The Glaucoma Foundation (TGF) was established by Dr. Robert Ritch in 1984 to support research into glaucoma.

Our pursuit of a cure has led to wide-ranging discoveries touching on many aspects of human health, and provided a platform for large research projects now led by the National Institutes of Health as well as the pharmaceutical industry.

For thirty-five years, TGF has funded groundbreaking research in the areas of neuroprotection and genetics. We are currently focused on finding a cure for exfoliation syndrome (XFS), the most common identifiable cause of open-angle glaucoma.

An increasing list of associations with cardiovascular and cerebrovascular diseases makes XFS a condition of general medical importance. Recently described associations include stroke, cardiovascular dysfunction, Alzheimer’s disease and hearing loss. We are also interested in how environmental factors contribute to exfoliation syndrome.

Dr. Ritch is the Shelley and Steven Einhorn Distinguished Chair, Surgeon Director Emeritus, and Chief of Glaucoma Services at the New York Eye & Ear Infirmary of Mount Sinai, New York City.
Exfoliation Syndrome

Exfoliation syndrome (XFS) is the most common recognizable cause of open-angle glaucoma in the world, affecting about 80 million people. It accounts for the majority of cases in some countries. Nevertheless, it was virtually ignored outside Scandinavia for nearly a century and the diagnosis was often overlooked, particularly in the United States. It was thought not to exist at all in Africa and East Asia.

For many years, funding for research into the causes of XFS was negligible.

We believe that, as a specific disease with potentially identifiable causes, XFS can be prevented, reversed, and even cured. Ten years ago, we decided to make XFS research our primary focus.

XFS is not a form or a type of glaucoma, but an ocular manifestation of a systemic disease. About 25 percent of persons with XFS develop elevated intraocular pressure (IOP) and one-third of these develop glaucoma. A person with XFS has about a six times higher chance of developing glaucoma compared with someone who doesn’t have XFS.

In part due to our annual international interdisciplinary Think Tank which we founded in 1994, leading scientists from diverse fields are working on the mysteries of glaucoma, and we have significantly increased the number of people working in this disease. In the last few years, research has more than tripled.
Held annually since 1994, The Glaucoma Foundation’s International Scientific Think Tank provides a unique opportunity for scientists to apply the research and progress in other diseases and systems to the challenges of glaucoma.

This interdisciplinary meeting fosters creative thought and collaboration among the world’s leading glaucoma experts, neuroscientists, geneticists, biologists, immunologists, and other specialists.

Traditionally, the two-day forum achieves three objectives:

- **To familiarize scientists from other fields with the subject of glaucoma**
- **To present critical scientific findings that may impact or redefine the future course of glaucoma research**
- **To identify novel approaches for gathering scientific data**

PHOTO: Think Tank 2019, June, NYC
Advances due to XFS Inquiry

Through our multi-disciplinary approach, seven genes have been discovered, primarily through a worldwide study led by researchers in Singapore.

XFS has been found to be associated with cardiovascular and cerebrovascular disease, hearing loss, and diseases of elastic tissue.

We have discovered several new systemic associations with XFS including inguinal hernia, atrial fibrillation, chronic obstructive pulmonary disease, basal cell carcinoma, and uterine/bladder prolapse.

There is now investigation into environmental risk factors for glaucoma, such as ultraviolet light and diet.

In addition, we are excited to explore the ways in which artificial intelligence can support future research.
Recent Research Grants

Summer, 2019

**Unraveling The Proteolytic Landscape Regulating OXL1 Implications In The Development Of Pseudoexfoliation Syndrome**

Principal Investigator: Fernando Rodriguez Pascual, PhD, Centro de Biologia Molecular “Severo Ochoa” (CSIC/UAM); Madrid, Spain

While precise pathogenesis of PEX syndrome remains unknown, the identification of genetic variants in the LOXL1 gene strongly associated to the disease has opened new avenues for the investigation on its molecular causes. The protein product of the LOXL1 gene belongs to the lysyl oxidase (LOX) family, a group of enzymes contributing to build the extracellular matrix (ECM) by promoting the covalent association (cross-linking) of elastin and collagens. In particular, LOXL1 plays an important role in the formation of elastic fibers, the ECM scaffold mostly imparting elasticity to animal tissues, an observation very consistent with its identification as an integral part of the PEX deposits.

