Lymphatic Voyage: Communicating 4D Immune Cell Dynamics and Lymph Node Architecture Using WebGL-based Animation and Interactivity

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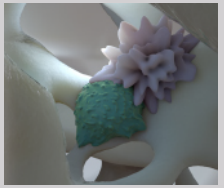

Abstract

Lymph nodes are secondary lymphoid organs where T cells and B cells meet antigens to initiate adaptive immune responses. The anatomical and molecular cues direct the cell and fluid movements to ensure that the antigens can meet the right immune cells effectively[1,2]. Advanced 3D imaging techinques[1] allowed the scientists to visualize the lymph nodes. However, Teaching lymph node architecture and immune cell dynamics at the cellular level is challenging due to the lack of visual teaching tools. **Lymphatic Voyage** is a widely accessible interactive 3D app designed as an educational tool to help instructors and graduate students.

Introduction

The complex tissue structure of the lymph node(Fig 1) makes studying the spatiotemporal cellular events happening within it challenging.

The purpose of this project is to develop a WebGL (Web Graphics Library) - based web application that is widely accessible and based on novel dynamic immune cell data. 3D animations and 3D interactive models were created, and a web application was coded and deployed. This web application allows audiences to go on a "**Lymphatic Voyage**" on both desktop computers and mobile devices, during which they can explore lymph node architecture and study didactic information that explains the animated cellular drama.

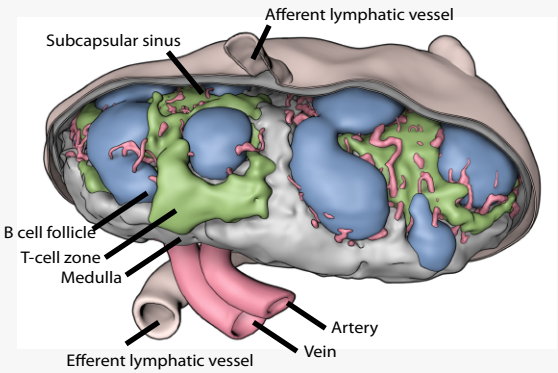

Fig 1. Anatomy of Mouse Lymph Node
The capsule, subcapsular sinus and afferent lymphatic vessel are shown in cross section to expose internal structures of the lymph node.

Materials & Methods

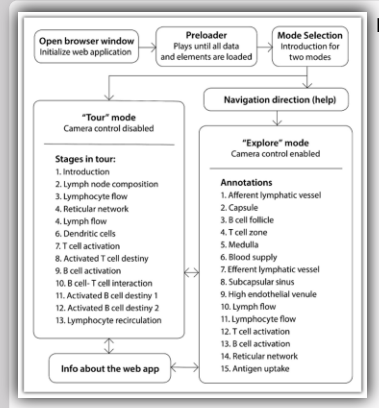

Fig 2. Diagram of Web App Structure

Diagram and flowcharts were created to plan the structure and logic of the web app. The app is composed of two main modes: the "Tour" mode and the "Explore" mode. In the "Tour" mode, the audience will be learning about the lymph node architecture and lymphocyte dynamics through a didactic 3D animation. The "Explore" mode allows the audience to explore the 3D lymph node, turn on and off structures, and read the annotations at their own pace for better learning experience.

The 3D mouse lymph node model with all the compartments were created based on the newest high resolution imaging data (shown in Fig 3) generated through an advanced tissue clearing method named Ce3D developed by Ronald Germain lab at National Institutes of Health. Fidelity of the raw data was maintained during the reconstruction process (Fig 4).

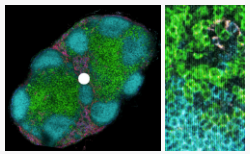

Fig 3. Microscopic Images of Tissue Cleared Mouse Lymph Node

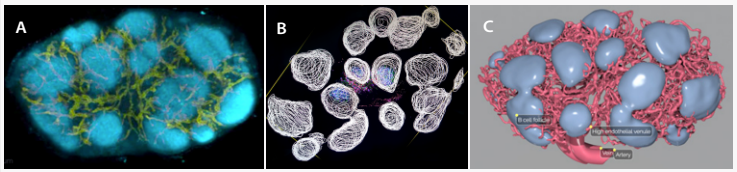

Fig 4. Progress from the Raw Data to Optimized Interactive 3D Model.
(A) Volumetric data in Imaris **(B)** Manual segmentation in Imaris **(C)** Surface rendering in Chrome

Workflow	Software/Programming
• **Diagram & Flowchart**	Adobe InDesign
• **Storyboards & Scripts**	Adobe Photoshop
• **User Interface Design**	Adobe Illustrator
• **3D Model Reconstruction**	Imaris
• **3D Model Optimization**	Meshlab, ZBrush
• **Interactive 3D Model**	Blender, Blend4web
• **Pre-rendered Animation**	Cinema4D, Adobe After Effects
• **Web App Development**	HTML, CSS, JavaScript, JSON, Sublime, Github

Results

Fig 5. Welcome Page

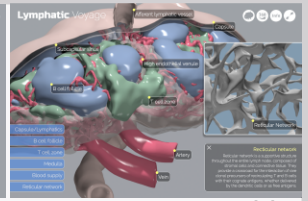

Fig 6. Interactive 3D Model

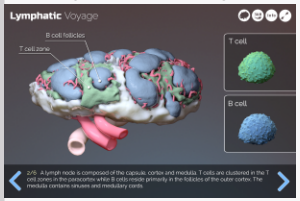

Fig 7. 3D Animation Tour

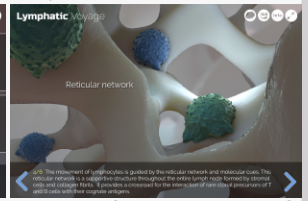

Fig 8. Lymphocytes on Network

Lymphatic Voyage, the interactive 3D web app was developed and deployed online, accessible from multiple browsers, including Chrome, Safari, IE and Firefox. The 3D interactive model (Fig 5 and 6) were designed to be freely rotatable and re-sizable. Different structures can be turned on and off and there is annotations associated with each structure. The pre-rendered 3D animation (Fig 7 and 8) was divided into steps to give enough time to the students to appreciate the educational material.

Discussion & Conclusions

Further work can be done to optimize the app for better performance and to implement the app on mobile devices. This project provides a novel cross-platform educational resource for instructors and graduate students to explore 4D lymph node architecture. It also contributes to the field of biomedical communication through the development of an innovative workflow utilizing WebGL to augment the learning experience.

Bibliography

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