, 15q11-q13, 22q11, 7q11.23, *NRXN1*, *SHANK3*, *NLGNs*...

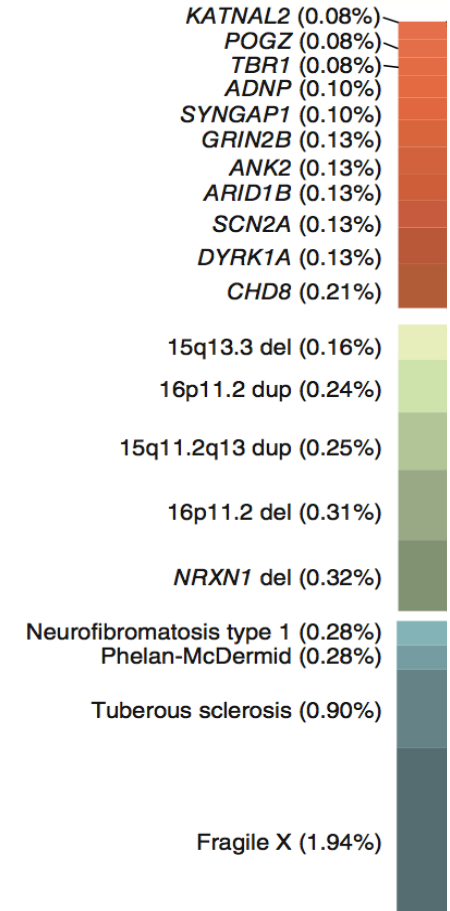
## Spontaneous (*de novo*) mutations

*CHD8*, *SYNGAP1*, *SCN2A*, *ADNP*, *ARID1B*, *FOXP1*...

## Inherited mutations

*SLC9A9*, *CC2D1A*, *BCKDK*, *AMT*, *KDM5A*, *UBE3B*...

## Somatic (in the brain) mutations



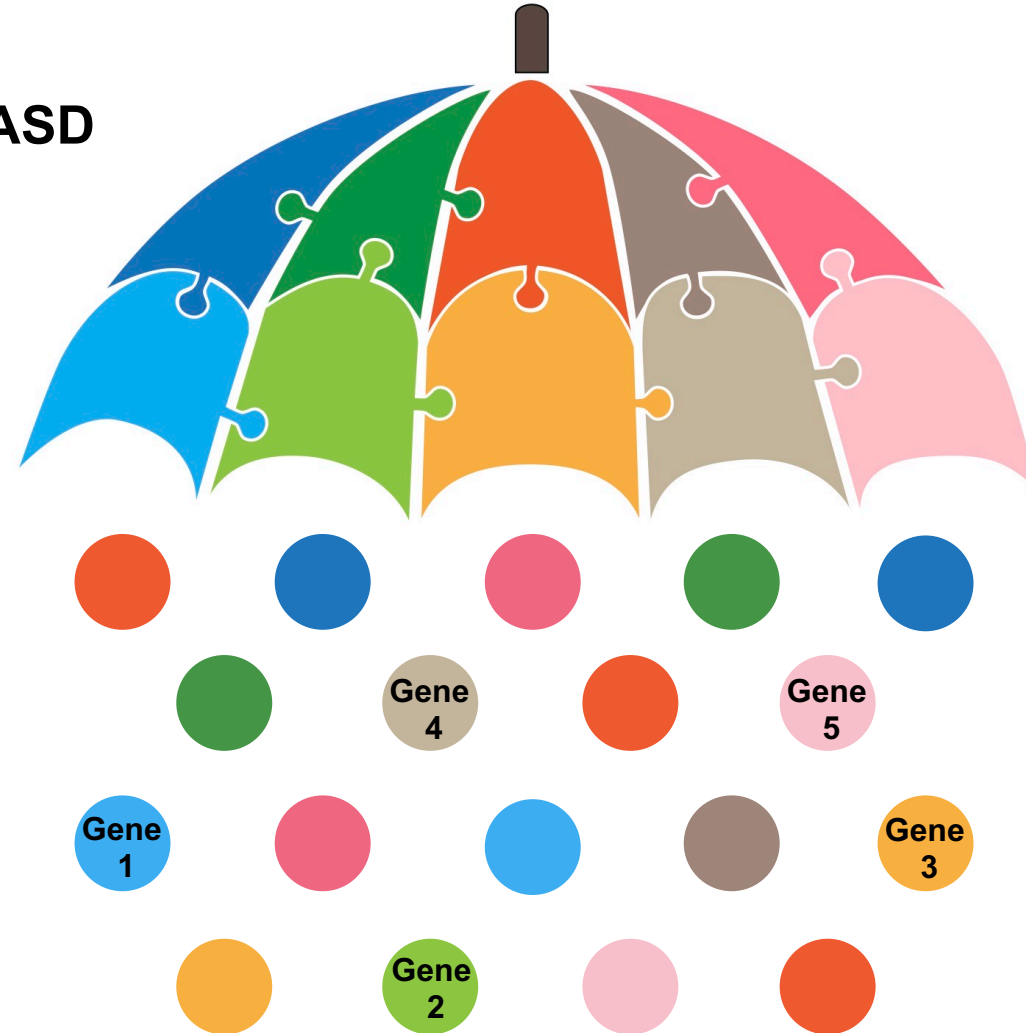
Modified from de la Torre-Ubieta et al., 2016

Sebat et al. 2007, Morrow et al. 2008, Weiss et al. 2008, Miller et al. 2010, Pinto et al. 2010, Betancur 2011, Sanders et al. 2011, O'Roak et al. 2011, Sanders et al. 2012, Neale et al. 2012, O'Roak et al. 2012, Iossifov et al. 2012, Chahrouh et al. 2012, Yu & Chahrouh et al. 2013, Lim et al. 2013, De Rubeis et al. 2014, Doan et al. 2019, Satterstrom et al. 2020, Fu et al. 2022, Tuncay et al. 2022, Zhou et al. 2022, Tuncay et al. 2023

# ASD as a collection of individually rare disorders

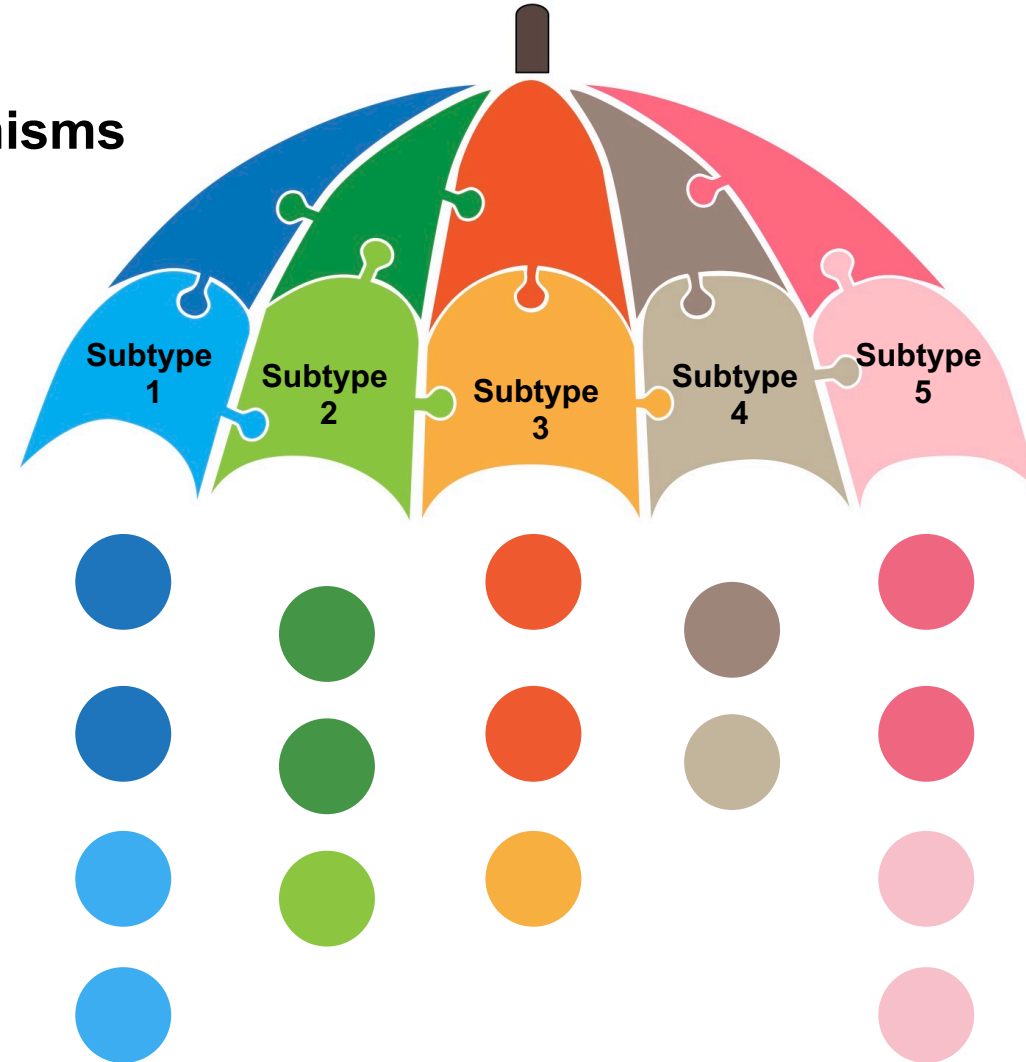
Hundreds of genes contribute to ASD

Each gene contributes to a small proportion of patients (< 2% of cases)