With the support of a previous grant from The Glaucoma Foundation, we initiated a line of research aiming to investigate the proteolytic processing of LOXL1 and its potential implications in the development of PEX syndrome. Far from being completed, our results provide a glimpse of the complexity of the proteolytic landscape regulating LOXL1 expression and activity, anticipating exciting findings potentially important for the development of PEX syndrome. Here we apply for a renewal of the support from TGF to accomplish the characterization of LOXL1 proteolytic regulation and to investigate its pathological relevance in the development of PEX syndrome.
Role Of LOXL1 Activity In TGFβ-1-Mediated Fibrosis In The Conventional Outflow Pathway

Principal Investigator: Heather Schmitt, BS, MS, PhD
Duke University; Durham, NC

The proposed research is designed to investigate the regulatory role of the LOXL1 protein that is associated with risk of pseudoexfoliation glaucoma. We are interested in how LOXL1 activity contributes to elevation in eye pressure that is typical of pseudoexfoliation glaucoma. Specifically, we will investigate the relationship between LOXL1, a signaling molecule called TGFβ-1 and eye pressure using a mouse model. TGFβ-1 is often elevated in eyes of people with pseudoexfoliation glaucoma, and it is known to induce “scarring” that causes elevated eye pressure. Results from this project will provide a better understanding of disease mechanism and may lead to targeted clinical interventions for pseudoexfoliation glaucoma.

New Understanding From Mouse Lines With Features Of Pseudoexfoliation Syndrome

Principal Investigator: Yong Yuan, PhD
College of Medicine, University of Cincinnati

Pseudoexfoliation syndrome is the most identifiable cause of open-angle glaucoma. Animal models are critical tools for finding the cause of the disease and for testing potential treatment regimens. Currently, no animal model is available that can recapitulate the symptoms of this disease. We found features of Pseudoexfoliation syndrome in several mouse lines with genetic defects affecting cellular functions. The objective of this proposal is to find what is the common cause of the disease among these mouse lines. New knowledge obtained from this study will lead to a better understanding of the disease as well as new strategies for combating the disease.
Spring, 2019

Growth Differentiation Factor 15 Levels In Pseudoexfoliation Glaucoma

Principal Investigator: Rajendra Apte, MD, PhD
Washington University; St. Louis, MO

Loss of vision can make it more difficult for people to work, get around, and enjoy daily life. The number one cause of irreversible vision loss in the world is glaucoma. There are several kinds of glaucoma, all of which can lead to the death of cells in the eye that send visual information to the brain. Preventing these cells from dying is an important part of the treatment for glaucoma. However, it can be difficult for physicians to identify which patients are at highest risk of developing glaucoma, or having their glaucoma get worse over time.

Finding a marker, such as a protein in the eye, whose presence might predict whether glaucoma will get worse would make it possible for physicians to better determine whether a patient should have surgery or another treatment. This project will study a protein called growth differentiation factor 15 (GDF-15), which is associated with retinal stress in rodents and humans. By measuring the levels of this protein in human patients with glaucoma before and after surgery, we hope to understand whether there is a relationship between GDF-15 levels in the eye, the severity of glaucoma, and success of glaucoma surgery. If high GDF-15 levels are linked with more severe glaucoma, it could be used as a marker to help determine treatment for patients at the highest risk of developing severe glaucoma.
Metabolomic Analyses Of Aqueous Humor Of Pseudoexfoliation Glaucoma

Principal Investigator: Sanjoy K. Bhattacharya, M. Tech, PhD
Bascom Palmer Eye Institute,
University of Miami Miller School of Medicine

We will identify the small molecules in the clear fluid of the front part of the eye termed aqueous humor. These small molecules are involved in all day-to-day functions of biological tissues in the eye. This analysis will show a difference in small molecules between pseudoexfoliation glaucoma and normal eyes. Their addition (for example the molecules that provide energy) or removal (for example known toxic molecules) may be early intervention strategies for treating pseudoexfoliation glaucoma.

