

## RESEARCH TOPIC PRIMES

### Oculomics-Based Stratification of Systemic Disease Risk Through Retinal and Multi-Omics Integration

#### Thematic field of the project

Oculomics

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#### Main field of interest

Ophthalmology

#### Abstract

##### BACKGROUND

The eye represents an entry point into systemic precision medicine. As an extension of the central nervous system, it enables direct, non-invasive visualization of microvascular and neuroaxonal structures. Ocular microcirculation reflects cerebral and systemic vascular networks, while neural layers mirror neurodegeneration and aging, positioning the eye as an accessible biosensor of systemic disease.

Oculomics integrates ocular imaging with clinical, computational, and molecular data to identify biomarkers of systemic conditions. Advances in optical coherence tomography, angiography, and AI enable extraction of quantitative features capturing subtle alterations associated with cardiovascular disease, neurodegeneration, and metabolic dysfunction. Integration with multi-omics as genomics, proteomics, metabolomics, and immunomics, further enables characterization of molecular and immune mechanisms underlying disease, including antigen-driven responses.

##### OBJECTIVES

The project aims to establish the eye as a predictive biosensor of systemic health through a multimodal AI framework. The primary objective is to develop a predictive model of cardiovascular and neurodegenerative risk integrating ocular imaging, multi-omics, and clinical data. Secondary objectives include improving risk stratification, identifying ocular signatures of systemic dysfunction, defining integrated molecular profiles, and investigating immune mechanisms. The project will also assess the systemic impact of cataract surgery and develop patient-specific models for validation.

## METHODS

This multicenter cohort study will include ~1,500 individuals across diverse risk groups. Participants will undergo ocular imaging, cardiovascular and neurological assessments, and biological sampling. Analyses will combine radiomics, multi-omics profiling, and AI-based data integration to develop an Oculomics Risk Score, supported by experimental and stem cell-based validation.

## IMPACT

The project will redefine the role of the eye as a key organ for early detection and precision prevention of systemic diseases.

### **Main technical approaches**

Strong background in machine learning and deep learning, with experience in model development, training, and validation

Proven experience in computer vision, particularly in medical imaging (e.g., segmentation, classification, feature extraction)

Proficiency in programming and relevant libraries (e.g., PyTorch, TensorFlow, scikit-learn)

Knowledge of multimodal data integration techniques

Understanding of statistical modeling, including regression methods and survival analysis

Experience with data preprocessing, cleaning, and harmonization in large and heterogeneous datasets

Familiarity with explainable AI methods for model interpretability

Basic knowledge of bioinformatics and omics data analysis (genomics, transcriptomics, proteomics)

Understanding of medical imaging modalities, particularly retinal imaging (OCT, fundus photography), is considered an asset

Experience with version control systems and reproducible research practices

### **Scientific references**

1. Zhu Z, Wang Y, Qi Z, Hu W, et al. Oculomics: Current concepts and evidence. *Prog Retin Eye Res.* 2025 May;106:101350. doi: 10.1016/j.preteyeres.2025.101350.
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3. Bisen JB, Sikora H, Aneja A, et al. *Cardiovasc Dev Dis.* 2025 Jun 17;12(6):230. Retinal Imaging as a Window into Cardiovascular Health: Towards Harnessing Retinal Analytics for Precision Cardiovascular Medicine.
4. Ong J, Jang KJ, Baek SJ, et al. Development of oculomics artificial intelligence for cardiovascular risk factors: A case study in fundus oculomics for HbA1c assessment and clinically relevant considerations for clinicians. *Asia Pac J Ophthalmol (Phila).* 2024 Jul-Aug;13(4):100095. doi: 10.1016/j.apjo.2024.100095.

5. Costello F, Norman GC. Artificial Intelligence and Ocular Imaging in the Evaluation of Neurologic Disorders: The New Era of Neuro-Oculomics? *Semin Neurol.* 2026 Feb;46(1):67-76. doi: 10.1055/a-2792-8597.

**Type of contract**

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