# ASD as a collection of individually rare disorders

Understanding molecular mechanisms underlying each genetic subtype

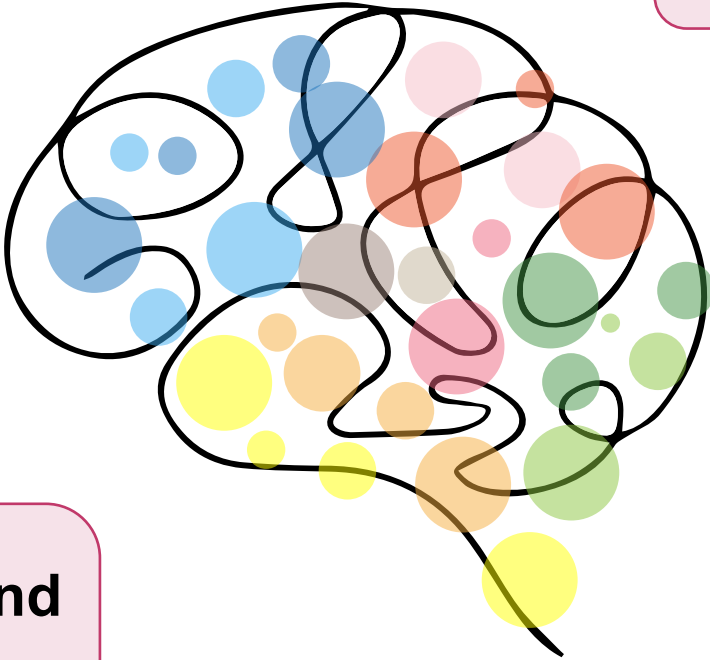


Grouping genes based on molecular pathways



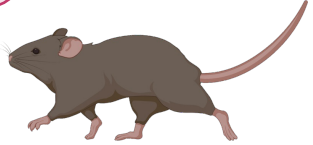
Genomics in familial cohorts  
Forward genetics

**Gene discovery  
in ASD**



Impact of patient mutations  
Neurobehavioral phenotyping of mouse models

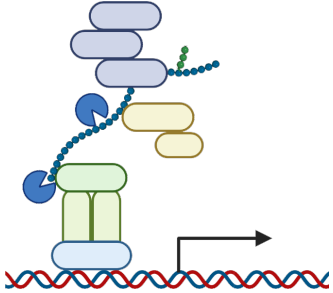
**Functional  
characterization**



**Diagnosis and  
targeted  
therapies**

Actionable pathways

**Molecular  
mechanisms**



Function-dependent questions:  
ex. ubiquitin proteasome pathway  
ex. single-cell transcriptional programs



### Genomics in familial cohorts

Forward genetics

**Gene discovery  
in ASD**



Impact of patient mutations  
Neurobehavioral phenotyping of mouse models

**Functional  
characterization**

**Molecular  
mechanisms**

**Diagnosis and  
targeted  
therapies**

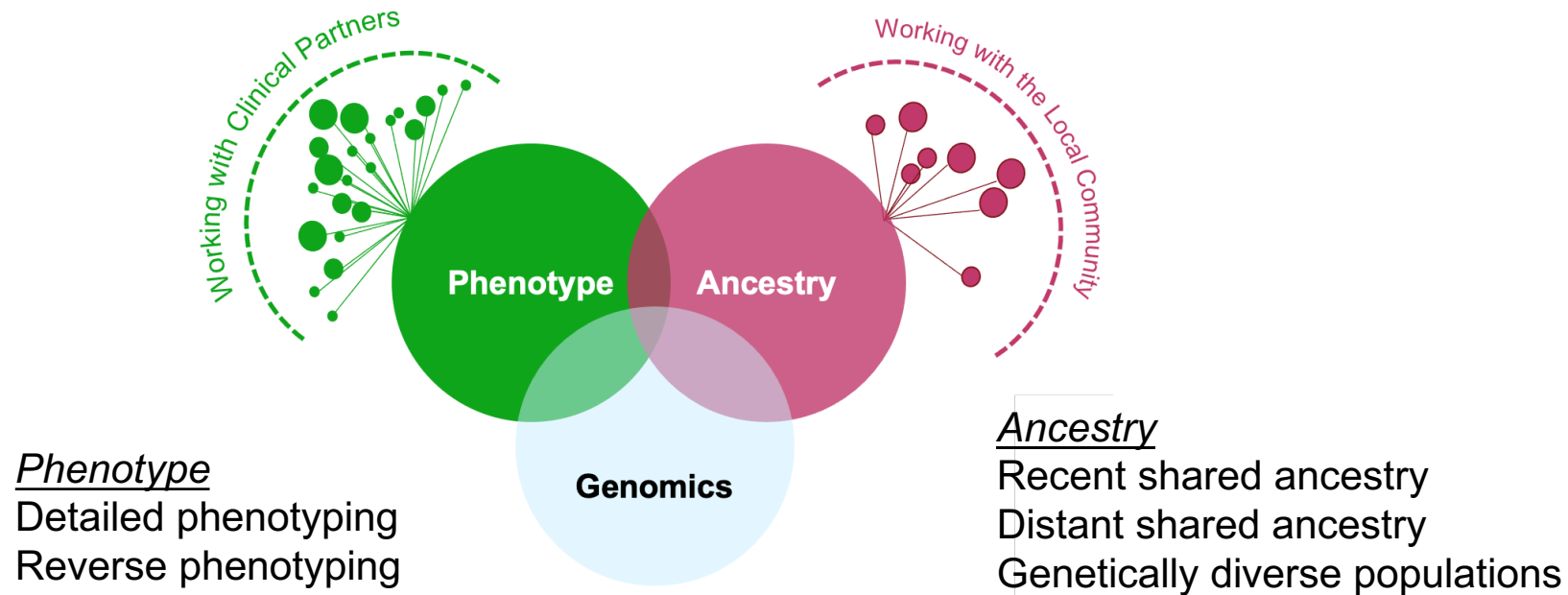
Actionable pathways

Function-dependent questions:  
ex. ubiquitin proteasome pathway  
ex. single-cell transcriptional programs



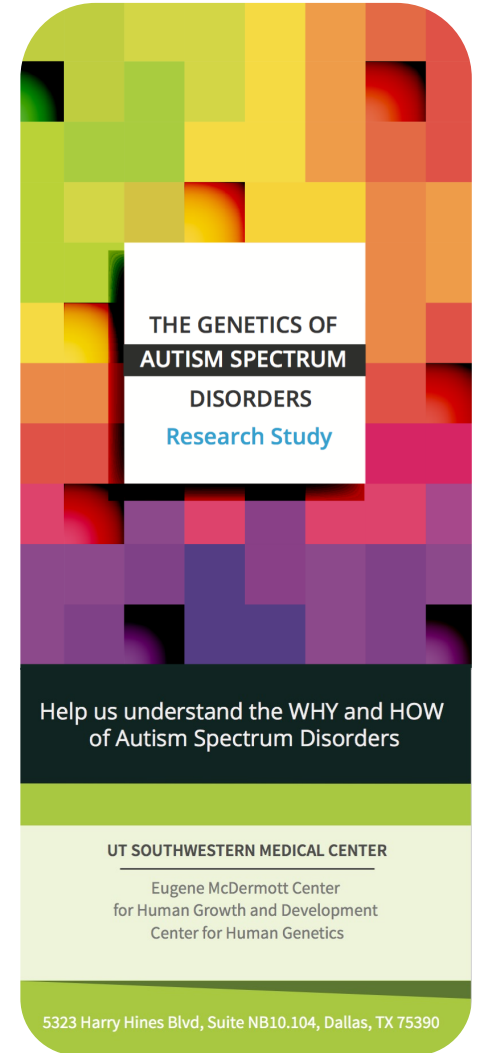


# Genomics in familial cohorts

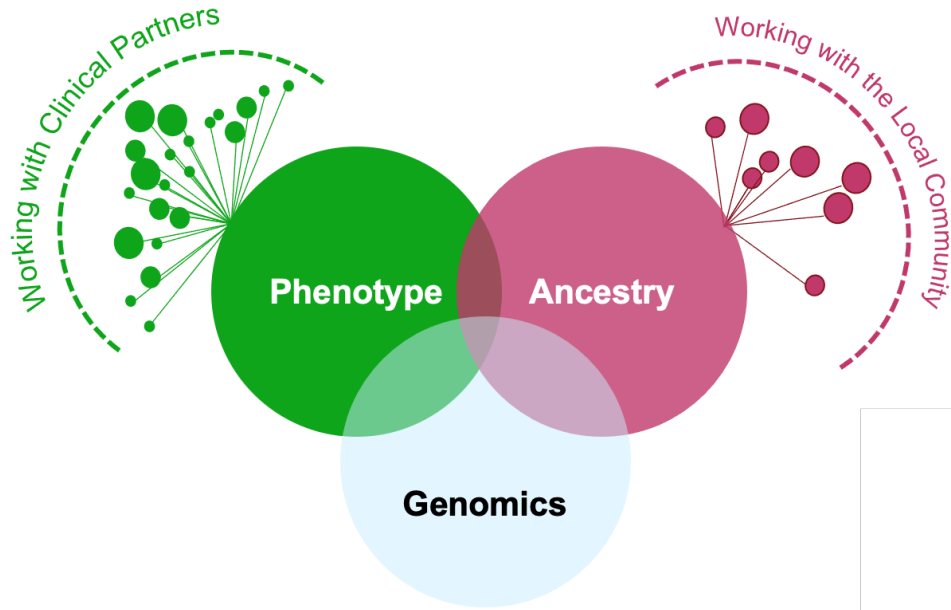


Diagnosis & Therapeutics

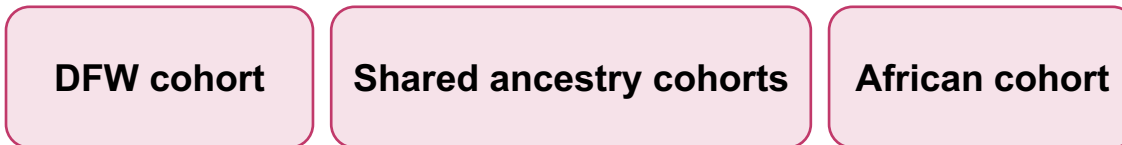
Brain development, Social behavior, Language