Winter, 2018

Towards An Understanding Of The Roles Of LOXL1 And BMP-1 In Exfoliation Syndrome

Principal Investigator: Ernst R. Tamm, MD
University of Regensburg; Regensburg, Germany

Exfoliation syndrome (XFS) is characterized by the deposit of whitish fluffy material throughout the anterior eye segment. Variants in the gene that codes for the protein LOXL1 are associated with exfoliation syndrome, and genetic and/or environmental factors may cause elevated levels of LOXL1 in the eye. This project tests the idea that cleavage of LOXL1 (when present in high amounts) by the protein BMP-1 causes molecular changes that induce the formation of exfoliation material. Investigators will increase BMP-1 levels in mouse eyes via gene transfer and examine the eyes for signs of exfoliation material. The genetically engineered mice already have high levels of LOXL1 in the eye. Parallel cell culture experiments will elucidate the molecular mechanisms of the LOXL1/BMP-1 interaction.
Evaluating The Effect Of Ocular UV Exposure As A Major Causative Factor in a Risk Model For Exfoliation Syndrome In Indian Population

Principal Investigator: Rashima Asokan, PhD
Medical Research Foundation, Sankara Nethralaya; Chennai, India

Certain changes in the genetic makeup of an individual make them more susceptible to developing exfoliation syndrome (XFS), the major cause of secondary glaucoma and associated vision loss. Similarly, environmental factors such as lifetime ocular UV exposure through solar radiation, inflammation and low oxygen supply to eye tissues also are known to play a role in XFS disease progression. However, the extent of influence that the factors have individually or in combination remains uncertain and needs to be investigated.

This study uses a single group of patients to address this issue and hopes to generate a profile accounting for the effect of both genetic and non-genetic factors in XFS disease pathology.
To effectively treat exfoliation glaucoma (XFG), precise understanding of its molecular mechanisms is needed.

The breakthrough genetic discoveries within the last decade have paved the pathways leading toward this goal. Lysyl oxidase-like 1 (LOXL1) is the most significant gene associated with XFG and the interaction between LOXL1 and fibrillin-1 has been increasingly recognized as they are two essential elements for proper elastic fiber formation and function. This study will use mouse models to study these two key molecules, affording the unique opportunity to test the hypothesis that mice with dual defects of those two proteins have more severe XFG. If successful, new treatments could be quickly tested.
Identifying Changes In Protein Syntheses And Secretion Induced By PXFG-Associated LOXL1 Mutants

Principal Investigator: Joshua Morgan, PhD
University of California; Riverside, CA

Pseudoexfoliative glaucoma (PXFG) occurs due to the production of extracellular deposits within the eye. By inhibiting the flow of aqueous humor, these deposits lead to a dangerous increase in IOP, the hallmark of glaucoma. In this project, investigators use a sequencing technique, ribosome profiling, to understand how mutations in the gene LOXL1 and PXFG-associated molecules alter the production and secretion of proteins. This knowledge will provide increased understanding as to how changes in protein production within the cell can contribute to the formation of these deposits.
**Spring, 2018**

**Robust Mouse Models Of Exfoliation Glaucoma**

Principal Investigator: Michael Anderson, PhD, University of Iowa

While some mouse models of exfoliation glaucoma exist, they lack some key features of the human disease. This project proposes generating new mouse models of exfoliation syndrome (XFS) by screening animals with targeted manipulations to genes that are known genetic risk factors for human disease. These mice could be used by the research community in a wide range of studies that will expedite development of new treatments and bring us closer to finding a cure.

**Winter, 2017**

**The Role Of Autophagy And Mitochondrial Dysfunction In The Pathogenesis Of Exfoliation Glaucoma**

Principal Investigator: John H. Fingert, MD, PhD
University of Iowa; Iowa City, IA

Exfoliation syndrome and exfoliation glaucoma at their core are caused by defects in cellular processes. Preliminary studies have suggested that abnormalities in the processes that cells use to eliminate waste products (autophagy) and by which cells produce energy in their mitochondria may be culprits in exfoliation syndrome. This study will comprehensively test a panel of cell lines from exfoliation patients and control subjects for abnormalities to determine if these cellular processes are involved in exfoliation glaucoma.
Optimization Of A Cell Culture Model For Pseudoexfoliation Syndrome

Principal Investigator: Pedro Gonzalez, PhD
Duke University; Durham, NC

Currently there is limited information about the mechanisms leading to the production of exfoliation material and no specific treatment to prevent its accumulation in the eye. A major limitation is the lack of experimental models in which to identify treatments to inhibit the production of exfoliation material. The potential of using induced pluripotent stem cells from exfoliation donors to generate a cell culture model for the disease is being investigated. Preliminary results show that under certain conditions it is possible to replicate the formation of a material similar to that observed in the tissue of exfoliation patients. The objective is to validate this cell culture model for exfoliation syndrome, which would open new avenues to understand the disease and develop treatments.

