Technology Offer

A Tunable Neuronal Network and an Artificial Eye: A Platform for Signal Processing and Retinal Research

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Abstract

This invention introduces a measurement device that utilizes three-dimensional neuronal tissue, specifically retinal tissue grown from stem cells, to analyze neuronal responses. The tissue mimics human retinal structures and reacts to external stimuli, such as light, by altering its electric potential. A specialized read-out system captures these changes in real-time and three dimensions. The technology enables the creation of customizable, tunable neuronal networks with controlled cell composition and tissue shape. It opens new possibilities for studying human-like neuronal signal processing, developing treatments for neurological diseases, and creating advanced bioinspired optical systems, such as artificial eyes and signal-processing devices.

Background

Understanding the functioning of human neuronal networks, particularly the retina, has been limited by the inaccessibility of human tissue and the lack of precise models. Animal models only approximate human neuronal structures and responses. Furthermore, traditional organoids lack reproducibility in shape and functionality. Current methods cannot control the growth of neuronal networks or measure three-dimensional neuronal activity with high temporal resolution. Therefore, there is a pressing need for tunable, human-like neuronal tissues, grown in controlled environments, coupled with systems capable of measuring complex three-dimensional neuronal responses.

Technology

The invention describes a system combining advanced tissue engineering with real-time neuronal activity measurement. Retinal tissue is generated from human induced pluripotent stem cells (iPSCs), enabling human-like cellular organization and functionality. During growth, the organoids are embedded in an environment with tunable mechanical properties, such as stiffness or viscosity, which are locally adjusted using methods like laser ablation or photo-tunable hydrogels. This control allows for precise shaping of the organoid to mimic natural or custom-designed tissue architectures.

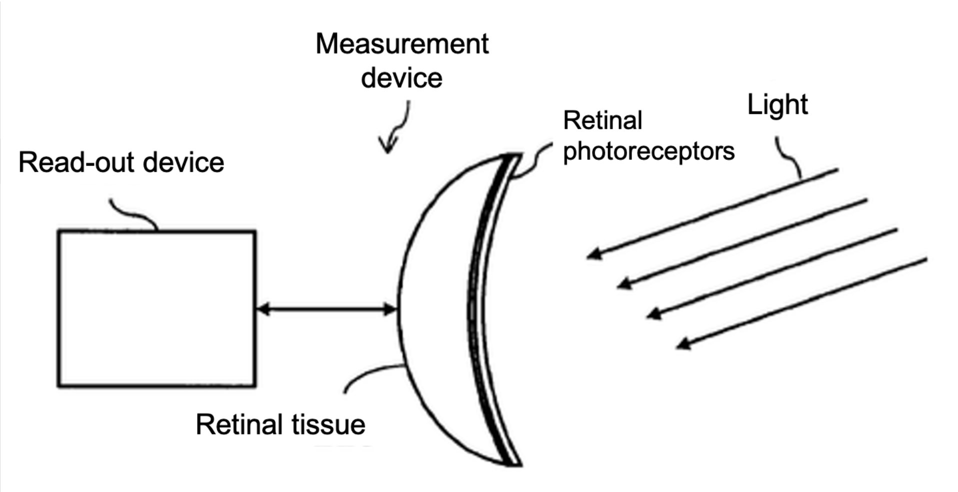

Figure 1: Schematic of the measurement device using stem cell-derived retinal tissue. Incoming light stimulates the retinal photoreceptors, generating electrical signals that are captured by a read-out device for functional analysis of the neuronal tissue.

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To capture neuronal activity, the system uses calcium-sensitive fluorescent dyes introduced into the neuronal cells. Upon stimulation, such as exposure to light, changes in intracellular calcium ion concentrations occur, reflecting neuronal responses. High-speed light-sheet fluorescence microscopy scans the entire 3D tissue volume at millisecond resolution, providing a full spatiotemporal map of neuronal activity at single-cell resolution.

Additionally, the system incorporates a feedback control unit that continuously monitors tissue shape and neuronal responses. Based on deviations from a desired state, it dynamically adjusts environmental factors to fine-tune tissue development and functionality. This approach enables not only modeling of healthy human retinal networks but also of pathological conditions by replicating disease-specific cellular environments. Thus, the invention provides a powerful platform for research, diagnostics, therapeutic development, and bioinspired technology design.

Advantages

- **Realistic human model**: Retinal tissue derived from human stem cells offers a closer biological match than animal models, improving the relevance of experimental results.
- **Controlled tissue architecture**: Growth environment manipulation enables precise shaping of organoids and adjustment of neuron type, density, and connectivity.
- **High-resolution functional imaging**: Lightsheet microscopy allows fast, three-dimensional mapping of neuronal activity at single-cell resolution.
- **Adaptive network development**: External influences and feedback control systems enable real-time tuning of neuronal properties during tissue formation.
- **Broad experimental flexibility**: The platform supports fundamental research, disease modeling, drug testing, and the development of bioinspired electro-optical devices**.**

Potential applications

- **Artificial retinal implants**: Building engineered tissues for vision restoration therapies.
- **Disease modeling**: Simulating human eye and brain diseases for research and treatment development.
- **Drug screening**: Testing pharmaceutical effects on functional human-like neuronal tissues.
- **Optical sensor innovation**: Creating imaging systems based on human retinal signal processing.
- **Neuroscience studies**: Investigating neuronal network formation and sensory processing in vitro.

Patent Information

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