# Genomics in familial cohorts

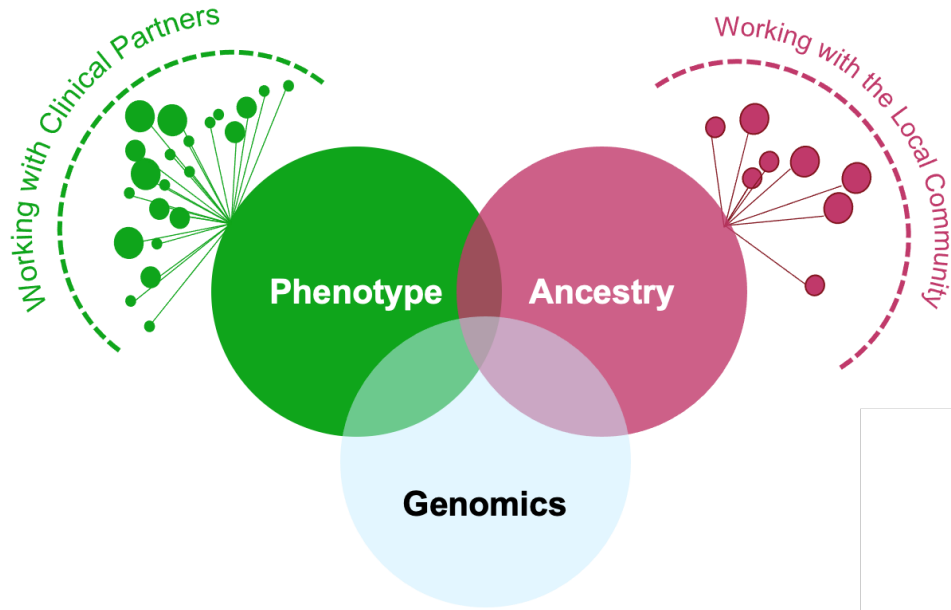


<b>Families</b>	859
<b>Individuals</b>	3,269



ASD variants in known genes and new candidates

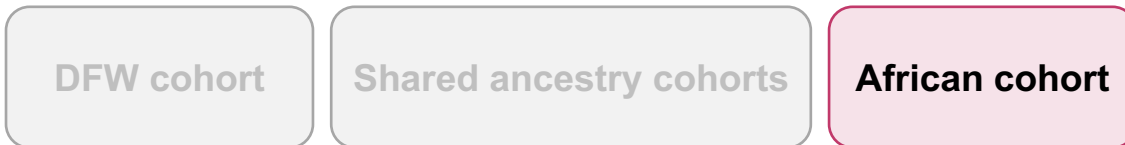
# Genomics in familial cohorts



**Families with ASD from the East African community in Dallas**

- Higher prevalence of ASD (~5%)
- Genetic diversity in Africa
- Underrepresented in genomics studies

Tuncay et al., 2023 *Cell Genomics*



ASD variants in known genes and new candidates

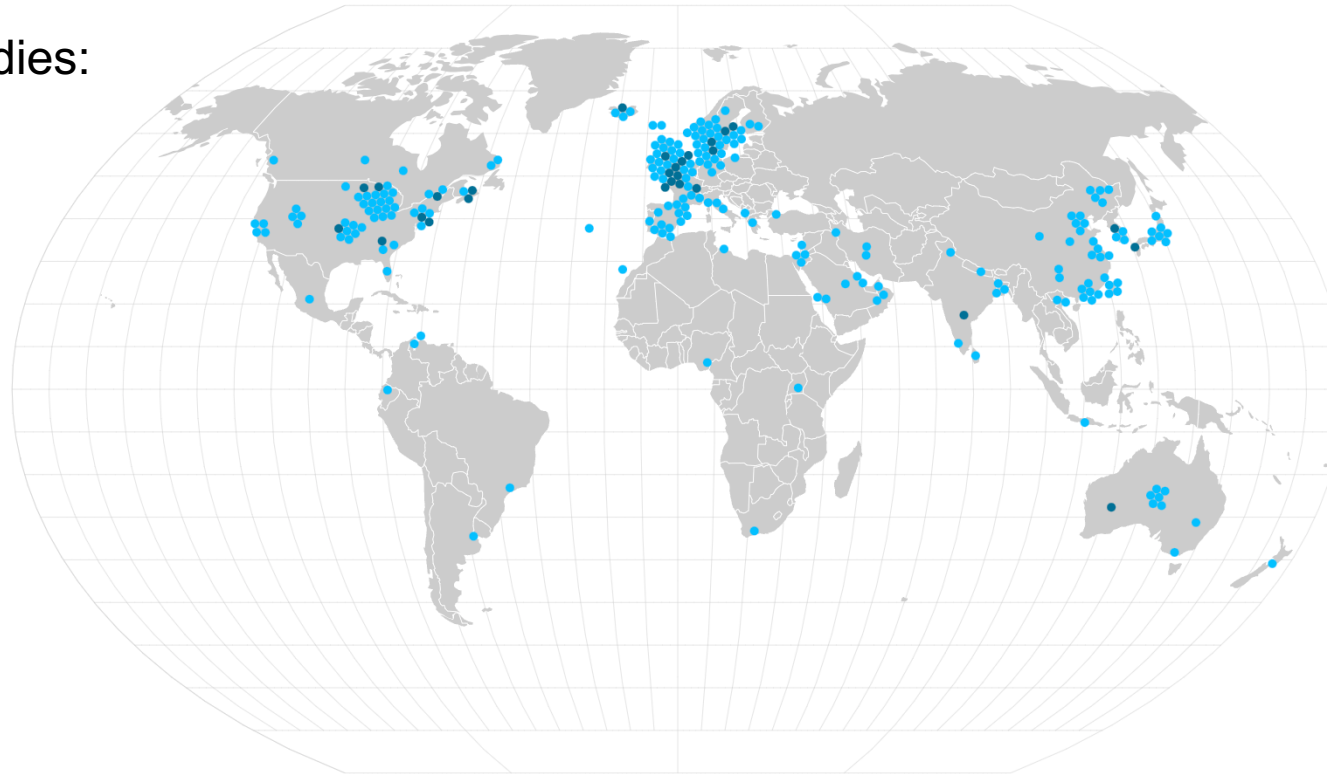


# Global prevalence of ASD

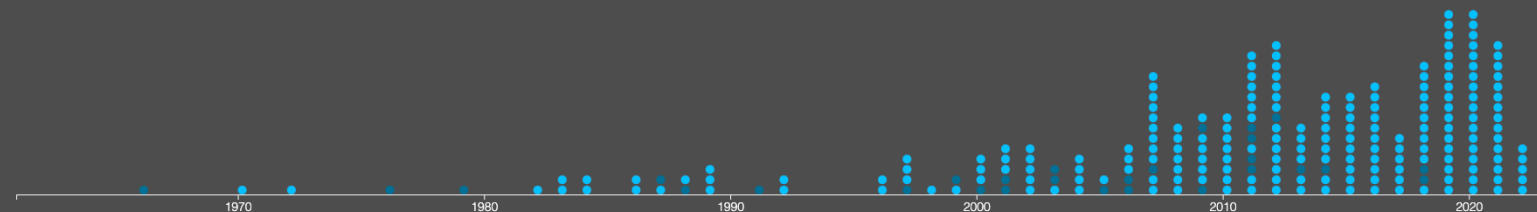
- ASD affects 1% of children **worldwide**; the prevalence in many low- and middle-income countries is unknown

# Global prevalence of ASD

- ASD affects 1% of children **worldwide**; the prevalence in many low- and middle-income countries is unknown
- Prevalence studies:



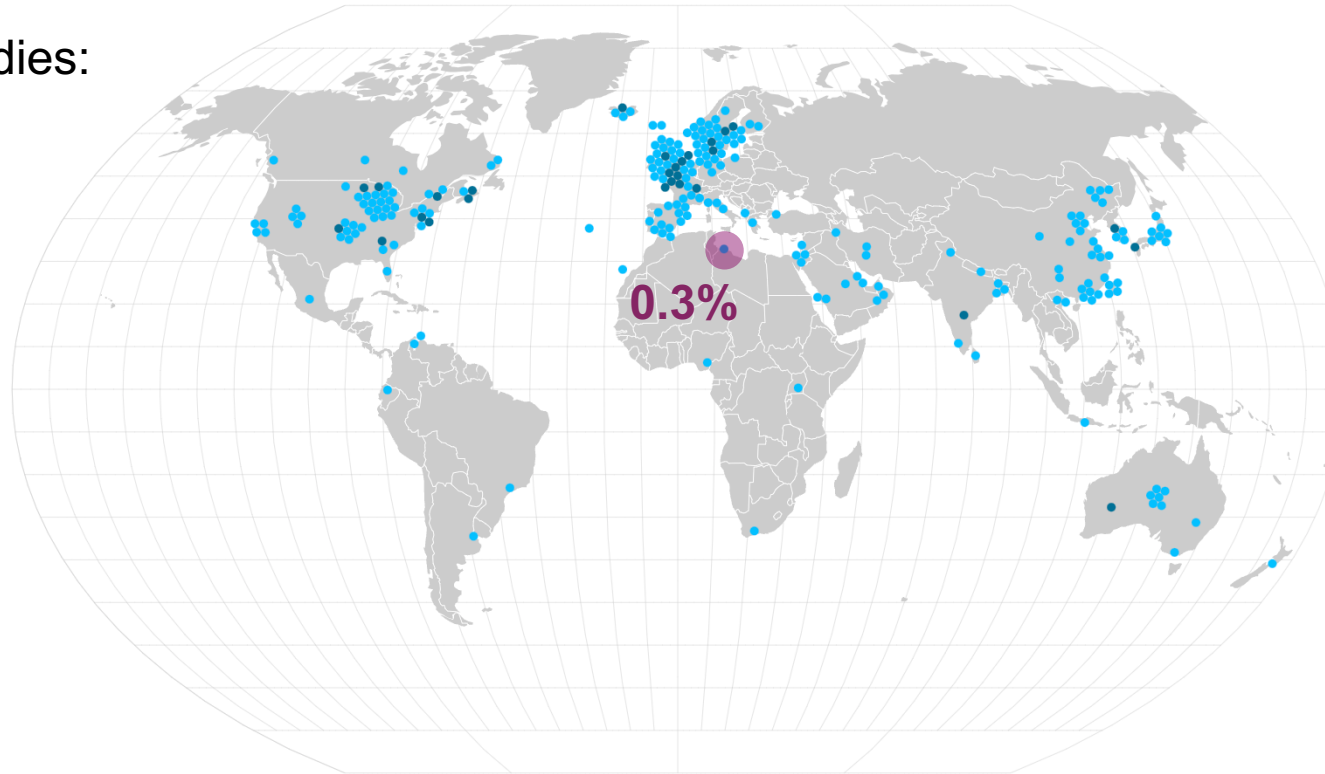
Global map of autism prevalence by Spectrum  
[Prevalence.spectrumnews.org](http://Prevalence.spectrumnews.org)