Lysyl Oxidase-Like 1 (Loxl1) Dysregulation Promotes Reactive Astrocytosis By Altering Calcium Signaling In Optic Nerve Head Astrocytes

Principal Investigator: Simon Kaja, B.Sc., PhD
Edward Hines Jr. VA Hospital, Hines, IL; Loyola University, Chicago, IL

Genetic factors can predispose to exfoliation glaucoma, however, the exact molecular mechanisms leading to the full-blown disease are still unknown. This investigation is studying a novel hypothesis of how an individual’s genetic makeup can cause exfoliation glaucoma. Specifically, the project is studying how genetic factors alter communication within and between cells in the eye. Identifying broken chains in cellular communication can help devise novel therapies for treating exfoliation glaucoma.
Development Of A Screening System To Identify Treatment Candidates For Exfoliation

Principal Investigator: Konstantin Petrukhin, PhD
Columbia University Medical Center; New York, NY

This study’s objective is to identify and characterize inhibitors of the gene that is associated with XFG, LOXL1 (lysyl oxidase-like 1). The overall goal of the proposed study is to develop an assay for LOXL1 modulators and to screen for compounds that inhibit it with the ultimate goal of developing a potent, selective, and non-toxic treatment for exfoliation glaucoma that can be topically administered as eye drops.

Spring, 2017

Role Of Lysyl Oxidase-Like-1 (LOXL1) Proteolytic Processing In The Development of Pseudoexfoliation Syndrome (PEX)

Principal Investigator: Fernando Rodriguez Pascual, PhD
Centro de Biologia Molecular; Madrid, Spain

Genetic Variations in the LOXL1 gene have been strongly associated with exfoliation syndrome (XFS). The protein product of the LOXL1 gene belongs to a group of enzymes which contributes to building the extracellular matrix (ECM) by promoting the cross-linking of elastin fibers, the ECM scaffold imparting elasticity to animal tissues. LOXL1 must be proteolytically processed in order to fulfill its biological function, but how this process occurs, what cellular enzymes (proteases) are involved, and whether this contributes to XFS disease are not yet known, and are the main questions this research will investigate.
Targeted Deep Sequencing Of
The FLT1 – POMP – SLC46A3
Susceptibility Locus For Exfoliation Syndrome
And Exfoliation Glaucoma

Principal Investigator: Chiea Chuen Khor, PhD
Genome Institute of Singapore

An earlier investigation studied 13,620 XFS patients from 33 countries and identified five new genes contributing to XFS susceptibility. The most significant newly identified loci include a gene encoded for a protein called POMP, which is responsible for ensuring cellular well-being by cleaning up harmful oxidative radicals and degraded proteins. The genetic association mapping to this POMP locus show clear evidence of interaction with geographical latitude, whereby genetic risk conferred increases with distance away from the equator. This grant, utilizing investigators from six countries, will be used to fully sequence this gene locus.
At first, glaucoma damages peripheral (or side) vision, but most people would not detect this early peripheral visual loss. At more severe stages, peripheral vision loss spreads toward the center of vision, causing the so-called “tunnel vision.” At this severe stage, some patients may still be able to see 20/20 centrally and not realize the severity of their peripheral vision loss. Eventually, even the little bit of central vision can be lost if glaucoma is not treated. For these reasons, glaucoma is sometimes called “The Silent Thief of Sight.”

These images are based on commonly used simulations of glaucomatous visual field defects:

A - black tunnel  B - blurred tunnel  C - black patches
D - missing parts
Prior Grants

-Fall of 2016-

Functional Analysis Of Rare Protective Coding Variants In LOX1
R. Rand Allingham, MD

Exfoliation Syndrome: Epidemiology And Association
With Systemic Diseases And Ocular Disorders
In The Maccabi Glaucoma Study
Hani Levkovitch-Verbin, MD, MPA

LOXL1-Associated Pathomechanisms Predisposing To Optic Nerve Damage In Pseudoexfoliation Glaucoma
Ursula Schlötzer-Schrehardt, PhD

Morbidity And Mortality In Patients With Exfoliation Syndrome:
A Large Database Analysis -
Utah Project On Exfoliation Syndrome (UPEXS)
Barbara Wirostko, MD

Development And Characterization Of Mouse Model
For Exfoliation Syndrome
Yong Yuan, PhD