# Global prevalence of ASD

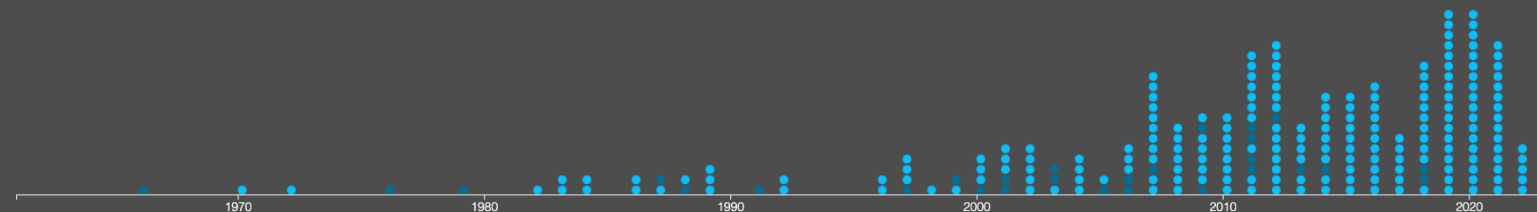
- ASD affects 1% of children worldwide; the prevalence in many low- and middle-income countries is unknown
- Prevalence studies:

Libya



Zeglam A.M. and Maound A.J. 2012

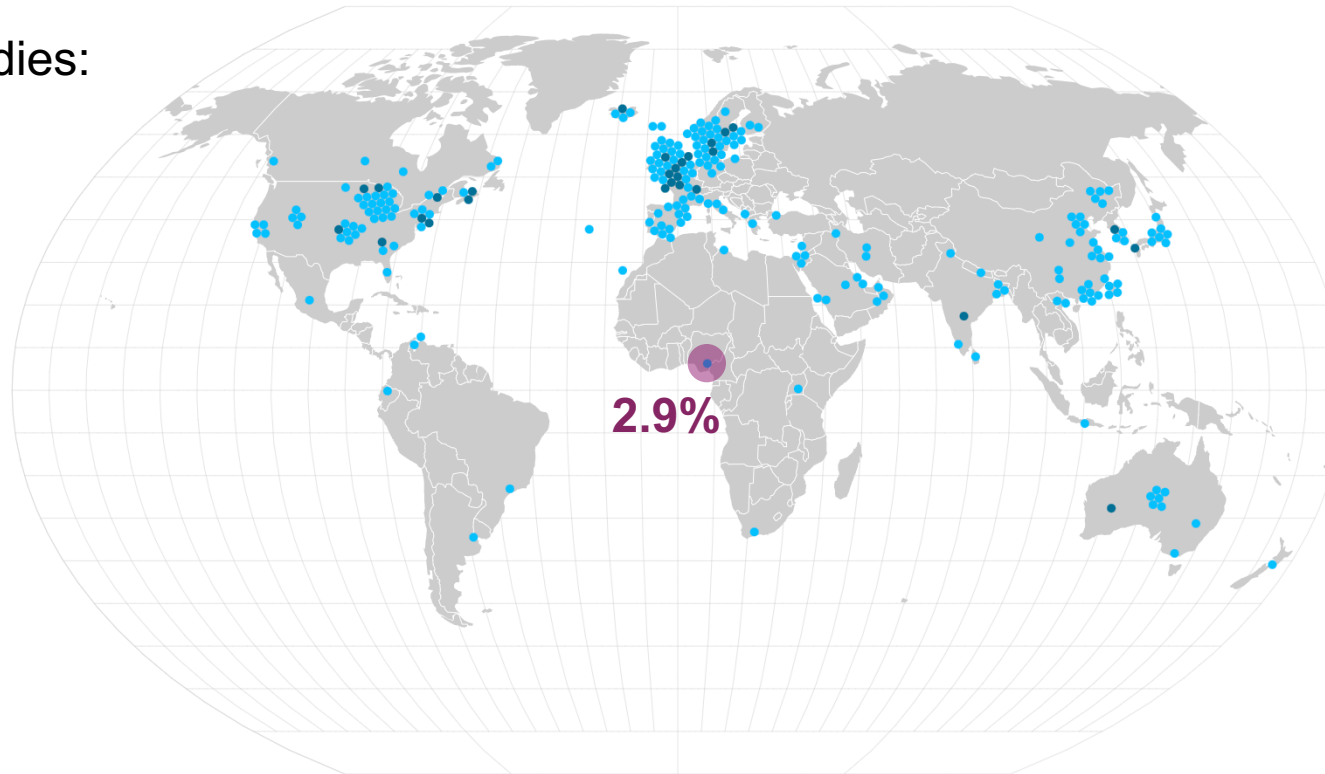
<b>Country</b>	Libya
<b>Area</b>	Tripoli
<b>Sample size</b>	30,508
<b>Age (years)</b>	0-16
<b>Diagnostic criteria</b>	DSM-IV
<b>Diagnostic tools</b>	Unavailable
<b>Percent w/ average IQ</b>	31
<b>Sex ratio (M:F)</b>	4
<b>Prevalence (per 10,000)</b>	33
<b>95% Confidence interval</b>	27.5-39
<b>Year(s) studied</b>	2005-2009
<b>Category</b>	ASD



# Global prevalence of ASD

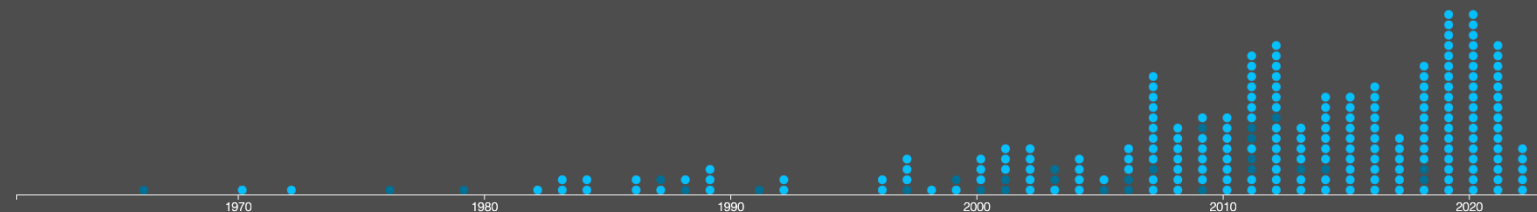
- ASD affects 1% of children worldwide; the prevalence in many low- and middle-income countries is unknown
- Prevalence studies:

Nigeria



Chinawa J.M. *et al.* 2016

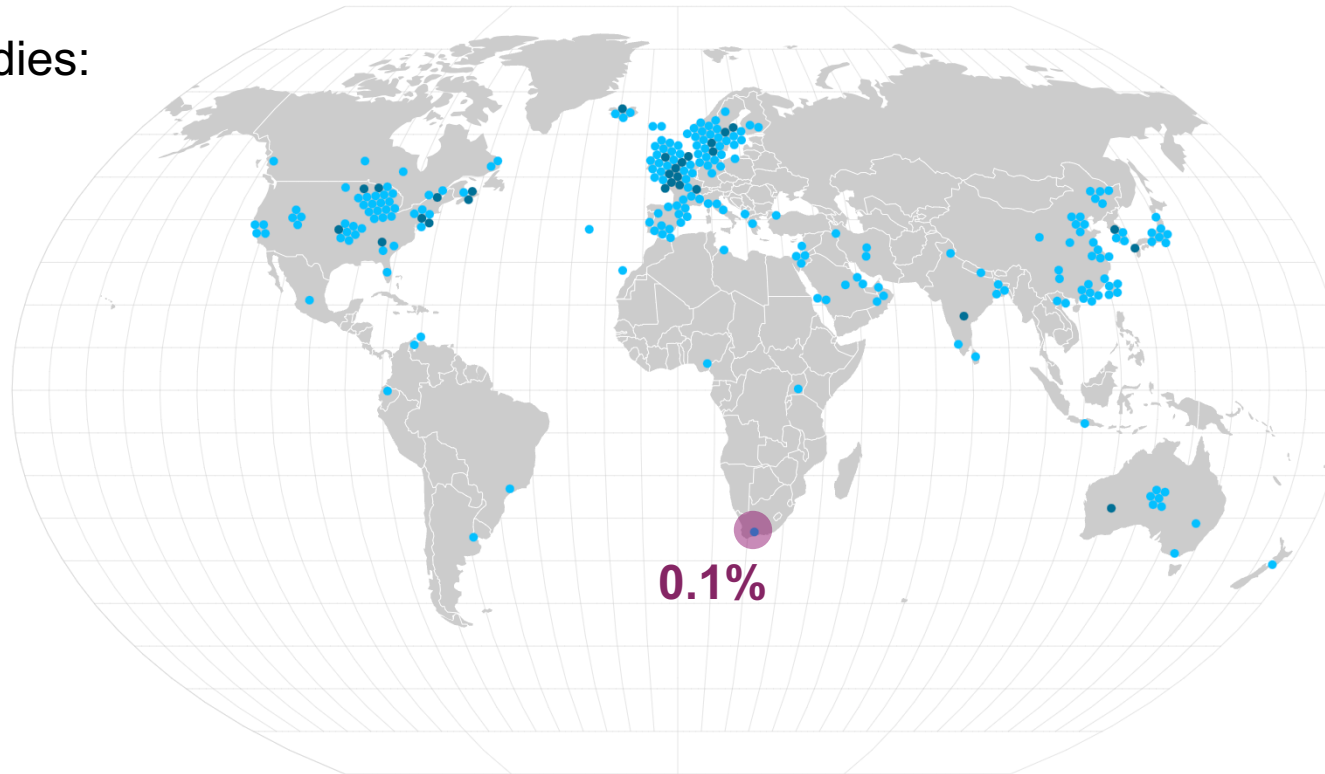
<b>Country</b>	Nigeria
<b>Area</b>	Enugu and Ebonyi states
<b>Sample size</b>	721
<b>Age (years)</b>	3-18
<b>Diagnostic criteria</b>	DSM-IV-TR
<b>Diagnostic tools</b>	Parent report, Teacher report
<b>Percent w/ average IQ</b>	Unavailable
<b>Sex ratio (M:F)</b>	0.9
<b>Prevalence (per 10,000)</b>	290
<b>95% Confidence interval</b>	169-414
<b>Year(s) studied</b>	2014
<b>Category</b>	ASD



# Global prevalence of ASD

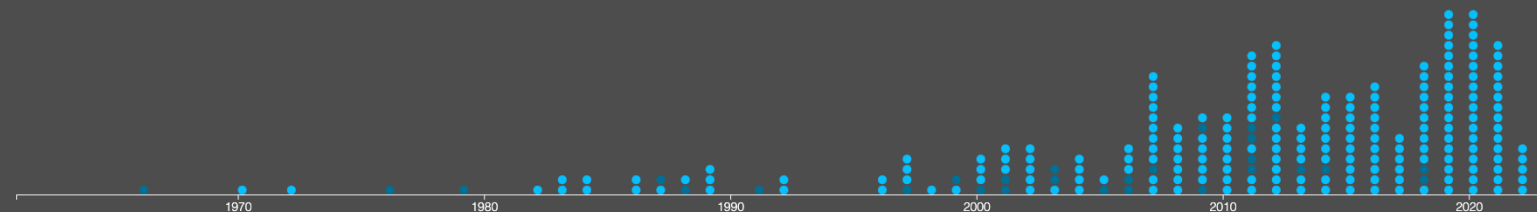
- ASD affects 1% of children worldwide; the prevalence in many low- and middle-income countries is unknown
- Prevalence studies:

South Africa



Pillay S. *et al.* 2020

<b>Country</b>	South Africa
<b>Area</b>	Western Cape
<b>Sample size</b>	1,154,353
<b>Age (years)</b>	3-23
<b>Diagnostic criteria</b>	Unavailable
<b>Diagnostic tools</b>	Unavailable
<b>Percent w/ average IQ</b>	77.8
<b>Sex ratio (M:F)</b>	5.5
<b>Prevalence (per 10,000)</b>	8.1
<b>95% Confidence interval</b>	7.6-8.7
<b>Year(s) studied</b>	2016
<b>Category</b>	ASD

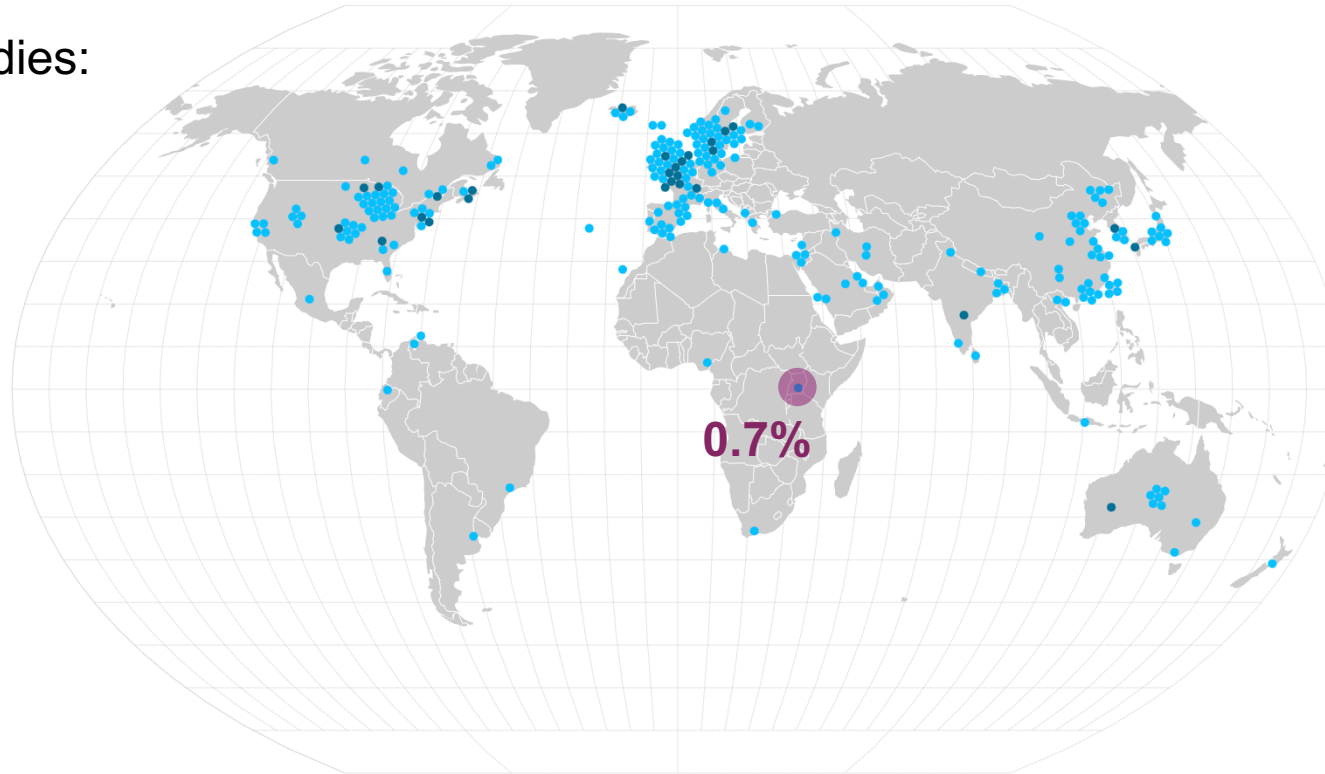




# Global prevalence of ASD

- ASD affects 1% of children worldwide; the prevalence in many low- and middle-income countries is unknown
- Prevalence studies:

Uganda



Kakooza-Mwesige A. *et al.* 2014

**Country**

Uganda

**Area**

Kampala and Wakiso Districts

**Sample size**

1,169

**Age (years)**

2-9

**Diagnostic criteria**

DSM-IV-TR

**Diagnostic tools**

23Q

**Percent w/ average IQ**

Unavailable

**Sex ratio (M:F)**

Unavailable

**Prevalence (per 10,000)**

68

**95% Confidence interval**

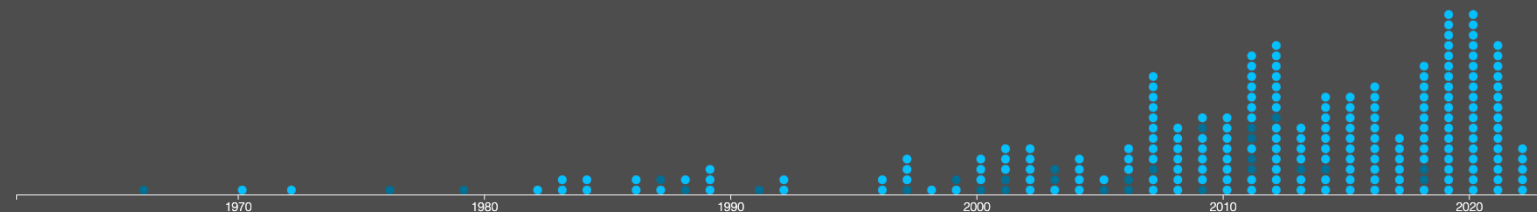
35-134

**Year(s) studied**

2010-2011

**Category**

PDD



# The Prevalence of Autism Spectrum Disorder in the East African Community

Leah Seyoum-Tesfa, RN, MEd  
Mother, Advocate, and  
Founder  
Reaching Families Advocacy  
and Support Group  
Dallas, Texas



# Reaching Families Advocacy and Support Group

- ▶ Non-profit organization
- ▶ Supports Ethiopian / Eritrean families who have children with special needs
- ▶ 25 support groups in major US cities and Europe
- ▶ Education, empowerment
- ▶ Advocacy, mentorship
- ▶ Community outreach to promote early identification and early intervention and break the stigma
- ▶ Individual and family counseling
- ▶ Grant and scholarship for therapies, swimming, and other immediate needs



**By gender**

Overall male 1 in 30	Overall female 1 in 126
Somali male 1 in 20	Somali female 1 in 95
White male 1 in 23	White female 1 in 86
Black (non Somali) male 1 in 36	Black (non-Somali) female 1 in 189
Hispanic male 1 in 43	Hispanic female 1 in 400

# Minneapolis Somali Autism Spectrum Disorder Prevalence Project (2013)

## Community Report



**Children with ASD who were identified as having ID**

	Percentage of children with ID	Percentage of children missing IQ scores
Overall	33%	28%
Somali	100%	35%
White	20%	26%
Black (non-Somali)	30%	19%
Hispanic	22%	40%

# The Prevalence of Autism Spectrum Disorder in Children of East African Descent in Texas (2013)

## Lonestar Lend Fellowship Training Program

- ▶ Prevalence rate was the highest among children whose parents migrated from Ethiopia.
- ▶ All subgroups had higher rates than that of other peers in Texas.
- ▶ Ethiopic: 1:22 (4.5%)
- ▶ Amharic: 1:40 (2.5%)
- ▶ Tigrinya: 1:51 (1.9%)
- ▶ Texas (all public-school students): 1:167

### oneStar LEND Prevalence of Autism in Children of East African Descent in Texas Leah Seyoum-Tesfa, RN, BSN<sup>1</sup>, Patricia Bowyer EdD, MS, OTR, FAOTA<sup>2</sup>, Aisha Dickerson, MSPH,<sup>1</sup> Parker Jackson, MSW,<sup>1</sup> and Leah Seyoum-Tesfa, RN, BSN<sup>1</sup> Affiliations: UT-Houston, Lonestar LEND, Texas Woman's University-Houston<sup>3</sup>

**Abstract**

Children have reported higher incidences of autism in the East African community. In 2009 Minnesota Department of Health reported significantly more children of Somali descent enrolled in educational programs than children from any other ethnic group.

In the 2009 study's procedures and validity of the tools and innovations for a larger study, a higher prevalence exists in Texas among students of East African descent.

The purpose of this study was to determine the prevalence of autism in children of East African descent in Texas. The study was conducted in Texas public schools. The study was a cross-sectional prevalence study using data from educational records. In accordance with Individuals with Disabilities Education Act (IDEA) 2004 statute, Section 118(b), Texas Education Agency (TEA) collects data on the number of students with disabilities receiving special education services by age, gender, disability category, etc. Special Education Database, a website created by TEA Division of Education Data, provides this de-identified data to the public. Special Education Database indicated that the total number of students (20,538 students) met the eligibility criteria for autism in 2010-2011 school year. In Texas to meet eligibility criteria for autism, the student has to adversely affect the child's educational performance, and by reason of the autism, the child needs special education and related services. Students who have autism but do not meet the criteria are not tracked and reported by TEA. Thus were excluded from this study.