-Summer of 2016-

LOXL1 Containing Exosomes
In Exfoliation Syndrome And Glaucoma
Yutao Liu, MD, PhD

-Fall of 2015-

Tear Cytokine And MMP Assay In Different Stages Of Pseudoexfoliation Syndrome
Aparna Rao, MD, FRCS
Impaired Lysosomal and Mitochondrial Function In Exfoliation Glaucoma
Audrey Bernstein, PhD

Determining The Genetic Basis Of Exfoliation Syndrome In A Large Pedigree Using Next-Generation Sequencing
Simon W. John, PhD

Unlocking The Hereditable Basis Of Exfoliation Syndrome
Chiea Chuen Khor, MB, BS, DPhil

Mechanisms In Exfoliation Glaucoma: Effect Of Genetic Risk Variants And Ocular Cell Stressors On LOXL1 Expression
W. Daniel Stamer, PhD

To Investigate The Role Of Methylation In The Regulation Of Lysyl Oxidase Like 1 Expression In Pseudoexfoliation Glaucoma
Deborah Wallace, PhD

Validation Of Pseudoexfoliation Glaucoma Biomarkers By MRM
Hector Gonzalez-Iglesias, PhD

Targeting wild-type and N-terminus-deleted LOXL1 to the iris pigment epithelium (IPE) in living rats. Effect on the formation of the IPE elastin network on IOP.
Terete Borrás, PhD
Development Of Mouse Models For Dissecting LOXL1-mediated Pathology
Michael G. Anderson, PhD

Targeting wild-type and N-terminus-deleted LOXL1 to the iris pigment epithelium (IPE) in living rats. Effect on the formation of the IPE elastin network on IOP.
Terete Borràs, PhD

Stem-cell Based Studies Of Retinal Ganglion Cells, The TBK1 Gene And Normal Tension Glaucoma
John Fingert, MD, PhD

Anti-glycan Immunoprofiles As Biomarkers In Early Detection Of Exfoliation Syndrome
Margaret E. Huflejt, PhD

Roles Of Regulatory Variants For LOXL1 In Pseudoexfoliation Glaucoma, Year 2
Yutao Liu, MD, PhD

Exome Analyses Of Families With Pseudoexfoliation Glaucoma, Year 2
Mansoor Sarfarazi, PhD
Next Generation Exome Sequencing In Families With Normal Tension Glaucoma (NTG)  
Mansoor Sarfarazi, PhD

Exome Sequencing Of Families With Pseudoexfoliation Glaucoma  
Mansoor Sarfarazi, PhD

InVivo Imaging Of Retinal Ganglion Cells - A New Model To Study Neuroprotection In Glaucoma – Year 2  
Christopher Kai Shun Leung, MD, MB, ChB, BMedSc, MSc

JNK Signalling Is Critical For Retinal Ganglion Cell Death After Axonal Injury  
Richard T. Libby, PhD

Rescuing Retinal Ganglion Cells By Survival Signaling  
Steven Roth, MD

A Novel Strategy To Prevent Retinal Ganglion Cell Degeneration In Experimental Glaucoma Using The Melanopsin Treatment  
Bin Lin, PhD

Exome Sequencing Of Families With Pseudoexfoliation Glaucoma  
Sotirios Koutsopoulos, BSc, PhD

RE1 Silencing Transcription Factor (REST) As A Repressor Of Neurogenesis By Müller Glial-Derived Stem Cells Following Ganglion Cell Injury  
Deborah C. Otteson, BSc, PhD
Robert Ritch, MD - Founder and Medical Director
Shelley and Steven Einhorn Distinguished Professor of Ophthalmology, Chief, Glaucoma Service
Surgeon Director, The New York Eye & Ear Infirmary

Louis Pasquale, MD, FARVO
Site Chair, Department of Ophthalmology, Mt. Sinai Hospital
Vice Chair, Translational Ophthalmology Research, Mt. Sinai Healthcare System- NYC

Michael Anderson, PhD
Professor, Department of Molecular Physiology and Biophysics, Carver College of Medicine, Iowa Glaucoma Center, Institute for Vision Research - Iowa City, Iowa

Tin Aung, MMed, FRCS, FRCOphth, FAMS, PhD, Executive Director, Singapore Eye Research Institute, Deputy Medical Director (Research) & Senior Consultant, Glaucoma Dept, Singapore National Eye Centre, Professor, Dept of Ophthalmology, Yong Loo Lin School of Medicine, National University of Singapore