Students who have autism but do not meet the criteria are not tracked and reported by TEA. Thus were excluded from this study. In Texas public schools (2010-2011), a publicly published of TEA reported that a total of 4,933,617 students were enrolled in Texas public schools. Autism prevalence rate for Texas public school students was derived using these sources:

In addition, in Texas, all school districts are required by law to provide IES forms to all parents enrolling their children in school for the purpose of identifying students who might benefit from English as a Second Language (ESL) program. This data is collected by all school districts annually and sent to TEA. TEA was able to provide cross referenced data on children who met autism eligibility criteria and were within specific language groups. Data was available on four of the languages spoken in Ethiopia, Eritrea and Somalia. Amharic is the national language of Ethiopia. Ethiopic signifies any of the languages spoken in Ethiopia, Tigrinya, the conventional language of Eritrea, is also spoken in northern Ethiopia. Somali is the main language spoken in Somalia. This de-identified data provided through PIR (Public Information Request) was used to calculate the prevalence in each sub-group.

**Methods**

**Study Design and Data Analysis**

We conducted a cross-sectional prevalence study using data from educational records. In accordance with Individuals with Disabilities Education Act (IDEA) 2004 statute, Section 118(b), Texas Education Agency (TEA) collects data on the number of students with disabilities receiving special education services by age, gender, disability category, etc. Special Education Database, a website created by TEA Division of Education Data, provides this de-identified data to the public. Special Education Database indicated that the total number of students (20,538 students) met the eligibility criteria for autism in 2010-2011 school year. In Texas to meet eligibility criteria for autism, the student has to adversely affect the child's educational performance, and by reason of the autism, the child needs special education and related services. Students who have autism but do not meet the criteria are not tracked and reported by TEA. Thus were excluded from this study.

Students who have autism but do not meet the criteria are not tracked and reported by TEA. Thus were excluded from this study. In Texas public schools (2010-2011), a publicly published of TEA reported that a total of 4,933,617 students were enrolled in Texas public schools. Autism prevalence rate for Texas public school students was derived using these sources:

**Results**

Prevalence was calculated for the school year of 2010-2011

- ▶ All subgroups had higher rates than that of Texas.
- ▶ Prevalence rate was the highest among children whose parents migrated from Ethiopia.
- ▶ Ethiopic: (all Ethiopic languages) 1 in 22 (4.5%).
- ▶ Amharic: (national language of Ethiopia) 1 in 40 (2.5%).
- ▶ Tigrinya: (government language of Eritrea and also spoken in northern Ethiopia) 1 in 51 (1.9%).
- ▶ Somali: (government language of Somalia) 1 in 114 (0.9%).
- ▶ Texas: (all public school students) 1 in 167 (0.6%).

**Conclusion**

Strengths

- ▶ Cost-effective and affordable.
- ▶ Data is accessible and collected on yearly basis.
- ▶ Data is collected over a period of time.
- ▶ Data is de-identified protecting the privacy of individual students.

Limitations

- ▶ Students in private schools or students who are not enrolled.
- ▶ Students who have ASD but do not meet TEA criteria were excluded.
- ▶ Parents on parents understanding and response to process on quality and quantity of information given.
- ▶ Individual case ascertainment was not done due to TEA's data.

**Recommendations for Larger Study**

In addition to TEA, data should be collected from private schools, faith school organizations and religious organizations such as U.S. faith community based managed care companies, Medicaid, Local MMRV of Agency of Disability Department of Assistance and Social Security Administration, which provide services should be investigated as well.

As done in the ACDM protocol records of all student education records and identified as well from records of students who have been evaluated for special education services and identified as well from autism should be reviewed.

Including siblings of children with ASD for possible cases of autism.

**References**

1. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

2. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

3. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

4. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

5. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

6. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

7. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

8. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

9. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.

10. Leah Seyoum-Tesfa, RN, BSN, Patricia Bowyer EdD, MS, OTR, FAOTA, Aisha Dickerson, MSPH, Parker Jackson, MSW, and Leah Seyoum-Tesfa, RN, BSN. Prevalence of Autism in Children of East African Descent in Texas. *Journal of Autism and Developmental Disorders*. 2013; 43(10): 2885-2890.



## References

- Fairthorne (2017) Australia: immigrant mothers from East Africa are 3.5 times more likely to have a child with ASD and ID
- Bacerra (2014) Los Angeles County, USA: higher incidence of ASD with ID in children of foreign-born black mothers
- Bolton (2014) Ireland: higher prevalence of ASD and more affected children in immigrants from Africa
- Magnusson (2012) Sweden: higher incidence of ASD born to immigrant mothers and more children with ID
- Dealberto (2011) Canada: immigration and black ethnicity associated with increased risk of having a child with ASD
- Kamer (2004) Israel: Higher incidence of ASD in Ethiopian Israeli children born in Israel than those who were born in Ethiopia
- Gillberg (1987) Sweden: autism more common from "Exotic" countries



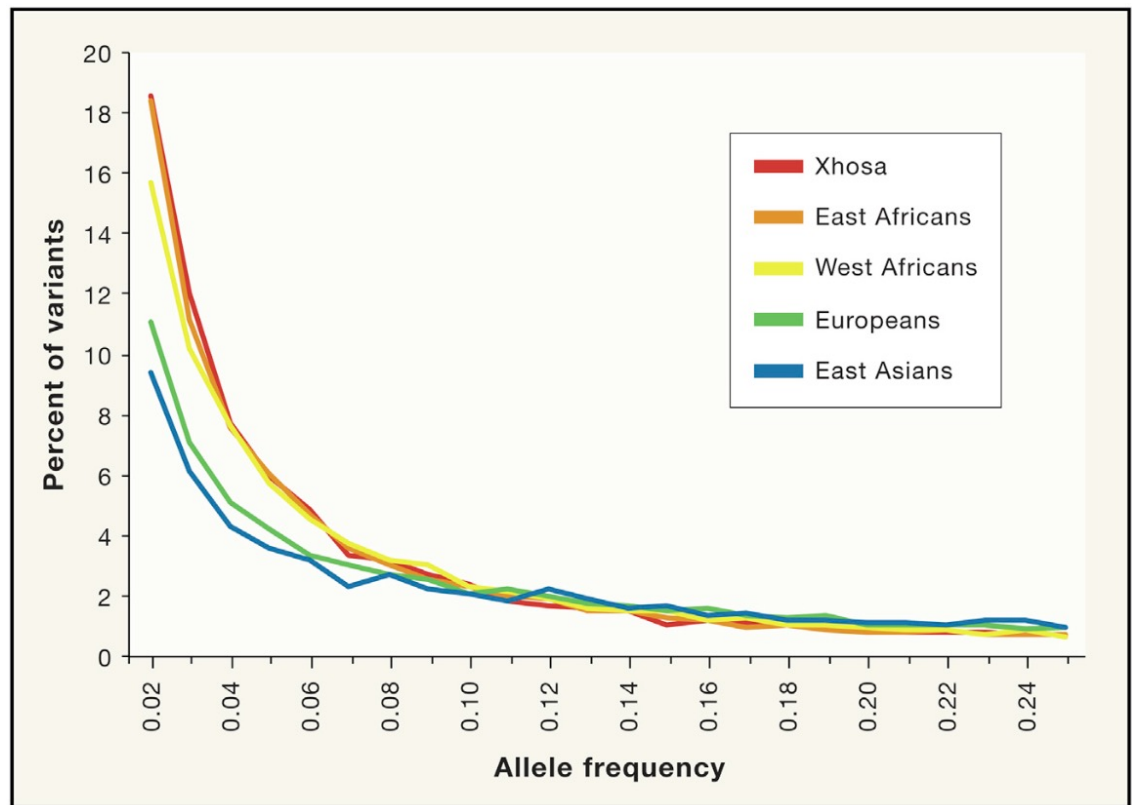
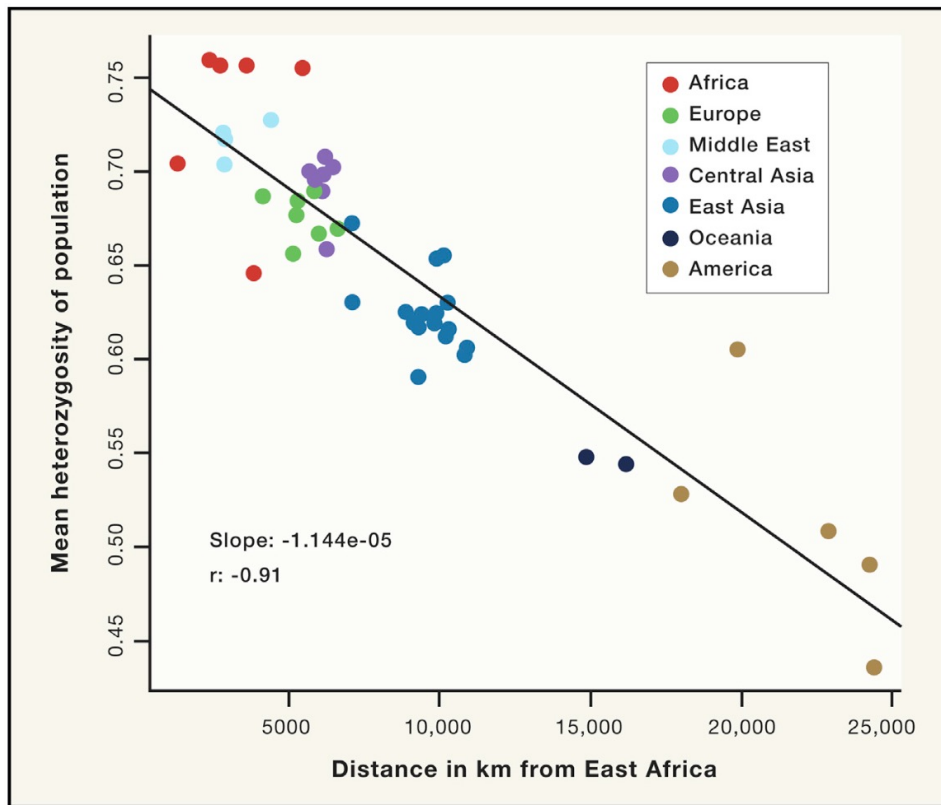
# Prevalence of ASD in African populations

- ASD affects an average of 1% of children worldwide (WHO) and 2.8% of children in the USA (CDC)
- Higher prevalence of ASD in children born to East African parents:
  - Prevalence is ~3-4 X higher in children of Somali parents in Sweden
  - Higher rate of autism in children born to East African (Somali and Ethiopian) parents in Sweden
  - Prevalence of ~3% in the Somali population in Minnesota
  - Prevalence of ~5% in the Ethiopian population in Texas
- The higher incidence of ASD in East African populations suggests possible shared genetic susceptibility factor(s) that predisposes to autism

What is the genetic contribution to the increased ASD prevalence in children from East African origin?

# Genetic diversity in Africa

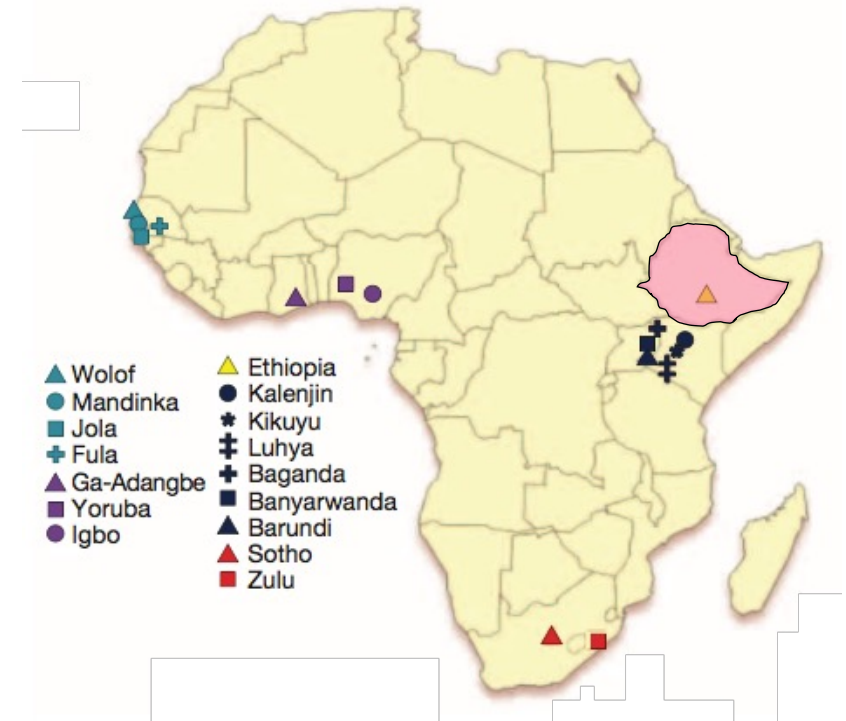
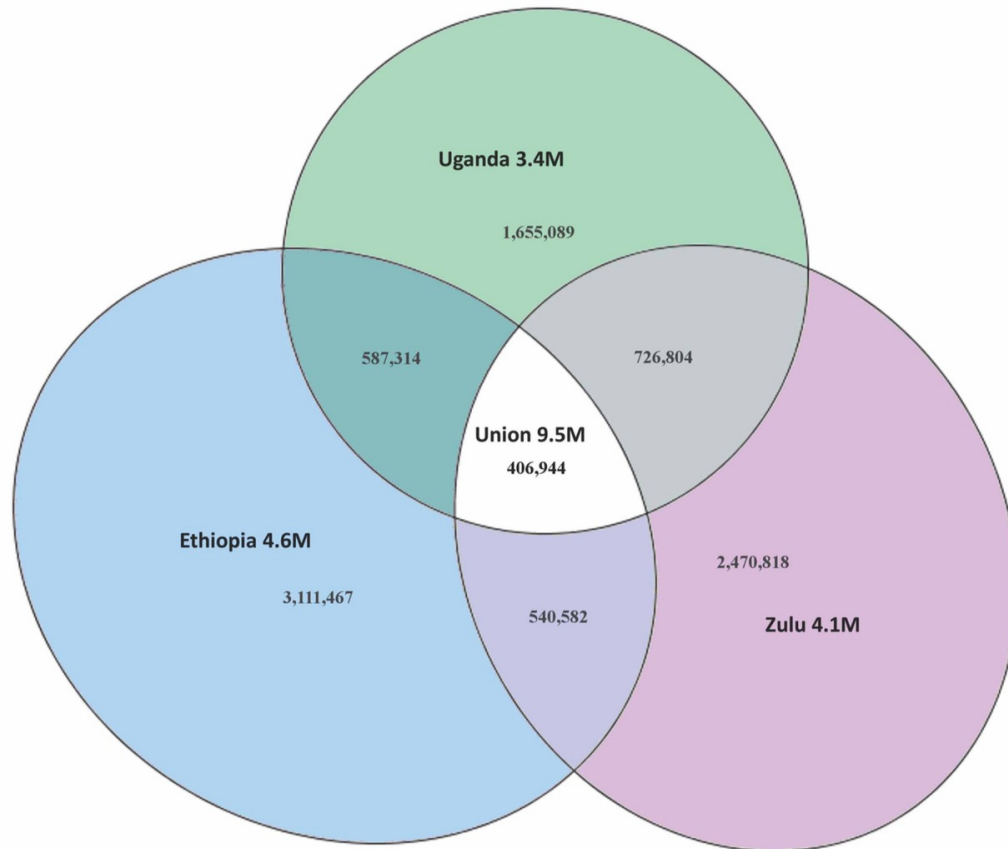
- Populations in Africa are the most genetically diverse in the world, carrying up to 3 times as many rare variants as populations of European or East Asian origin





# Genetic diversity in Africa

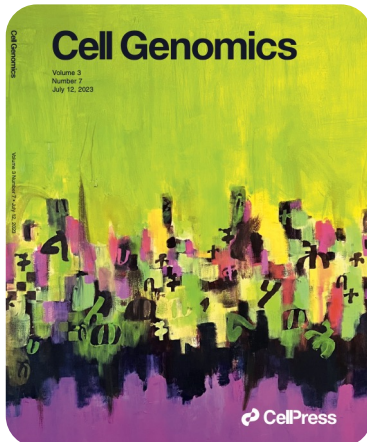
- The **Ethiopian** population has the greatest proportion of all the novel and private genomic variation found in Africa (~24% of genomic variants)



# The genetics of ASD in an East African familial cohort

Leverage ancestral genomic information to identify ASD genes through whole genome sequencing and admixture analysis in a familial cohort from a population with an unusually high rate of ASD

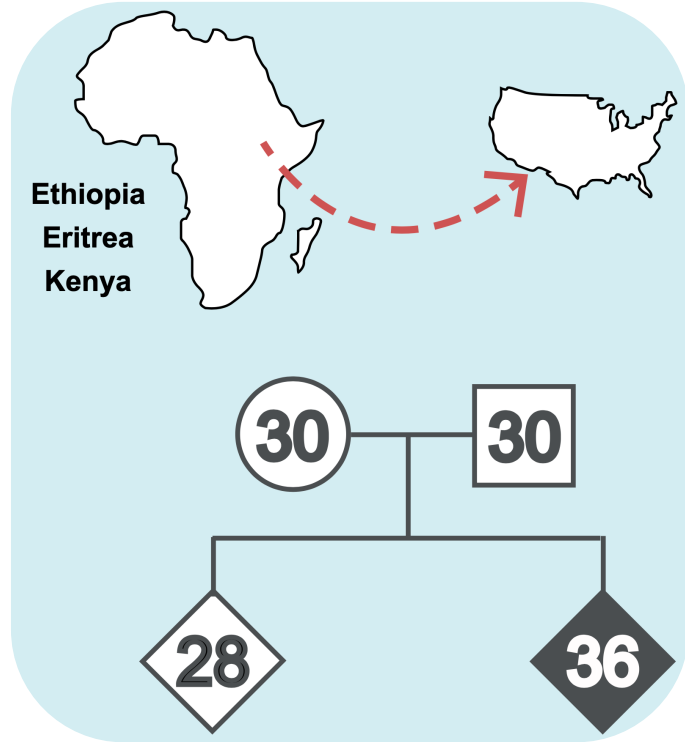
One of the first studies to investigate the genetic underpinnings of ASD in an African population



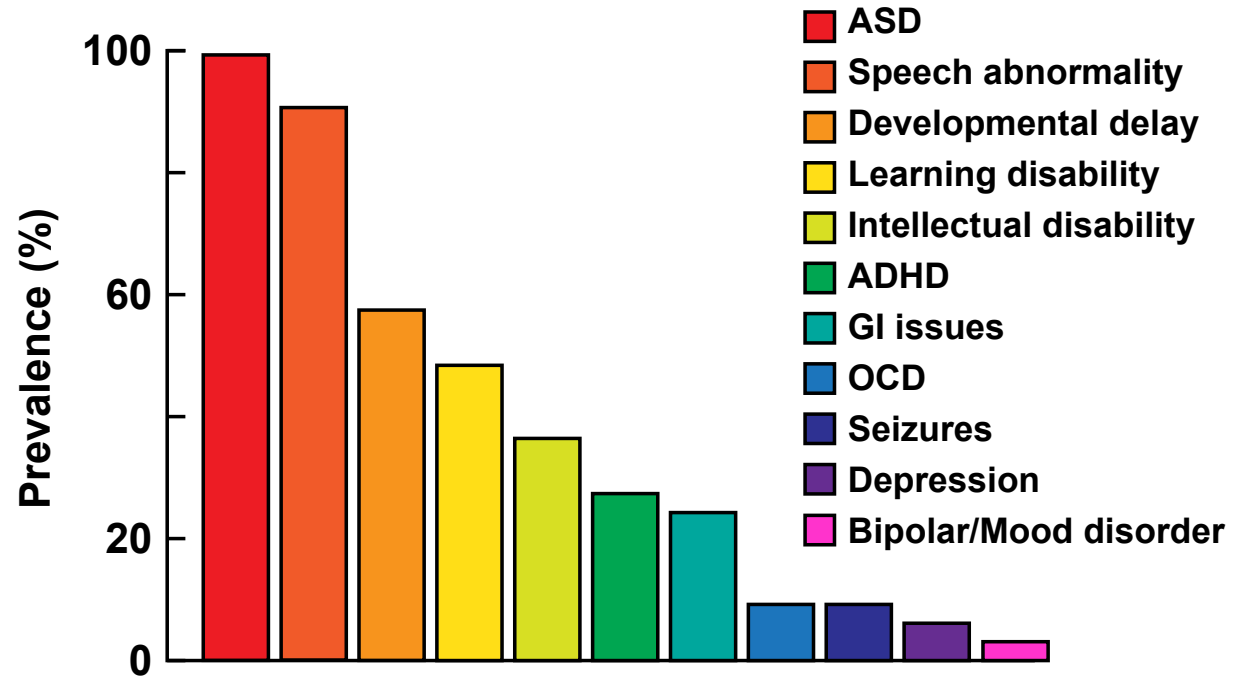
Ongoing enrollment through collaboration with our community partner