Steven Bassnett, PhD
Professor, Ophthalmology and Visual Sciences, Washington University School of Medicine - St, Louis, Missouri

Audrey Bernstein, PhD
Associate Professor, Center for Vision Research, Department of Ophthalmology, SUNY Upstate Medical University - Syracuse, New York
Terete Borras, PhD
Professor, Department of Ophthalmology, Gene Therapy Center, University of North Carolina School of Medicine - Chapel Hill, North Carolina

Claude F. Burgoyne, MD
Senior Scientist and Research Director, Optic Nerve Head Research Laboratory, Devers Eye Institute & Research Laboratories - Portland, Oregon

Abbot Clark, PhD
Regents Professor, Pharmacology & Neuroscience, Executive Director, North Texas Eye Research Institute, University of North Texas Health Science Center - Fort Worth, Texas

Miguel Coca-Prados, PhD
Professor (Adjunct) of Ophthalmology, Department of Ophthalmology and Visual Sciences, Yale University School of Medicine - New Haven, Connecticut

Jonathan G. Crowston, BSc, MBBS, PhD, FRCOphth, FRANZCO
Ringland Anderson Professor, Head of Ophthalmology, University of Melbourne, Director, Centre for Eye Research - Australia

John Danias, MD, PhD
Professor and Interim Chair, Department of Ophthalmology, State University of New York, Downstate - Brooklyn, New York
John H. Fingert MD, PhD, FARVO
Hadley-Carver Chair in Glaucoma, Professor, Department of Ophthalmology and Visual Sciences, Carver College of Medicine, University of Iowa, Director Glaucoma Research Center, Institute for Vision Research, Iowa City, Iowa

Jeffrey L. Goldberg, MD, PhD
Professor and Chair, Department of Ophthalmology, Byers Eye Institute at Stanford University
Palo Alto, California

Neeru Gupta, MD, PhD, MBA, FRCSC, DABO
Professor and Dorothy Pitts Chair, Chief of Glaucoma, University of Toronto, Departments of Ophthalmology & Vision Sciences, Laboratory Medicine and Pathobiology, Faculty of Medicine, Professor, Dalla Lana School of Public Health University of Toronto - Canada

Michael Hauser, PhD
Professor of Medicine and Ophthalmology,
Duke University Medical Center, Senior Scientist, Singapore Eye Research Institute
Durham, North Carolina

Simon John, PhD
Principal Investigator, Howard Hughes Medical Institute, The Jackson Laboratory - Bar Harbor, Maine

Paul L. Kaufman, MD
Ernst H. Barany Professor of Ocular Pharmacology and Chair Emeritus of the Department of Ophthalmology & Visual Sciences, School of Medicine & Public Health, University of Wisconsin-Madison
Uday B. Kompella, PhD
Professor, Department of Pharmaceutical Sciences, University of Colorado, Denver

Richard K. Lee, MD, PhD
Walter G. Ross Distinguished Chair in Ophthalmic Research, Associate Professor of Ophthalmology, Cell Biology, and Neuroscience Graduate Program, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine - Miami, Florida

Jeffrey M. Liebmann, MD
Shirlee and Bernard Brown Professor of Ophthalmology, Vice Chair, Department of Ophthalmology, Director, Glaucoma Service, Harkness Eye Institute, Columbia University Medical Center - New York, New York

Yutao Liu, MD, PhD
Associate Professor, Cellular Biology & Anatomy, Graduate Studies, Augusta University - Augusta, Georgia

Robert W. Nickells, PhD
Professor, Department of Ophthalmology & Visual Science, University of Wisconsin Medical School Madison, Wisconsin

Colm O’Brien, FRCS, MD
Professor of Ophthalmology, Mater Misericordiae University Hospital - Dublin, Ireland
Dieter Reinhardt, PhD
Professor and Canada Research Chair in Cell-Matrix Biology, Department of Anatomy and Cell Biology, McGill University - Quebec, Canada

Julia E. Richards, PhD
Harold F. Falls Professor of Ophthalmology & Visual Sciences, Professor of Epidemiology, W. K. Kellogg Eye Center, The University of Michigan - Ann Arbor

Ursula Schlötzer-Schrehardt, PhD
Professor, Department of Ophthalmology, University of Erlangen - Nurnberg, Germany

Joel S. Schuman, MD, FACS
Professor and Chairman of Ophthalmology, NYU Langone Health, NYU School of Medicine, Professor of Electrical & Computer Engineering, NYU Tandon School of Engineering - New York, New York

Baldo Scassellati Sforzolini MD, PhD, MBA
Senior Vice President, Drug Development Operations and Global Evidence & Value, Allergan, Inc.