Tuncay et al., 2023 *Cell Genomics*

# The genetics of ASD in an East African familial cohort



33 families (129 individuals)



# The genetics of ASD in an East African familial cohort

The human genome has **3 billion** “letters”



~ **3 to 4 million** “changes” in the genome



~ **1 to 2** “changes” in the genome  
that cause autism



## WHOLE GENOME SEQUENCING

AGCTTCCCTGAATCAATCCCCATGCAAATGC →

**5,016,279** TOTAL VARIANTS PER GENOME

**223,867** RARE VARIANTS PER GENOME

**132,314** NOVEL VARIANTS PER GENOME

**2,130,150** PRIVATE VARIANTS IN COHORT

# The genetics of ASD in an East African familial cohort

## ASD VARIANTS

### VARIANTS IN KNOWN GENES

#### CODING

*CACNA1C*  
*CHD7*  
*TCF7L2*

#### NONCODING

*CTCF*  
*MED13L*  
*PTPN11*

### VARIANTS IN NEW GENES

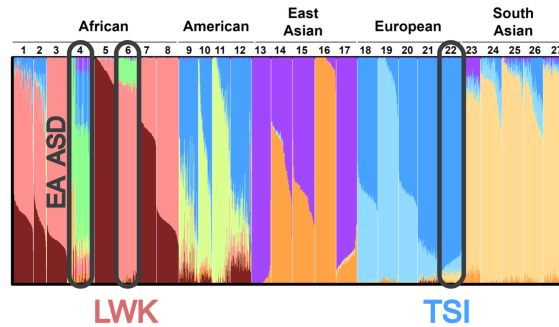
#### CODING

*GLUD2*  
*IDH3G*

#### NONCODING

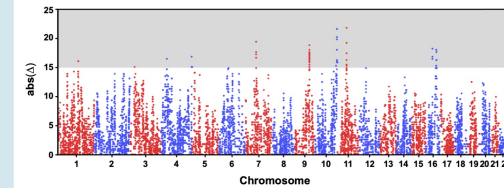
*BDNF*  
*NPAS4*

## POPULATION ADMIXTURE



Luhya in Webuye, Kenya (LWK) and the Toscani in Italy (TSI) are the most closely related to the ancestral admixed populations in the East African ASD cohort (EAASD)

## POPULATION SPECIFIC ASD VARIANTS



Population specific variants are preferentially transmitted to affected offspring

Transmission disequilibrium test identified 10 loci that confer ASD risk on the African haplotypes

Known ASD genes in these loci: *ASDL*, *CREBBP*, *EHMT1*, *GRIN1*

# Summary and ongoing work

- Established an African ASD familial cohort for **genetics research through community partnership**
- Leveraged ancestral genomic information and genetic diversity in an **African cohort** with increased prevalence to identify ASD variants and risk loci
  - Discovered 2.13 million **novel private variants**
  - Rare variants in known and in new candidate **ASD genes**
  - Admixture mapping identified several **ASD risk loci** on the African haplotypes

Tuncay et al., 2023 *Cell Genomics*

- **Actively enrolling to expand** the ASD cohort
- **Prioritizing** genes for follow up functional studies
- Investigate the underlying **mechanisms**

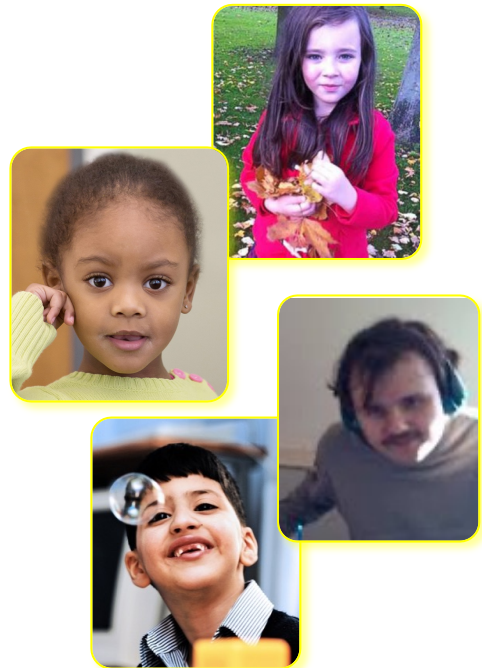
# Conclusions

- Community partnerships to drive research
- Equity in healthcare depends on inclusion of all human populations
- The power of African genetic diversity to inform complex disorders, even for the highly heterogeneous ASD
  - Ultra rare (private) variants
  - Population allele frequencies
  - Ancestral information
- Concerted efforts; the Human Heredity and Health in Africa (H3Africa) consortium

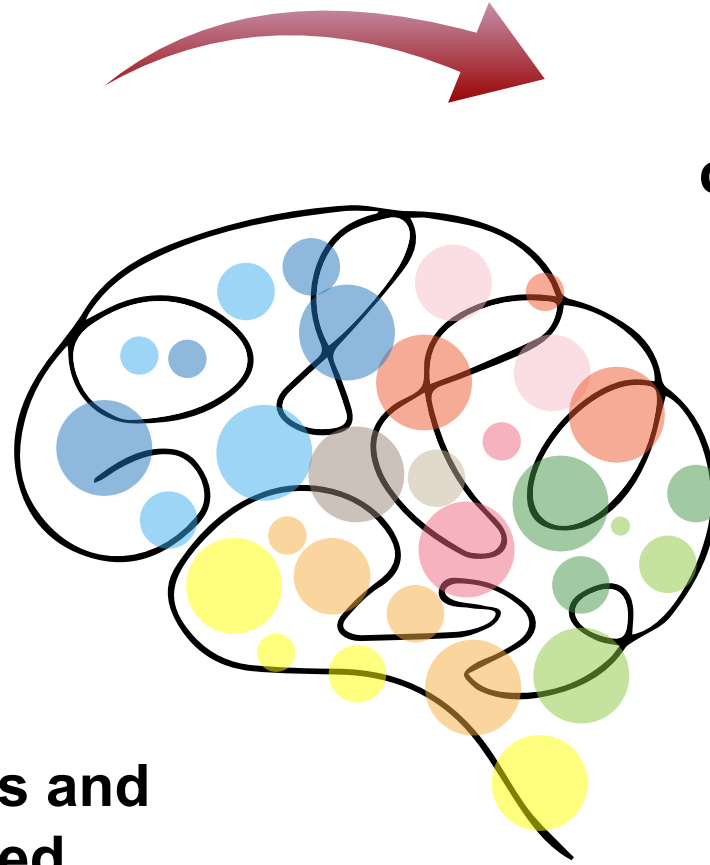




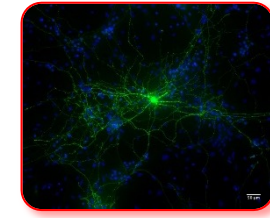
## Gene discovery in ASD



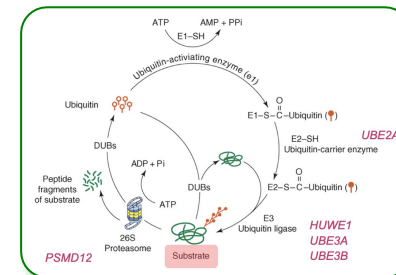
## Diagnosis and targeted therapies



## Functional characterization

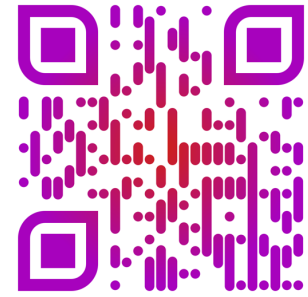


## Molecular mechanisms





# Acknowledgements



## LAB MEMBERS

Kiran Kaur, Ph.D.  
Lauretta El Hayek  
Shayal Vashisth  
Ariel Aiken  
Ashlesha Gogate

## Alumni

Oguz Tuncay, Ph.D.  
Darlene DeVries

## PATIENTS & FAMILIES

### COLLABORATORS

**Leah Seyoum-Tesfa, RN, MEd (RFASG)**

Berge Minassian, MD  
Patricia Evans, MD, PhD  
Jeff Waugh, MD, PhD  
Kimberly Goodspeed, MD

### H3Africa

*Human Heredity and Health in Africa*

## CORES

McDermott Center Human Genetics Clinical Lab  
*Markey McNutt II, MD, PhD*  
*Barbara Gilbert*

McDermott Center Sequencing Core  
*Ralf Kittler, PhD*  
*Vanessa Schmid*

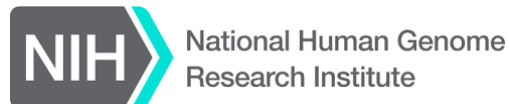
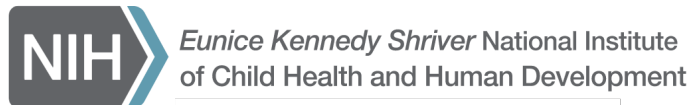
McDermott Center Bioinformatics Lab  
*Chao Xing, PhD*



@MariaChahrouh

Chahroulab.org

AutismGenetics@UTSouthwestern.edu



*The Walter & Lillian Cantor Foundation*



**Chan  
Zuckerberg  
Initiative**