W. Daniel Stamer, PhD
Joseph A. C. Wadsworth Professor of Ophthalmology, Professor of Biomedical Engineering, Duke University - Durham, NC

Ernst R. Tamm, MD, FARVO
Professor and Chairman, Institute of Human Anatomy & Embryology, University of Regensburg - Regensburg, Germany
Gülgün Tezel, MD  
Professor, Department of Ophthalmology Sciences, Harkness Eye Institute, Columbia University Medical Center - New York, New York

Robert N. Weinreb, MD  
Chairman and Distinguished Professor of Ophthalmology, Director, Shiley Eye Center, Director, Hamilton Glaucoma Center, University of California San Diego - La Jolla, California

Janey L. Wiggs, MD, PhD, FARVO  
Paul Austin Chandler Professor of Ophthalmology, Vice Chair for Clinical Research in Ophthalmology, Co-Director, Glaucoma Center of Excellence, Harvard Medical School / Associate Director, Ocular Genomics Institute, Associate Director, Howe Laboratory, Associate Chief for Ophthalmology, Clinical Research Senior Scientist, Associate Member, Broad Institute of Harvard and MIT Massachusetts Eye and Ear - Boston, Massachusetts

M. Roy Wilson, MD, MS  
President, Wayne State University - Detroit, Michigan

Barbara Wirostko, MD  
Clinical Adjunct Associate Professor, Ophthalmology/Visual Sciences, Moran Eye Center, University of Utah, Adjunct Associate Professor, Dept. of Bioengineering, University of Utah - Salt Lake City, Utah

Ting Xie, PhD  
Investigator and Professor, Department of Anatomy and Cell Biology, The Stowers Institute for Medical Research, University of Kansas Medical Center - Kansas City, Missouri
I began glaucoma research 8 years ago at the beginning of my first postdoc. I wanted to know how the disease begins.

When I first entered the field, I was struck by how much of the research focused on the changes that occur late in the disease, when the patient’s vision is already compromised. Of course, it is incredibly challenging to study events that occur before the patient even knows there is a problem, which is why much of my research has focused on building better models of glaucoma to study.
With a grant from TGF, I investigated changes in the proteins secreted by healthy and glaucomatous cells using a technique called Ribo-Seq. Ribo-Seq is a next generation sequencing technique which tells us every protein that is actively being produced by the cells. While we are just now getting our first sequencing data back, we hope that this non-biased approach will allow us (and other researchers in the field!) to identify unknown differences in proteins produced by glaucomatous cells, opening up new therapeutic targets.

Right now we are asking why it is that trabecular meshwork cells, the cells responsible for maintaining low eye pressure, do not repair and replace tissue as it is damaged.

Most tissues in the body are under continuous replacement and repair ...as a particularly remarkable example, the gut replaces its lining every two days throughout your entire life. In glaucoma, damage in the trabecular meshwork accumulates over time. I’d like to begin by investigating the dynamics of healthy and diseased trabecular meshwork to identify the healthy turnover rate for the tissue and if it is compromised in glaucoma.

TGF’s support is crucial to my work because it directly supports sequencing projects. Sequencing studies generate a huge amount of data that is very beneficial to the entire research community, helping everybody understand the disease better and identify better targets. Unfortunately, very few funding agencies and foundations support this kind of hypothesis-generating research, and I am glad TGF takes on this important role.

TGF helps me answer questions that are important to people. My mentor told me on my first day that he measures his career in the vision he saves. That has stuck with me throughout my career and I measure myself the same way.

-Joshua Morgan, PhD
Principal Investigator: Joshua Morgan, PhD
University of California; Riverside, CA
Support Glaucoma Research

Since 1984, it has been the mission of The Glaucoma Foundation to facilitate, promote and fund cutting-edge research into glaucoma, and to educate the public about timely and appropriate eye care, glaucoma in particular.

The progression of our understanding of the disease, our search for new and better treatments, and our ability to identify paths to the cure, are only possible because of individuals, corporations and foundations who understand the relevance of our approach and achievements.

Thank you for being a part of the quest to eradicate the ‘thief of sight.’

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